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**DRAFT**
**FOCUSED FEASIBILITY STUDY**
**UNITED HECKATHORN SUPERFUND SITE**

**RICHMOND**
**CONTRA COSTA COUNTY, CALIFORNIA**

USEPA CONTRACT NO. EP-S9-08-04
USEPA WORK ASSIGNMENT NO. 025-RIFS-09R3
CH2M HILL PROJECT NO. 385441

Prepared for
U.S. Environmental Protection Agency
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February 2015

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# Acronyms and Abbreviations

| | |
|---|---|
| µg/kg | microgram(s) per kilogram |
| µg/L | microgram(s) per liter |
| ARARs | applicable or relevant and appropriate requirements |
| AWQC | ambient water quality criteria |
| BMPs | best management practices |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act of 1980 |
| cm | centimeter(s) |
| CSM | conceptual site model |
| DDD | Dichlorodiphenyldichloroethane |
| DDE | Dichlorodiphenyldichloroethene |
| DDT | Dichlorodiphenyltrichloroethane |
| ERA | ecological risk assessment |
| EFDC | Environmental Fluid Dynamics Code |
| ELCR | excess lifetime cancer risk |
| ERDC | Engineer Development and Research Center (U.S. Army) |
| FFS | Focused Feasibility Study |
| FS | Feasibility Study |
| $ft^2$ | square feet |
| GHG | greenhouse gas |
| g/year | grams per year |
| HAP | hazardous air pollutant |
| HHRA | human health risk assessment |
| HQ | hazard quotient |
| L | liter(s) |
| LRTC | Levin Richmond Terminal Corporation |
| mg/kg | milligram(s) per kilogram |
| mL | milliliter(s) |
| MLLW | mean lower low water |
| MNR | monitored natural recovery |
| NAPL | nonaqueous phase liquid |
| NCP | National Oil and Hazardous Substance Pollution Contingency Plan |
| ng/L | nanogram(s) per liter |
| NOx | nitrogen oxides |
| NPL | National Priorities List |
| OBM | Older Bay Mud |
| O&M | operations and maintenance |
| ORD | Office of Research and Development (USEPA) |
| OSWER | Office of Solid Waste and Emergency Response |

| | |
|---|---|
| PAC | powdered activated carbon |
| PDMS | Polydimethylsiloxane |
| PED | polyethylene device |
| PM | particulate matter |
| PRC | performance reference compound |
| POTW | publicly owned treatment works |
| RAO | remedial action objective |
| PRG | preliminary remediation goal |
| RBC | risk-based concentration |
| RCRA | Resource Conservation and Recovery Act |
| RG | remediation goal |
| RI | Remedial Investigation |
| ROD | Record of Decision |
| SEFA | Spreadsheet for Environmental Footprint Analysis |
| SEI | Sea Engineering, Inc. |
| Site | United Heckathorn Superfund Site |
| SOx | sulfur oxides |
| SPMD | semipermeable membrane device |
| SPME | solid phase microextraction |
| SVOC | semivolatile organic compound |
| TBC | to be considered |
| USACE | U.S. Army Corps of Engineers |
| USEPA | U.S. Environmental Protection Agency |
| USFWS | U.S. Fish and Wildlife Service |
| VOC | volatile organic compound |
| YBM | Younger Bay Mud |
| $yd^3$ | cubic yards |

# Executive Summary

This Focused Feasibility Study (FFS) presents the development and analysis of remedial alternatives for the United Heckathorn Superfund Site (the Site), in Richmond, California. This FFS was prepared for the U.S. Environmental Protection Agency (USEPA) Region 9 by CH2M HILL under Contract EP-S9-08-04, Work Assignment No. 025-RIFS-09R3.

The Site includes the former United Heckathorn facility where organochlorine pesticides were processed, packaged, and shipped, and the adjacent waterways that have been affected by releases from the former facility. Dichlorodiphenyltrichloroethane (DDT) was the most commonly processed pesticide. Aldrin, dieldrin, and endrin were also processed onsite in smaller quantities. The Site was placed on the National Priorities List in 1990 and a Record of Decision (ROD) was issued in 1994 (USEPA, 1994). The remedy for the upland part of the Site included excavation and offsite disposal of soils, and capping of the former United Heckthorn plant site with concrete and asphalt. Sediments from the Lauritzen Channel and Parr Canal were dredged and transported offsite for disposal. Post-remediation monitoring data indicate that the remediation goals (RGs) have not been maintained in the Lauritzen Channel, as documented in the Five-Year Reviews for the Site (USEPA, 2001, 2006 and 2011).

This FFS was performed to address contamination remaining in the Lauritzen Channel. The FFS has been prepared in accordance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended.

## Feasibility Study Objectives and Scope of Work

This FFS identifies the sources of DDT[1] and dieldrin that recontaminated sediments in the Lauritzen Channel, updates the conceptual site model (CSM) for the Site, presents updated remedial action objectives (RAOs) and RGs, and develops and evaluates source control measures and remedial alternatives for sediments within the channel. The FFS was prepared following USEPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA, 1988 [herein referred to as the USEPA RI/FS Guidance]), USEPA's *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA, 2005 [herein referred to as the USEPA Sediment Remediation Guidance]), and other relevant guidance.

## Conceptual Site Model

The updated CSM for the Lauritzen Channel summarizes and integrates information about the bathymetry, present-day sources of contamination, the nature and extent of contamination, sediment and DDT fate and transport, and the risks to humans and wildlife from exposure to contaminated sediment and surface water. The CSM provides the framework for developing the amended RAOs and remediation goals and for developing and evaluating remedial technologies and alternatives.

The Source Identification Study technical memorandum concluded that dredging residuals are the primary source of the DDT mass currently found in the Lauritzen Channel. Other sources that contribute much smaller amounts of DDT mass to the channel include embankment soil erosion, leaching and groundwater seepage, and the contaminated wood pilings. Discharges from pipes, outfalls, and seeps visible along the eastern embankment do not appear to be ongoing sources of DDT contamination to the Lauritzen Channel under dry weather conditions. However, other pipes and conveyances that are not visible may exist (i.e., features that terminate behind rip rap or sheetpile, or are subtidal) and may still act as preferential pathways for the transport of DDT from the upland area to the Lauritzen Channel. No non-site related

[1] In this report, DDT generally refers to the sum of DDT and its breakdown products DDD and DDE except where stated otherwise. Total DDT concentrations are the sum of the 4,4'- and 2,4'- isomers of DDT, DDD, and DDE.

sources of DDT and dieldrin to the Lauritzen Channel or the rest of Inner Richmond Harbor have been identified.

The present-day nature and extent of sediment contamination in the Lauritzen Channel show the following general trends:

- The average total DDT concentration in Younger Bay Mud is several orders of magnitude higher in the Lauritzen Channel than in the Santa Fe Channel
- The Older Bay Mud is uncontaminated except where disturbed by dredging or other anthropogenic activity (e.g. anchoring)
- Dieldrin concentrations show similar trends

Within the Lauritzen Channel, total DDT and dieldrin concentrations in the Younger Bay Mud show the following trends:

- The average concentrations are highest near the former plant site, followed by the northern portion of the channel. The average concentrations in the east and west subareas are an order of magnitude lower.
- The average total DDT concentrations in surface sediment in all subareas are above the 1994 RG of 590 µg/kg.
- Total DDT and dieldrin tend to co-occur ($R^2 = 0.76$).

Surface sediment concentrations are highest along the Lauritzen Channel embankment, particularly near the former plant site, former train scale area, and at the head of the channel. Mid-channel concentrations are higher in the northern half of the channel compared to the southern half. The core maximum concentrations show the same spatial patterns, but concentrations are higher at depth than at the surface.

The Lauritzen Channel is a low-energy, protected region with tidal velocities that are not likely to result in sediment resuspension. The low energy coupled with sediment input from San Francisco Bay result in a net sediment accumulation in the channel. Ongoing vessel operations in the channel are responsible for localized sediment bed resuspension. The resuspended sediment is primarily deposited locally within the channel, within a few hundred meters from where it was resuspended.

The largest amount of sediment accumulation is in the berth on the east side of the Lauritzen Channel. The accumulation is occurring in the deep dredged region where currents are likely the lowest, causing the berth to behave as a sediment trap. Conversely, the west side of the channel, which experiences the highest vessel activity in relatively shallow regions, exhibits generally low accumulation of Younger Bay Mud. Finally, the head of the channel, with low-energy, shallow water and moderate barge activity, shows a moderate Younger Bay Mud accumulation and a mix of potential erosion and deposition.

# Remedial Action Objectives and Remediation Goals

The original human health risk assessment for the Site indicated that the consumption of whole fish or fish fillets contaminated with DDT and dieldrin posed an unacceptable human health risk (ICF Technology, 1994). An updated evaluation of risks and hazards from fish consumption was performed in 2010 using the 2008 fish tissue data and the updated risk calculations indicated that total DDT and dieldrin concentrations in fish tissue from the Lauritzen Channel could pose unacceptable risk to people consuming fish.

The ecological risk assessment performed for the initial remedial investigation concluded that DDT and dieldrin at the Site posed an unacceptable risk to benthic organisms, water column organisms, and sensitive fish-eating birds. Due to the elevated levels of total DDT and dieldrin consistently measured in sediment and biota at the Site, the ongoing presence of ecological risks is assumed (CH2M HILL, 2010b).

The chemicals and pathways driving unacceptable risk for the marine portion of the United Heckathorn Superfund Site have not changed since the 1994 ROD was issued. However, the remedial action objectives (RAOs) and RGs were updated to be consistent with USEPA Sediment Remediation Guidance (2005) and approaches used more recently at similar contaminated sediment sites. The revised RAOs include:

- **RAO 1**: Reduce to acceptable levels the risks to human health from the consumption of fish contaminated with total DDT and dieldrin.
- **RAO 2**: Reduce to acceptable levels the risks from total DDT and dieldrin to ecological receptors, including benthic invertebrates, water column organisms, and fish-eating marine birds.
- **RAO 3:** Reduce concentrations of total DDT and dieldrin in surface waters to levels that meet USEPA ecological and human health AWQC.
- **RAO 4**: Control remaining active sources of total DDT and dieldrin to the Lauritzen Channel to reduce the potential for recontamination of marine sediments.

In order to achieve the RAOs listed above, risk-based, numerical RGs for total DDT and dieldrin in fish tissue, sediment, and surface water were developed. The proposed RGs are:

- Fish tissue: Total DDT - 0.12 milligrams per kilogram (mg/kg) wet weight; dieldrin - 0.0025 mg/kg wet weight
- Sediment: Total DDT - 400 micrograms per kilogram (µg/kg); dieldrin - 4.3 µg/kg
- Surface Water: Total DDT - 0.00022 micrograms per liter (µg/L); dieldrin - 0.000054 µg/L

# Identification and Screening of Remedial Technologies

Technology screening was conducted following the technology screening guidance described in the USEPA RI/FS Guidance. In addition, the technologies identified and screened are consistent with the USEPA Sediment Remediation Guidance (2005*).* Potential remedial technologies and process options were screened according to the following three established criteria:

- Technical effectiveness
- Implementability
- Cost

Remedial technologies and process options that would not effectively address sediment contamination within the Lauritzen Channel were eliminated. The technologies and process options that were retained from the initial screening process were carried forward for the development of remedial alternatives.

# Development and Evaluation of Remedial Alternatives

The descriptions of the remedial alternatives in this FS are conceptual and have been developed to a level of detail sufficient for the purposes of evaluating the alternatives against the National Contingency Plan (NCP) criteria, developing cost estimates of plus 50 to minus 30 percent, and comparing the alternatives. The selected alternative will be further developed during the remedial design process, and the specific methodologies and construction sequences utilized may change based on additional information that is gathered as part of predesign investigations.

The following alternatives were developed for impacted sediment within Lauritzen Channel at the United Heckathorn Superfund Site:

- Alternative 1: No Action
- Alternative 2: Dredge East Side Area and West Side Area, Cap Northern Head Area, Implement Source Control Measures, Offsite Landfill Disposal, Long-Term Monitoring, and Institutional Controls

- Alternative 3: Dredge East Side Area, West Side Area, and Portion of Northern Head Area, Cap Portion of Northern Head Area, Implement Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls
- Alternative 4: Dredge East Side , West Side, and Northern Head Areas, Implement Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls

Consistent with USEPA Sediment Remediation Guidance, for sites with various site characteristics or uses (such as the embankment area versus the main channel at the United Heckathorn Superfund Site), the remedial alternatives combine a variety of remediation approaches including dredging and capping.

The cap utilized in the Northern Head Area for Alternatives 2 and 3 is assumed to be an active cap (activated carbon or modified clay) based on treatability testing results, and would require a protective rock armor layer. The West Side and East Side Areas of the Lauritzen Channel are both subjected to high levels of vessel activity that are incompatible with capping. The armor layer thickness that would be required to protect an active cap from damage would reduce the water depth to a level that is incompatible with its current and future use, and removal of sediment to accommodate the required cap thickness would effectively require dredging the same quantity of contaminated sediment as Alternative 4. For this reason, capping the entire Lauritzen Channel was not included as a viable remedial alternative.

Alternatives 2 through 4 all include sediment removal using mechanical dredging, sediment dewatering, transportation, and disposal, as well as the following source control measures:

- Sheet piling along sections of the shoreline
- Active cap (activated carbon or modified clay) on retained (i.e. shoreward) side of sheet piling
- Remove and/or seal non-functional pipes and outfalls along the eastern shoreline
- One time removal of sediment from the City of Richmond storm drain system

The NCP defines nine criteria, classified as threshold, balancing, or modifying, to be used for the detailed analysis of remedial alternatives. The remedial alternatives were evaluated against the first seven of nine criteria in the FFS. :

- Threshold criteria
    1. Overall protection of human health and the environment
    2. Compliance with applicable or relevant and appropriate requirements
- Balancing criteria
    3. Long-term effectiveness and permanence
    4. Reduction of toxicity, mobility, or volume through treatment
    5. Short-term effectiveness
    6. Implementability
    7. Cost

The remaining two NCP criteria will be evaluated after comments are received on the Proposed Plan:

- Modifying criteria
    8. State acceptance
    9. Community acceptance

In addition to the NCP criteria, the remedial alternatives were qualitatively evaluated with respect to sustainability and green remediation metrics.

The detailed analysis was performed using a two-step process. During the first step, each alternative was evaluated individually against the NCP criteria and the sustainability/green remediation metrics. In the second step, a comparative analysis was performed using the same criteria to identify key differences

between alternatives. Tables ES-1 and ES-2 present the results of the detailed evaluation and comparative analysis of the alternatives, respectively. Upon completion of the FFS, the next step in the CERCLA process is the preparation of a Proposed Plan. The Proposed Plan will document the USEPA's preferred remedy for the United Heckathorn Superfund Site in Richmond, California and will allow for evaluation of the last two NCP criteria, State and Community acceptance (also referred to as the modifying criteria).

SECTION 1

# Introduction

This Focused Feasibility Study (FFS) presents the development and analysis of remedial alternatives for the United Heckathorn Superfund Site (the Site), in Richmond, California (Figure 1-1). This FFS was prepared for the U.S. Environmental Protection Agency (USEPA) Region 9 by CH2M HILL under Contract EP-S9-08-04, Work Assignment No. 025-RIFS-09R3.

The Site includes the former United Heckathorn facility where organochlorine pesticides were processed, packaged, and shipped, and the adjacent waterways that have been affected by releases from the former facility. Dichlorodiphenyltrichloroethane (DDT) was the most commonly processed pesticide. Aldrin, dieldrin, and endrin were also processed onsite in smaller quantities. The Site was placed on the National Priorities List (NPL) in 1990 and a Record of Decision (ROD) was issued in 1994 (USEPA, 1994). The remedy for the upland part of the site included excavation and offsite disposal of soils, and capping of the former United Heckathorn plant site with concrete and asphalt. Sediments from the Lauritzen Channel and Parr Canal were dredged and transported offsite for disposal. Post-remediation monitoring data indicate that the remediation goals (RGs) have not been maintained in the Lauritzen Channel, as documented in the Five-Year Reviews for the Site (USEPA, 2001, 2006 and 2011).

This FFS was performed to address contamination remaining in the Lauritzen Channel. The FFS has been prepared in accordance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended.

## 1.1 Purpose and Organization of Report

This FFS identifies the sources of DDT[2] and dieldrin that recontaminated sediments in the Lauritzen Channel, updates the conceptual site model (CSM) for the Site, presents updated remedial action objectives (RAOs) and RGs, and develops and evaluates source control measures and remedial alternatives for sediments within the channel. The FFS was prepared following USEPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA, 1988 [herein referred to as the USEPA RI/FS Guidance]), USEPA's *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA, 2005 [herein referred to as the USEPA Sediment Remediation Guidance]), and other relevant guidance. The report is organized into the following sections:

1. **Introduction**. Briefly describes the regulatory framework, FFS purpose and organization, site setting and physical characteristics, site history, and previous remedial actions at the Site.

2. **Post-Remediation Investigations**. Summarizes the monitoring and investigation activities performed for the marine portion of the Site after the 1996-1997 remedial action.

3. **Conceptual Site Model.** Presents an updated CSM, including the sources of recontamination, nature and extent of contamination, DDT fate and transport, and human health and ecological risks.

4. **Remedial Action Objectives and Remediation Goals**. Presents the amended RAOs and RGs for the marine portion of the Site, and summarizes the potential applicable or relevant and appropriate requirements (ARARs). This section also identifies the area and volume of the sediments to be targeted by the remediation.

[2] In this report, DDT generally refers to the sum of DDT and its breakdown products DDD (dichlorodiphenyldichloroethane) and DDE (dichlorodiphenyldichloroethene) except where stated otherwise. Total DDT concentrations are the sum of the 4,4'- and 2,4'- isomers of DDT, DDD, and DDE.

5. **Identification and Screening of Remedial Technologies.** Identifies a range of remedial technologies and process options that could be used to address contaminated sediments at the Site, and screens them based on effectiveness, implementability, and cost.

6. **Development and Evaluation of Remedial Alternatives**. Develops remedial alternatives for the Lauritzen Channel sediments by combining the remedial technologies and process options that were retained after the screening step, and presents detailed individual and comparative analyses of the remedial alternatives using the evaluation criteria defined in the National Oil and Hazardous Substance Pollution Contingency Plan (NCP). Source control measures are also identified and evaluated.

7. **References**. Provides the references cited in the report.

Supporting information is provided in the report appendices.

# 1.2 Site Setting

The Site is located within Richmond Harbor on the east side of San Francisco Bay in Contra Costa County, California (Figure 1-1). The Site is composed of two areas: (1) the upland area, which is the location of the former United Heckathorn facility, and (2) the marine area, which includes the Lauritzen Channel and Parr Canal.

## 1.2.1 Upland Area

The former United Heckathorn facility is located in an upland area of approximately 5 acres located on the east side of the Lauritzen Channel (Figure 1-1). The former United Heckathorn property is currently owned by the Levin Richmond Terminal Corporation (LRTC), which operates a dry bulk-cargo shipping terminal with berths for ocean-going vessels. The 5-acre upland area has been covered with an asphalt and concrete cap and is mainly used for cargo stockpiling and railroad operations. The upland area is level and approximately 7 to 11 feet above mean lower low water (MLLW)[3] .

The stormwater drainage system in the upland area of the Site is shown in Figure 1-2. Stormwater runoff from the 5-acre upland cap is directed by surface swales and subsurface piping into five stormwater interceptors (SW-3 through SW-7). The interceptors are designed to have sufficient capacity to hold all stormwater runoff generated during the rainy season (October through May) to prevent direct discharge to the Lauritzen Channel. Stormwater runoff from the cap is monitored and discharged to City of Richmond publicly owned treatment works (POTW). The City of Richmond municipal stormwater system provides drainage for the area surrounding the upland cap and discharges to a 48-inch diameter outfall at the head of the Lauritzen Channel.

Land use at the Site, and in the surrounding area, is primarily industrial and dominated by active petroleum and bulk materials shipping terminals. Land use is consistent with designations and zoning classifications presented in the *San Francisco Bay Plan* (San Francisco Bay Conservation and Development Commission, 2008) and the *Richmond General Plan* (City of Richmond, 2012). The *San Francisco Bay Plan* designates the area for port-priority or water-related industrial use and the *Richmond General Plan* classifies the area as heavy industrial (M3) zoning. No significant changes to land use at the Site are anticipated in the near future.

## 1.2.2 Marine Area

The marine portion of the Site includes the Lauritzen Channel, Parr Canal, Santa Fe Channel and Richmond Inner Harbor Channel.

[3] MLLW is the average height of the lower low water over a 19-year period referenced to a datum based at the Port of Richmond Terminal 2 (White et al., 1994).

#### 1.2.2.1 Lauritzen Channel

The Lauritzen Channel is a tidal waterway in Richmond Harbor. The Lauritzen Channel is a single spur off of the Santa Fe Channel (Figure 1-1). Richmond Harbor was originally intertidal marsh that was dredged and filled in the early 1900s (White et al., 1994). The tidal range in the harbor is approximately -2 to 7 feet MLLW.

The Lauritzen Channel is approximately 1,800 feet long and 120 feet wide at the head widening to over 350 feet at the mouth. The depth of the channel ranges from approximately -10 to -39 feet MLLW. The western shoreline is presently occupied by the Manson Construction Company and LRTC occupies the eastern shoreline. LRTC maintains two berths (Berths B and C) on the southeast side of the Lauritzen Channel and one berth (Berth A) in the Santa Fe Channel. The most recent maintenance dredging in the Lauritzen Channel occurred in 1985 and reached a depth -41 feet MLLW in the Levin berths (White et al., 1994). LRTC has continued to conduct advanced maintenance dredging of Berth B in the Santa Fe Channel as recently as 2013, according to LRTC staff.

The sediments in the Lauritzen Channel are comprised of two stratigraphic units: the Younger Bay Mud and Older Bay Mud. The Younger Bay Mud consists of dark gray to black very soft to soft clay, silt, and fine-grained sand with a high water content (White et al., 1994). The Older Bay Mud underlies the Younger Bay Mud, and consists of dry, consolidated, firm to hard silts and clays with varying amounts of sand and gravel.

Features of the Lauritzen Channel, along with previously dredged areas, are shown in Figure 1-3. A numbering system was established along the eastern shoreline by LRTC based on “bent” numbers assigned to the rows of pilings supporting the Levin pier. Each row of pilings is assigned a whole number, starting with positive numbers from the north end to south end of the pier ranging from 1 to 73 (Figure 1-3 ). North of the Levin pier, the abandoned rows of pilings where the pier deck has been removed are assigned negative numbers from (0 to -47).

Prior to 2014, the eastern shoreline of the Lauritzen Channel consisted of sheet pile (steel plates supported by railroad ties), concrete, riprap, and/or shotcrete (pneumatically applied concrete). In addition, a site survey in 2012 documented a number of small outfall pipes on the banks of the Lauritzen Channel (Appendix B). The large outfall at the northern end of the channel is a City of Richmond municipal outfall that provides the primary storm drainage from the surrounding area into the channel. In October 2012, USEPA installed a flap gate on this municipal outfall to prevent the potential movement of DDT-contaminated sediment into the storm drain system during high tide. In the summer and early fall of 2014, during extreme low tides, LRTC continued placing shotcrete along the eastern shoreline. The west to east portion of the shoreline along the head of the channel was shotcreted from the negative tide line to the top of the sea wall. From approximately bent -47 south to bent 0 the shoreline was partially shotcreted from approximately two feet below to the base of the sheetpile. From bent 1 south to bent 9, bent 28 to bent 60, and bent 64 to 69.5, the face of the shoreline from the negative tideline to above the high tideline was shotcreted. The majority of the western shoreline of the Lauritzen Channel consists of rock and riprap.

#### 1.2.2.2 Parr Canal

The Parr Canal lies to the east of the Lauritzen Channel (Figure 1-1) and is not actively used. It is approximately 750 feet long, a maximum of 100 feet wide, and generally less than 10 feet MLLW in depth. The shoreline surrounding the Parr Canal is armored with riprap typically derived from concrete construction debris. A City of Richmond stormwater outfall is located at the northern end of the Parr Canal. In 2011, the City installed a flap gate on the outfall to prevent tidal inflow into the storm drain system.

#### 1.2.2.3 Santa Fe Channel and Inner Harbor Channel

The Santa Fe Channel is approximately 4,000 feet long and up to 380 feet wide. Approximately one-half of the Santa Fe Channel is maintained at a depth of -35 feet MLLW by the U.S. Army Corps of Engineers (USACE). The head of the channel and its berth areas are maintained by the Port of Richmond or private

owners. The Inner Harbor Channel extends south to Point Potrero and is maintained by the USACE at a depth of -37 feet MLLW.

## 1.3 Site Operational History

The Lauritzen Channel was created in the 1940s by dredging a marshy area adjacent to the Santa Fe Channel to support shipbuilding activities during World War II. A shipyard operated between the Lauritzen Channel and Parr Canal, and at the conclusion of the war all the buildings were demolished. Between 1945 and 1966, the site was used by several companies, including the Parr Richmond Terminal Company, the Universal Pigment and Chemical Company, R.J. Prentiss and Company, Heckathorn and Company, United Chemetrics, and Chemwest to process and package various chemical products. DDT, dieldrin and other pesticides were formulated, processed and packaged on the site until 1966, but no chemicals were manufactured on site. Pesticide processing operations ended in 1966 (White et al., 1994; Lincoff et al., 1994).

United Heckathorn used the facility to receive technical grade pesticides from manufacturers, grind the pesticides into powder, add solvents and other components to facilitate its application, and package the product for final use in liquid and powder forms. Information regarding the exact types and quantities of materials used and onsite waste disposal methods is limited. Equipment containing pesticide residues was routinely washed, and wash water reportedly was permitted to infiltrate through the ground surface or discharge directly to nearby waterways. Later modifications included incorporating settling tanks to recover pesticide residuals; however, leaks from these tanks were believed to have occurred. Additionally, poor housekeeping practices and spills, leaks, and other releases resulted in the direct discharges of DDT to soils and waterways.

In 1960, the San Francisco Bay Regional Water Quality Control Board observed bulk storage of pesticides and solvents, leaking pipelines, and release of pesticide-laden wastewater to the Lauritzen Channel. In 1965, California Department of Fish and Game staff reported leakage from settling tanks and a discharge of water overflow to the Lauritzen Channel. Buildings associated with United Heckathorn were demolished by 1970. Levin Metals Corporation purchased the site in 1981. In 1980, the California Department of Health Services investigated the Site and chlorinated pesticides and metals were discovered in soil samples. In March 1990, the Site was placed on the NPL, and the USEPA assumed lead agency status. A chronology of site events is presented in Table 1-1.

## 1.4 Remedial Investigation and Feasibility Study

The Remedial Investigation (RI) for the marine sediments at the United Heckathorn Superfund Site was completed in 1994 (White et al., 1994). The RI found that total DDT and dieldrin in marine sediments were present at higher concentrations and over a larger area than other contaminants. The highest total DDT concentrations were found in Lauritzen Channel and Parr Canal sediments. DDT concentrations decreased with increasing distance from the Site, reaching background levels for San Francisco Bay near Point Potrero at the south end of the Inner Harbor Channel. Contamination was concentrated in the Younger Bay Mud; in general, only traces were found in the Older Bay Mud.

The human health risk assessment (HHRA) for the Site indicated that the consumption of whole fish or fish fillets contaminated with DDT and dieldrin posed an unacceptable human health risk (ICF Technology, 1994). The ecological risk assessment (ERA) concluded that DDT and dieldrin at the Site posed an unacceptable risk to benthic (bottom-dwelling) organisms, water column organisms, and sensitive fish-eating birds (Lee et al., 1994). The Feasibility Study (FS) was completed in July 1994 (Lincoff et al., 1994) and the ROD was signed in October 1994 (USEPA, 1994a). Updated risk evaluations (developed after the dates listed) are summarized in Section 4.

# 1.5 Previous Remedial Actions

Multiple remedial actions have been implemented at the Site to address DDT and dieldrin contamination in upland soil and marine sediment at the Site. These activities took place from the early 1980s through 1999 and are summarized below.

1. Soil excavation and offsite disposal at the former United Heckathorn facility. Removal of contaminated soil, asphalt, and concrete began in 1982 and additional removal actions were performed in 1983 and 1986. Between November 1990 and April 1991, approximately 3,300 cubic yards ($yd^3$) of contaminated soil and visible pesticide residue were removed from the upland and embankment areas of the Site. The extent of the excavation is shown in Figure 1-3. An additional soil removal action was completed in May 1993 (USEPA, 1994).

2. Capping of former United Heckathorn facility. In accordance with the ROD, the former facility footprint in the upland area (approximately 5 acres) was capped with concrete and asphalt in 1998 and 1999. The extent of the cap is shown in Figure 1-3. Maintenance and inspection of the cap system continue, and the most recent Five-Year Review indicates that the cap is functioning as intended (USEPA, 2011).

3. Dredging and offsite disposal of sediment. Between August 1996 and March 1997, a total of approximately 108,000 $yd^3$ of sediment were removed from the Lauritzen Channel and the Parr Canal; 105,000 $yd^3$ from the Lauritzen Channel, and3,000 $yd^3$ from the Parr Canal. The extent of dredging is shown in Figure 1-3. The sediment was dewatered and transported to offsite disposal facilities.

Clean sand was placed to a nominal thickness of 6 inches over dredged portions of the Lauritzen Channel to facilitate colonization by benthic organisms (Chemical Waste Management Inc., 1997). A thicker layer of sand (approximately 18 inches) was reportedly placed in inaccessible areas that were impractical to dredge (i.e., in the areas of abandoned pilings). No sand was placed underneath the Levin pier because the slope was too steep to hold sand, or in the Levin berth so that its full operating depth could be maintained. The sand was hydraulically pumped from a barge into the channel. A bathymetric survey was performed after sand placement was completed; however, the distribution and thickness of the sand layer do not appear to have been verified. No other dredging activities have been conducted in the Lauritzen Channel since 1997.

SECTION 2

# Post-Remediation Investigations

This section summarizes the investigations that have been performed since the 1996-1997 remedial action in the marine portion of the Site. The analytical data for the surface water, mussels and fish tissue from the biomonitoring studies are provided in Appendix A. Data from the recontamination investigations (i.e., sediment, embankment soil, groundwater, and wood chip results) are included in Appendix B. The data have been incorporated into the updated CSM in Section 3. The post-remediation activities are summarized in the site chronology in Table 1-1.

## 2.1 Post-Remediation Biomonitoring

Post-remediation biomonitoring was performed yearly from 1998 through 2003, and in 2007, 2009, 2012, and 2013 to monitor trends of total DDT and dieldrin concentrations in mussel tissue and surface water. Biomonitoring locations are shown in Figure 2-1. The following stations are typically monitored: two in the Lauritzen Channel (Stations 303.2 and 303.3), one in the Santa Fe Channel (Station 303.4), one in Richmond Inner Harbor (Station 303.1), and one in the Parr Canal (303.6), which was added in 2002. Four additional Lauritzen Channel stations were sampled in 2007. The sampling program is summarized in Table 2-1.

Both resident and transplanted mussels have been utilized for biomonitoring as shown in Table 2-1. Resident mussels have been collected in every biomonitoring event, and transplanted mussels were deployed in a subset of events. Transplanted mussels were deployed for up to 4 months (September through January); however, in 2009, 2012, and 2013 mussels were deployed for approximately 1 month.

Surface water samples are collected from each monitoring location using direct grab/direct fill methods. Water samples are collected approximately 1 foot below the water surface. Passive samplers were included in the Year 5 (2001-2002) and Year 16 (2013) events. Biomonitoring results are discussed in Section 3.3.

## 2.2 Sediment Recontamination Investigation

In October 1998, the University of California, Santa Cruz reported elevated DDT concentrations in sediment samples from the Lauritzen Channel (Anderson et al., 2000). A sediment recontamination investigation was completed in 1999 to characterize the condition of the sediments at the Site 2 years after remediation (Kohn and Gilmore, 2001). Twenty-five sediment cores were collected from the Lauritzen Channel, three cores were collected from the Parr Canal, and two grab samples were collected from the Santa Fe Channel. Sediment sample locations and DDT results for the northern and southern portions of the Lauritzen Channel are shown on Figures 2-2 and 2-3, respectively. The major findings of the sediment recontamination investigation were as follows:

- Total DDT concentrations in the Younger Bay Mud samples collected from the Lauritzen Channel ranged from 26 to 180,000 micrograms per kilogram (µg/kg). Nearly all of the DDT concentrations exceeded the RG of 590 µg/kg. The highest concentrations were detected at locations adjacent to the north end of the Levin pier, west of the former United Heckathorn buildings.
- The Younger Bay Mud layer in the Lauritzen Channel was 0 to 2.7 feet thick, with the greatest accumulation in the Levin berths and at the head of the channel.
- The sand layer placed as part of the remedial action was found in only three cores in the Lauritzen Channel.
- Only minor changes were seen in the Parr Canal; the sand layer was intact and little deposition of new Younger Bay Mud sediment on top of the sand had occurred.

- The total DDT concentration in a grab sample from the Santa Fe Channel was below the RG.

Figures 2-2 and 2-3 present the historical sediment data collected from 1998 through 2008. These figures are intended to provide a comprehensive summary of the data collected after the remedy was implemented, but prior to the 2013 source identification investigation. The shape of the station marker indicates the year the data were collected, the color denotes the total DDT concentration, and the size of the marker indicates the sampling depth. The sediment sampling results from the 2013 source identification investigation were used to establish the remedial footprints for this FFS and are discussed in Section 3.

## 2.3 Phase I and Phase II Source Investigations

After the recontamination of the Lauritzen Channel was established, a phased study was performed to identify the source(s) of the recontamination. A summary of these investigations is provided below.

### 2.3.1 Phase I Source Investigation

The Phase I investigation focused on the most likely sources of DDT recontamination to the Lauritzen Channel, including outfall pipes, undredged sediment, and unexcavated embankment soil and sediment (Kohn and Evans, 2002). The objectives of the Phase I investigation were as follows:

- Evaluate pesticide concentrations associated with outfall discharges.
- Identify any additional outfalls under the Levin pier.
- Identify the type, quantity, and distribution of sediment under the Levin pier.
- Quantify pesticide concentrations in sediment under the Levin pier.
- Evaluate sediment structure and slope stability under the Levin pier.
- Identify locations where unexcavated embankment material or undredged channel sediment were potentially contributing to the high DDT levels observed in post-remediation sampling.

The study scope included outfall sampling (sediment and water), an underwater reconnaissance survey along the eastern embankment of the Lauritzen Channel, and sediment and embankment soil sample collection. The underwater survey documented the sediment type, slope, and thickness under the Levin pier and identified additional outfall pipes. Outfall pipes were sampled for sediment and water, when possible. Sediment was either collected directly from the pipe or from a specially designed sediment trap placed at the end of the pipe. Passive samplers were deployed to determine whether water flowing from outfall pipes carried significant quantities of pesticides. Embankment soil and sediment samples were collected from 17 locations to target suspected source areas based on the former United Heckathorn building footprints, the extent of previous removal actions, the thickness of soft sediment under the pier, and historical sediment data. USEPA collected an additional 21 sediment samples to delineate the area of highest sediment contamination.

The Phase 1 investigation concluded that most of the identified outfalls were not likely to be significant sources of the DDT to the Lauritzen Channel, but two outfalls were identified for further investigation:

- Concrete outfall at T-8.5 - a concrete outfall on the eastern bank of the channel was found to be discharging a small volume of water during the Phase I sampling event. The water contained part-per-million levels of total DDT and dieldrin.
- 8-inch outfall at T-27—this outfall was recommended for further investigation because the data collected during the Phase I investigation were inconclusive and the outfall could not be ruled out as a potential source.

The underwater survey results indicated that the volume of sediment along the eastern shoreline from the south end of the Levin pier to T-24.5 was approximately 830 $yd^3$, with most of the volume under the Levin Pier. The volume of Younger Bay Mud in the rest of the Lauritzen Channel was estimated to be 12,770 $yd^3$.

Embankment soil and sediment results are shown on Figure 2-3. Embankment soil samples collected near the north end of the Levin pier contained higher DDT concentrations than those found in Lauritzen Channel sediments, indicating that shoreline erosion could be acting as a source of DDT to the channel sediments.

The Phase I Source Investigation concluded that undredged sediment under the Levin pier that had been redistributed throughout the Lauritzen Channel was the most likely source for the recontamination of the channel sediment. Although the volume of soft sediment along the embankment was estimated to be relatively small, two of the cores collected from this area had the highest total DDT concentrations found in Lauritzen Channel sediment at that time (23,190,000 µg/kg and 1,591,000 µg/kg at location T+2.5 between bents 2 and 3). These concentrations were one to two orders of magnitude higher than the concentrations found in surface sediment during the 1999 sediment recontamination investigation (Kohn and Gilmore, 2001).

### 2.3.2 Phase II Source Investigation

The Phase I Source Investigation identified several potential sources that required further investigation including highly contaminated sediment beneath the north end of the Levin Pier, embankment soils, and previously unidentified outfall pipes discharging into the Lauritzen Channel. The objectives of the Phase II investigation were to delineate the sediment hotspot under the north end of the Levin pier, further characterize the depth of contamination in embankment soils, verify the outfall discharges, and survey the Younger Bay Mud thickness and total DDT concentrations in the Lauritzen Channel (Kohn and Evans, 2004). Sediment and soil results sampling locations and results are shown in Figures 2-2 and 2-3.

The Phase II study objectives were achieved through the collection of embankment soil samples using hand augering methods. Sediment cores were collected by divers at 17 locations and by vibracore at 11 locations. Samples collected from the vibracoring effort were used to document the Younger Bay Mud thickness and for chemical and physical characterization. During the field sampling, water was observed discharging from a broken concrete outfall on the embankment below the high tide line near the northern end of the former building footprint at T-12.5. This feature was referred to as the “seep.”

Embankment soils were analyzed to assess the vertical distribution and extent of total DDT. The results varied by sampling location, with the highest concentrations at the surface at some locations and in the subsurface at others. Under the north end of Levin pier, embankment soils were substantially more contaminated at depth than at the surface.

Sediment cores were collected near the north end of the Levin pier to delineate the sediment hotspot identified in the Phase I study. The results indicated that total DDT concentrations decreased by three to four orders of magnitude within 40 feet to the east of the hotspot, under the pier. Total DDT concentrations also decreased steeply to the north and south, but remained elevated down slope (west) of the hotspot.

The Phase II investigation concluded that the hotspot under the north end of the Levin pier and the seep at T-12.5 were most likely contributing to high DDT concentrations detected in mussels collected from the T+2 pilings. The highest concentrations of total DDT were measured in water, sediment, and mussels sampled from the seep pipe, and high total DDT in water samples taken approximately one year apart suggested that the seep was an ongoing source. The seep was plugged and sealed in July 2003.

A smaller hotspot was identified on the west side of the Lauritzen Channel, west of the Levin pier. No source of DDT was identified on the west side of the channel, and the hot spot was attributed to the resuspension and redistribution of sediment in the channel by a combination of vessel disturbance and tidal currents. The Phase II data indicated that the total DDT concentrations in almost all the Younger Bay Mud samples collected from the Lauritzen Channel exceeded the RG for total DDT.

## 2.4 Phase III Source Investigation

The purpose of the Phase III investigation was to refine the understanding of the processes contributing to exceedances of the surface water RGs for total DDT and dieldrin in the Lauritzen Channel. The principal study questions for this investigation were as follows:

1. Is fluid mud present?
2. Does water from the near-bottom of the water column significantly differ from the mid- to upper- water column contaminant loads, such that the lower water column could be an active contributor to the mid- to upper-water column?

These questions were investigated because suspended sediments at the Site could be acting as an ongoing source of DDT to the water column, which could potentially affect the selection of technologies in the FFS. The study methods and results are provided in two letter reports prepared by the USACE (Welp, 2005 and Wakeman, 2004). The term "fluid mud" was used to describe a "high (solids) concentration suspension that can exist on the bottom of waterways with favorable mineralogical and hydrodynamic conditions." This layer is also known as the nepheloid layer, a high turbidity suspension, fluff layer, colloidal layer, and flocculation layer, among other descriptors.

### 2.4.1 Fluid Mud Survey

The fluid mud survey was performed by USACE District San Francisco, USACE District Seattle, The U.S. Army Engineer Development and Research Center (ERDC), and USEPA. The purpose of the survey was to determine if fluid mud existed on the bottom of Lauritzen Channel, and if so, to map the spatial boundaries and density structure. The survey was performed using conventional dual frequency hydrographic surveying techniques and with a Densitune and SILAS system developed by STEMA Survey Services of the Netherlands.

A fluid mud layer was not detected by the dual frequency hydrographic survey, although several locations were identified as having what appeared to be a "soft" bottom. A second survey was performed with the Densitune and SILAS system. Eight sediment profiles were performed using this system; the profiles targeted areas that had been identified as potentially having a soft bottom. Surface sediment grabs were also collected to calibrate the Densitune probe. USACE and USEPA concluded that it was highly unlikely that fluid mud, defined as a sediment/water suspension with a fluid consistency, existed in measurable quantities in the Lauritzen Channel at the time of the survey.

### 2.4.2 Water Column Evaluation

Water column sampling was performed to determine whether highly concentrated suspended sediments were present near the bottom of the Lauritzen Channel, and whether the bottom of the water column contained a significant reservoir of DDT and dieldrin. Water samples were collected from two depths at four locations. Each location was sampled at the mid-point of the water column and 6 to 7 inches above the sediment surface. The water sampling results indicated that the total DDT concentrations in the mid-depth samples from three of the four sampling locations were lower than the sample collected near the bottom of the water column, and that the deeper sample had more particulate-phase contamination. The report concluded that there was evidence that mobile reservoirs of total DDT and dieldrin exist near the sediment surface, and mix with the rest of the water column.

## 2.5 2007 Data Gaps Investigation

The objective of the 2007 Data Gaps Investigation was to characterize DDT and dieldrin concentrations in mussel tissue, water, and sediment to establish updated baseline site conditions for the FFS (CH2M HILL, 2008a). Resident mussel tissue samples were collected from nine locations in June 2007. The mussel sampling locations included five biomonitoring stations and four new stations along the Lauritzen Channel embankment, including a location near the City of Richmond outfall at the northern end of the channel (Figure 2-1). Twenty-eight surface water samples were collected from 11 locations in August 2007. Water samples were collected from multiple depths at each location. A whole water and filtered sample were collected from each sampling interval. The mussel and surface water data are discussed in Section 3.3.

Sediment cores were collected from 21 locations in the Lauritzen Channel, four locations in the Santa Fe Channel (near the mouth of the Lauritzen Channel), and three locations in the Parr Canal. Sample locations and results are shown on Figures 2-2 and 2-3. The total DDT concentrations in Younger Bay Mud samples

ranged from 6.7 to 88,830 µg/kg. The maximum concentration was detected in a near-surface sample from the northern end of the Lauritzen Channel. Total DDT concentrations in sediment samples collected from the embankment ranged from 26.7 µg/kg to 4,525 µg/kg.

# 2.6 Storm Drain Investigation

A storm drain investigation was performed to determine whether the City of Richmond municipal storm drain system was a source of DDT and dieldrin to the Lauritzen Channel (USEPA, 2011). Field studies were performed to determine the hydraulic connectivity of the storm drain structures to the outfalls at the head of the Lauritzen Channel and Parr Canal, and to characterize the residual sediments in the storm drain system. Additionally, a video survey was performed to assess the integrity of the storm drains that extend under the upland cap. The sampling results indicated that sediment in one storm drain had a maximum total DDT concentration of 52,000 µg/kg. This portion of the municipal storm drain system has not been cleaned out by the City of Richmond in many years, and the DDT-contaminated sediments from this drain may be a remnant of historical operations at the Site.

# 2.7 Fish Tissue Investigations

Fish tissue sampling was performed in Inner Richmond Harbor in 2008 and 2013.

## 2.7.1 2008 Fish Tissue Investigation

The objective of the 2008 fish sampling event was to characterize post-remediation concentrations of DDT and dieldrin in fish tissue near the Site. Fish sampling was conducted in May and June 2008. Fish were collected from the five biomonitoring locations: two in the Lauritzen Channel, Santa Fe Channel, Parr Canal, and Inner Richmond Harbor. The fish species collected included shiner surfperch, bay shrimp, anchovy, staghorn sculpin, starry flounder, walleyed perch, sanddabs, California halibut, bay goby, and jacksmelt. White croaker, a target fish species, was not caught. The results of the 2008 fish sampling event are reported in CH2M HILL (2008b). The data are evaluated in the updated CSM in Section 3.3.

## 2.7.2 2013 Fish Tissue Investigation

The objective of the 2013 community fish sampling effort was to determine concentrations of DDT and dieldrin in fish caught for personal consumption in areas where local fisherman would fish adjacent to the Lauritzen Channel in the Richmond Inner Harbor. Fish were collected in November 2013 from the Santa Fe Channel, Ferry Point, and Sheridan Point. Fish species captured and processed during this event included barred surfperch, white surfperch, shiner surfperch, and jacksmelt. Detailed methodology and results of the 2013 fish sampling effort are reported in CH2M HILL (2014).

# 2.8 Carbon Amendment Treatability Study

A treatability study using sediments from the Laurtizen Channel was performed by Stanford University. Tomaszewski and others (2007) assessed the potential effectiveness of activated carbon amendment as an in situ treatment method for DDT-contaminated sediments from the Lauritzen Channel. Laboratory bench-scale studies were performed to measure uptake by semipermeable membrane devices (SPMDs) over a 2-year treatment period.

As part of the study, the amount of total DDT in untreated sediment was quantified by particle size fraction and particle type. The clay and silt fraction of the sediment (<63 micron) accounted for 82 percent of the sediment mass and 77 percent of the total DDT mass. Sediments from the Lauritzen Channel contained relatively small amounts of black carbon and were mostly composed of fine-grained, inorganic minerals, and the majority of total DDT was found to reside in the fine, heavy-density mineral fraction. Because of the lack of black carbon, it was hypothesized that small additions of a highly sorptive activated carbon amendment would result in significant effects on partitioning and availability of total DDT.

The study also measured desorption of various DDT metabolites from sediment over a 55-day period. The major finding was that the DDT metabolites (dichlorodiphenyldichloroethane [DDD] and dichlorodiphenyldichloroethane [DDE] isomers) exhibited much faster release from sediments, and therefore are likely to be more bioavailable than the parent DDT.

Two series of experiments were performed: the first to test various types and sizes of activated carbon amendments, and the second to test various doses and treatment times for the reactivated carbon amendment, which is less costly than virgin carbon. The treatability tests were performed using samples of Younger Bay Mud collected from the Lauritzen Channel in 2003.

The first series of experiments evaluated four different types of activated carbon. Three of these were new or "virgin" carbon amendments and the fourth was a reactivated carbon. Amendments were tested using the particle size distribution as received from the manufacturer, and after being to ground to a uniform, smaller particle size. Aqueous-phase DDT concentrations were reduced by up to 83 percent after one month, and the reactivated carbon amendment was as effective as the more expensive virgin materials. A uniform, smaller particle size for the amendment was associated with a larger reduction of SPMD uptake (i.e., increased sorption to the carbon, and therefore greater effectiveness).

In the second series of tests, various dosage rates, treatment times and sizes of reactivated carbon were tested. Doubling the dosage corresponded to a near doubling of the effectiveness. As the treatment time increased, the uptake of total DDT by the SPMDs was significantly reduced. The ground, reactivated carbon resulted in a 91 percent reduction in SPMD uptake after 1 month and a 99 percent reduction in SPMD uptake was achieved after 26 months (using 3.2 percent application rate). The effectiveness of reactivated carbon for sequestering DDT was not diminished over 26 months of treatment, demonstrating that DDT was not rereleased from the activated carbon.

## 2.9 Bioaccumulation and Passive Sampler Studies

The use of passive sampling approaches to assess DDT transport and bioavailability at the Site has been evaluated by several research groups. Passive sampling devices include polyethylene devices (PEDs), SPMDs, and solid phase microextraction (SPME) methods. This section summarizes the passive sampling bench-scale studies and field-testing that have been performed at the Site.

### 2.9.1 Bench-Scale Accumulation Study—2008

Tomaszewski and others (2008) performed a 28-day accumulation study using mussels, passive samplers, and biodynamic modeling to assess the reduction of DDT bioavailability in the water column following activated carbon amendment of sediment collected from the Lauritzen Channel. The sediments were mixed with different forms of activated carbon and the amended sediment samples were used in 28-day laboratory exposures using caged mussels (*Mytilus edulis*), SPMDs, and PEDs.

Tissue concentrations in mussels at the end of the exposure period correlated to those in the SPMDs and PEDs from the same sample. Linear regression analysis of the passive sampler and mussel data indicated high regression values for both the PED and SPMD samplers. The results of the 28-day exposure test indicated that both types of passive samplers sufficiently detected changes in the water column concentrations of total DDT. The PEDs accumulated approximately twice the amount of total DDT per unit weight than similarly sized SPMD samplers. DDD and DDE metabolites exhibited a higher degree of mass transfer from the sediment to the water column, and therefore to the mussels and passive samplers, than the parent DDT.

### 2.9.2 Field Deployment of Passive Samplers—2009

USEPA's Office of Research and Development (ORD) conducted a joint study with Massachusetts Institute of Technology (MIT) and the USACE to examine the use of passive samplers at the Site to characterize and monitor total DDT and dieldrin concentrations in biota, sediment and water. The scope of this investigation included the collection of surface water samples and the deployment of polydimethylsiloxane (PDMS) SPME

fibers, PEDs, and transplanted mussels. PED and SPME samplers were deployed in the water column at nine locations for 30 days in September and October 2009: five biomonitoring locations, one additional location at the northern end of the Lauritzen Channel, and three additional locations in the Santa Fe Channel. Resident and transplanted mussels were collected at a subset of locations.

The PED data set was of limited use because few deployed samplers were recovered and the samplers that were analyzed all exhibited losses of the performance reference compound (PRC) over the 1 month deployment. The DDT concentrations on the SPME fibers were used to estimate the corresponding dissolved-phase surface water concentration. In samples where all of the DDT compounds were detected, the ratio of SPME-estimated aqueous concentration to the filtered water concentration averaged 4 ± 6. Dissolved-phase concentrations were also estimated using transplanted mussel tissue concentrations. The average ratio of the mussel-estimated concentration of dissolved DDT to the measured water concentration was much higher (20 ± 13) than those observed for the SPME samplers. Analysis of the filtered water and SPME samples indicated that the DDD isomers had the greatest relative concentration, followed by DDT and then DDE. The results of this field study were used to develop the approach for subsequent investigations, which are summarized below.

### 2.9.3 Bench-Scale Bioaccumulation and PDMS-SPME Testing—2012

In 2012, ORD and ERDC performed additional bench-scale testing using Lauritzen Channel sediments to assess bioavailability of DDT to benthic organisms and assess the relationship between accumulation by PDMS-SPMEs and two test organisms - a burrowing amphipod (*Leptocheirus plumulosus*) and a free-burrowing bivalve (*Macoma nasuta*) (Lotufo and Burgess, 2012). Sediments were collected from three locations in the Lauritzen Channel and one location in Richmond Inner Harbor. Briefly, the exposure design included the placement of 50 amphipods into 1-liter (L) beakers containing a 3-centimeter (cm) -thick layer of sediment and approximately 700 milliliters (mL) of overlying water. Two clams were placed in 2-L beakers containing 200 grams of sediment and 1.4 L of overlying water. Sediment exposures were 28 days long for the clams and 14 days for amphipods. PDMS-SPMEs were inserted into the sediment to estimate DDT concentrations in pore water. The SPME fibers were removed when the exposure period ended.

Clam mortality was observed in replicates of the control and the sediment sample collected from the northern end of the Lauritzen Channel. Complete amphipod mortality was observed in the treatments for the northern and central-northern areas of the channel. A significant decrease in amphipod survival relative to the control was observed in the tests utilizing sediment from the southern area of the Lauritzen Channel and from Richmond Inner Harbor.

The highest total DDT concentrations in clam tissue were associated with the sediments collected from the central-northern and northern areas of the Lauritzen Channel. Concentrations of 4,4'-DDD were the highest of the DDT isomers for both species. DDT was detected in the PDMS-SPME fibers for all treatments except Richmond Inner Harbor. The DDD and DDE isomers typically showed the greatest relative abundance. DDT concentrations on the SPME fibers were used to estimate freely dissolved pore water concentrations.

The study concluded that the DDT isomers in Lauritzen Channel sediments are bioavailable and toxic to marine organisms, and the accumulation of DDT compounds predicted by the PDMS-SPMEs was well correlated with the bioaccumulation measured in the test organisms, although the SPMEs consistently underestimated the bioaccumulation.

### 2.9.4 Field Deployment of Passive Samplers—2012

In February 2012, ORD and Massachusetts Institute of Technology deployed PEDs, SPMEs, and transplanted mussels at three locations in the Lauritzen Channel to assess DDT bioavailability. Where possible, the PEDs and SPMEs were inserted into the sediment so that approximately 10 cm was left extending into the bottom of the water column and the remainder (approximately 30-40 cm) was pressed into the sediment bed. Surface sediment from the PED locations was also collected and analyzed for pesticides. PEDs and mussels

were deployed at five stations in the water column. The sampling devices were deployed for one month and of the 13 deployed PED samplers, 10 were successfully recovered (Gschwend and Burgess, 2012).

The PED and SPME samplers were extracted and analyzed, and the results were used to estimate the freely dissolved DDT concentrations in near-bottom surface water and pore water. Mussel tissue results were also used to estimate freely dissolved DDT concentrations in the water column using lipid-normalized tissue results and lipid-water partitioning coefficients.

The PED data indicated that the estimated sediment pore water concentrations were highest at the northern end of the channel. The estimated pore water concentrations were elevated to the bottom of the sampled interval, between 30 and 40 cm below the sediment surface at all the locations.

The DDD metabolites showed the greatest relative abundance in the PEDs and the transplanted mussels. The PED and mussel data were well correlated, suggesting that PEDs potentially could be substituted for mussels in future monitoring activities.

### 2.9.5 2013 Passive Sampler Investigation

In September 2013, MIT deployed PEDs in the sediment bed at 10 stations located in the Lauritzen Channel. These sample locations were chosen to fill in the spatial coverage that had been acquired during the 2012 passive sampler study (Gschwend and Burgess, 2012). Methods similar to those employed during the 2012 study were used and at every site, a portion of the sampler was purposefully left sticking up above the sediment bed so that that portion of the PE strip would sample the bottom water. At one of the locations, duplicate samplers were deployed beside each other. Water column PEDs were also deployed at five locations along the eastern edge of the Lauritzen Channel, one location in the Santa Fe Channel, one location in Parr Canal, and at a background location near Ford Point. Many of these water column samplers were located at the same stations where cages of transplanted mussels were deployed. The PED results are presented in the DDT fate and transport study report (Sea Engineering, Inc. [SEI], 2014a).

## 2.10 Source Identification Study

A source identification study was performed in 2013 (CH2M HILL 2014). The objective of this investigation was to identify and quantify potential ongoing sources of total DDT and dieldrin to the Lauritzen Channel. Potential sources evaluated in this study include:

1. Areas not previously dredged
2. Embankment along the eastern shoreline
3. Leaching from contaminated soil under the cap
4. Groundwater seepage
5. Wood pilings
6. Stormwater outfalls or other conduits
7. Sources outside of the Lauritzen Channel

The field activities associated with the source identification study included a site survey, sediment sampling, groundwater sampling and determination of groundwater seepage rates, and wet-weather outfall sampling (CH2M HILL, 2014). These activities are briefly described below. The source identification study technical memorandum is provided in Appendix B. The results have been incorporated into the updated CSM in Section 3.

### 2.10.1 Site Survey

A site survey was performed in November and December 2012. The Lauritzen Channel shoreline was inspected by boat and potential point sources of contamination including outfall pipes, breaks in the sheet pile walls, and other features that could potentially act as preferential pathways for DDT transport into the channel were documented. The locations of previously documented outfall pipes/structures were verified,

and previously unidentified features were located and mapped. A summary of the field activities and results is provided in Appendix C.

## 2.10.2 Sediment Sampling

Surface sediment grab and sediment core samples were collected in March and April 2013 to assess the present-day nature and extent of contamination and determine the thickness of the DDT-contaminated sediment layer in the Lauritzen Channel. Fourteen grab samples were collected near the head of the channel and along the eastern embankment to evaluate potential ongoing sources from the embankment. Eleven grab samples were unbiased and were collected near the head of the channel and along the eastern embankment. The other three grab samples were biased and were collected at locations previously identified as potential ongoing sources identified in the Phase I source investigation (Kohn and Evans, 2002): one outfall, one former seep, and a hot spot under the Levin pier. Five additional grab samples were collected along the northwest shoreline of the Lauritzen Channel in September 2013 to investigate potential shoreline sources to channel sediments in this area. Four of the samples were collected near the tide line, and one sample was an upland embankment soil sample.

Vibracore samples were collected to delineate the extent and volume of the contaminated Younger Bay Mud. A total of 24 sediment cores were collected from a sampling grid in the Lauritzen Channel and 3 cores were collected in the Santa Fe Channel. The analytical results for sediment samples are provided in Appendix A and the field summary report is provided in Appendix C. The nature and extent of contamination based on the 2013 data are summarized in Section 3.3.

## 2.10.3 Groundwater Characterization

Groundwater sampling and hydraulic testing were conducted in March 2013 to evaluate the potential for DDT transport into the Lauritzen Channel by groundwater discharge from the upland part of the site. Groundwater samples were collected from ten temporary soil borings and two monitoring well locations. The borings and monitoring wells were located to provide systematic spatial coverage along the shoreline adjacent to the former plant site and to target areas where the highest DDT and dieldrin concentrations had been measured historically in embankment soils. The borings were drilled to a depth of at least 10 feet below the water table and 10-foot screens were installed to allow sufficient borehole length to obtain the required volume of water for sampling. All groundwater samples were analyzed for total and dissolved DDT and dieldrin, total and dissolved semivolatile organic compounds (SVOCs), and volatile organic compounds (VOCs).

Two sets of paired, flush-mounted monitoring wells were installed for hydraulic testing. All wells had a 10-foot screen interval. Groundwater samples were collected from two of the wells. Slug tests were performed on each of the four monitoring wells on March 26, 2013, to estimate hydraulic conductivity of subsurface soils and groundwater flow velocities. In addition, a 72-hour tidal fluctuation study was performed to estimate mean water levels and propagation of tidal influence through the aquifer. This study was conducted using the two sets of monitoring wells from March 26 to March 29, 2013. The analytical results for groundwater samples are Appendix A and the field summary report is provided in Appendix C.

## 2.10.4 Outfall Sampling

Table 2-3 summarizes the outfalls and other conduits that have been identified in the Lauritzen Channel. This information was most recently updated during the site survey in December 2012 (Appendix C). Outfall locations are shown in Figure 1-2. Additional outfall pipes identified in the 2012 survey include the five storm water interceptor pipes (SW-3 through SW-7) that were installed during the final remedy for the upland portion of the Site (PES Environmental, 1998), four pipes along the western side of the channel (P4-4 through P4-7), and eight new pipes (P4-8 through P4-15) along the eastern side of the channel underneath the Levin pier. Additionally, two electrical conduits were observed on the eastern side of the channel beneath the Levin pier.

The municipal outfall at the head of the Lauritzen Channel was not sampled because DDT-contaminated sediment identified in the storm drain system has not yet been removed. The municipal outfall will be

sampled after the drains have been cleaned to verify that the system is no longer acting as an active contaminant transport pathway from the Site to the Lauritzen Channel. The other outfalls identified in the 2012 site survey were not sampled because they were either plugged or located near or below the water line.

# 2.11 Sediment Transport Study

A sediment transport study was performed in 2013 to assess the sediment dynamics in the Lauritzen Channel because (1) a substantial amount of sediment had accumulated in the channel since the remedy was completed; (2) surface and subsurface sediment DDT concentrations are above the RGs and near pre-remediation levels; 3) a definitive source(s) of the sediment and sediment-associated contamination had not been identified; and 4) additional cleanup cannot occur until any active, ongoing source(s) are controlled (CH2M HILL and SEI, 2013).

It is not clear whether the sediments that have accumulated in the channel since 1997 were already contaminated (i.e., sediments from undredged areas that have been resuspended and redistributed throughout the channel), or whether they were transported into and deposited in the channel and subsequently contaminated by an ongoing local or far-field source (or whether both processes have occurred). Additionally, the amounts of sediment and sediment-associated DDT that are being transported into and out of the Lauritzen Channel and redistributed within the Lauritzen Channel were not known.

The sediment transport study was performed in two phases. The results of the Tier 1 evaluation were used to establish the scope for the Tier 2 field investigation. The data collection activities are summarized below. The results of the Tier 1 and Tier 2 sediment transport studies have been evaluated in conjunction with the results of the source identification study and DDT fate and transport study, biomonitoring data, and data from previous investigations to update the CSM in Section 3.

## 2.11.1 Tier 1 Sediment Transport Study

The Tier 1 study was based on the evaluation of sediment core data, hydrodynamic data, aerial photographs, bathymetry survey data, and information about vessel movement within the channel. In 2012, SEI conducted high-resolution multibeam bathymetric and sidescan sonar surveys in the Lauritzen Channel and a portion of the Santa Fe Channel. The field summary report for the geophysical surveys is provided in Appendix C. The multibeam survey provided a detailed characterization of the bottom elevation and features, and the sidescan survey helped image hard structures, sediment characteristics, and other features on the bottom. The Tier 1 sediment transport technical memorandum is provided in Appendix D.

## 2.11.2 Tier 2 Sediment Transport Study

The Tier 2 sediment transport study addressed the following study questions:

1. What is the source(s) of the sediment accumulating in the Lauritzen Channel?
2. How does sediment transport lead to the redistribution of contamination within the Lauritzen Channel, or movement of contamination out of the channel?
3. If part of the Lauritzen Channel is actively remediated, could sediment transport lead to the recontamination of the remediated area?

The Tier 2 sediment transport study characterized the sediment erosion/resuspension and transport processes in Lauritzen Channel as follows:

- Hydrodynamic data, suspended solids, particle tracking, and sediment bed data were collected and analyzed to determine transport and potential recontamination within the Lauritzen Channel.

- Erosion potential was assessed using a propeller scour model to quantify sediment mixing depths and volumes during typical vessel operations. Model calibration and validation were accomplished using the bathymetric, sediment erosion, and suspended solids data.
- Sediment resuspension, transport, and deposition were modeled for the study site using the hydrodynamics model, Environmental Fluid Dynamics Code (EFDC). EFDC determined spatial and temporal patterns of resuspended sediment and associated contaminant transport in the Lauritzen and Santa Fe Channels. The primary goal of the modeling was to determine transport and deposition patterns of material resuspended during various anthropogenic events.
- The quantitative model was coupled with the analysis of the field data to refine the CSM and help provide answers to sediment management questions.

The Tier 2 evaluation used data from previous investigations at the Site, field measurements from the summer of 2013 led by SEI, and specific modeling analyses. The data collection methods are described in detail in the Tier 2 sediment transport study report, which is provided in Appendix D. The results are incorporated into the updated CSM in Section 3.

## 2.12 DDT Fate and Transport Study

The objective of the DDT fate and transport study was to develop a sediment and contaminant budget for the Lauritzen Channel using the results from the sediment transport study, source identification study and other investigations. The following activities were performed:

- Calculated the mass of DDT resuspended by vessel movements
- Developed a quantitative contaminant fate and transport CSM and DDT mass balance for the Lauritzen Channel
- Used the mass balance model to assess trends in DDT mass and concentration in sediment

The DDT fate and transport study report is provided in Appendix E and the results are incorporated into the updated CSM in Section 3.

SECTION 3

# Conceptual Site Model

The updated CSM for the Site focuses on the Lauritzen Channel, summarizing and integrating information about bathymetry, present-day sources of contamination, the nature and extent of contamination, sediment/DDT fate and transport, and the risks to humans and wildlife from exposure to contaminated sediment and surface water. The CSM provides the framework for developing the amended RAOs and RGs in Section 4 and for evaluating and developing remedial alternatives in Sections 5 and 6.

## 3.1 Bathymetry and Bottom Features

High-resolution multibeam bathymetry surveys and side scan sonar surveys conducted in 2012 provided a detailed characterization of the bottom of the Lauritzen Channel. The site bathymetry is shown in Figure 3-1 and the side scan sonar data are provided in Appendix D. The survey clearly shows the extents of the Levin berths, the shallower region in the northern part of the channel, and the deeper dredged channel in the Santa Fe Channel, including the Levin berth on the south side of the Levin terminal.

The bathymetric and side scan sonar surveys reveal features that form in response to processes occurring at the channel bottom. For example, generally smooth, featureless sediment beds are indicative of a depositional environment where sediments are steadily accumulating in a pattern where sediment essentially "snows" down, creating a smooth surface. Alternatively, a rippled pattern at the bottom can be indicative of an active sediment transport environment. At the head of the Lauritzen Channel, the bottom appears generally smooth, punctuated near the shorelines by some abnormal "hard" features that are likely due to shoreline debris, piers, and other structures. Of particular note in the upper channel is a single linear feature from north to south that resembles a furrow. This type of feature is typically the result of scour by a vessel propeller (i.e. prop scour) or the keel of a vessel dragging along the bottom. Further south in the channel, these linear furrow features become more evident, particularly in the deeper dredged channel. In the region of higher ship and associated tug activity near the Manson Construction and Levin facilities, more scour features are evident. Of additional note are the "crater" features near the Manson facility. When Manson brings large crane barges into this area, the large vertical spuds are dropped into the sediment to anchor the barges in place. The craters are the bottom expression due to these spuds.

## 3.2 Sources of Contamination

The source identification study technical memorandum is provided in Appendix B. The results and conclusions of the source identification study with respect to each of the sources listed in Section 2.3 are summarized below.

### 3.2.1 Undredged Areas

Two types of undredged sediment remained in the Lauritzen Channel after the remedy was completed: (1) undredged inventory—sediments that were not dredged either because of obstructions (e.g., abandoned pilings in the northeastern section of the channel, sediments beneath the Levin pier) or because they were impractical to remove (e.g., sediments along the embankment, rip-rapped areas); and (2) generated residuals - fine-grained material that was resuspended during dredging, escaped from the dredge bucket, or ran out of the scow. Additionally, undredged sediment along the sides of the channel and underneath the Levin pier continually sloughed into the dredged portions of the channel (Chemical Waste Management Inc., 1997; Kohn, 1998). The areas that were dredged during the 1996-1997 remedial action are shown in Figure 1-4.

Dredging residuals are the primary source of the DDT mass currently found in the Lauritzen Channel. The channel and embankment sample data collected since 1997 indicate that sediments and soils with DDT

concentrations above the 1994 remediation goal of 590 µg/kg have been present in and near the Lauritzen Channel since the time the remedy was completed. The surface sediment data show that the highest concentrations are found in samples collected in the undredged and partially dredged areas on the eastern embankment, and in the northern two-thirds of the channel. Additionally, none of the other potential sources that were identified appear to be contributing sufficient masses of DDT to the Lauritzen Channel to account for the concentrations currently seen in the channel sediments.

### 3.2.2 Embankment Areas

The embankment areas include the slope from the upland portion of the site down to the area where the sediment surface begins to flatten out at the edge of the channel. This area includes both upland material (soils and fill) and submerged materials (sediments). The eastern embankment of the Lauritzen Channel corresponds with the footprint of the present-day pier, as well as the location of the former pier (characterized by the presence of pier pilings). The eastern embankment was inspected and surveyed in December 2012 (Appendix C). At the time of the survey, the embankment consisted of sheet pile (steel plates supported by railroad ties), concrete, riprap, and/or shotcrete, as shown on Figure 3-1 of Appendix B; however, additional areas of the shoreline were covered with shotcrete by the property owner subsequent to the survey as discussed in Section 1.2.2.1. Erosion under the sheet pile wall (approximately 1-2 foot voids) was observed at the northern end of the embankment, beginning around bent -37 and extending north to the head of the channel. The majority of the western shoreline of the Lauritzen Channel consists of rock and rip rap. The eastern embankment soil, where exposed, was described by Kohn and Evans (2002) as mostly rocks and cobbles with interstitial gravel, sand and silt.

The underwater survey performed in 2002 indicated that the sediments under the Levin pier consisted of soft silt, sand and gravel at the pier face to steep clay banks and cobbles and boulders at the shoreline. The near-shore sediments near the embankment north of the Levin pier consisted of a fine flocculated layer over clay and occasional sand and gravel (Kohn and Evans, 2002). The under-pier sediment volume was estimated to be 465 cy (Kohn and Evans, 2004).

The embankments along the shoreline of the Lauritzen Channel were identified as a potential ongoing source of DDT contamination to channel sediments. The following contaminant transport pathways were evaluated:

- Discharges from features along the embankment that could act as preferential pathways for the transport of DDT from the former plant site to the Lauritzen Channel, including seeps and outfalls that are not related to the municipal or LRTC stormwater systems
- Erosion of contaminated embankment soils above the tide line into the Lauritzen Channel

The findings associated with these potential contamination sources are summarized below.

#### 3.2.2.1 Pipes, Outfalls and Seeps

Based on the 2012 site survey and the 2013 sampling results, the pipes, outfalls and seeps do not appear to be ongoing sources of DDT contamination to the Lauritzen Channel under dry weather conditions. The pipes and outfalls identified do not convey dry weather flow, and the one continuously flowing seep that was sampled contained only low levels of pesticides. However, other pipes and conveyances that are not visible may exist (i.e., features that terminate behind rip rap or sheetpile, or are subtidal) and may still act as preferential pathways for the transport of DDT from the upland area to the Lauritzen Channel, particularly adjacent to the former plant site and former train scale area where highly contaminated soils and groundwater still exist. Additionally, the pipes and outfalls have not been inspected or sampled during wet weather conditions.

#### 3.2.2.2 Embankment Soil Erosion

The 2013 sediment grab sample data in conjunction with historical embankment soil and sediment data indicate that DDT contamination is widespread along the eastern, northern, and northwestern shorelines of

the Lauritzen Channel. The highest DDT concentrations correspond to the areas where interim removal actions (Figure 1-3) along the embankment were previously completed, as shown on Figures 3-3, 3-6, and 3-7. These interim soil removal actions did not address sediments below about 0 feet MLLW or embankment soils with DDT concentrations below 100 mg/kg. Additionally, the dredging remedy extended only to the toe of the slope, and the area around the abandoned pilings was only partially dredged. The high DDT concentrations that persist in this area appear to be attributable to historical contamination that was not addressed in either the upland or the marine remedies.

Although the shoreline is largely armored with riprap and sheetpile, fine-grained sediments are present in pockets in the riprap and soils are eroding from under the sheetpile in some areas; therefore, erosion of contaminated embankment soils on the northern and eastern sides of the channel is an ongoing source of contamination to the Lauritzen Channel. However, the magnitude of the source is difficult to quantify because most of the embankment is lined with sheetpile, riprap, and/or concrete, with only localized areas of exposed soil subject to erosion.

### 3.2.3 Leaching and Groundwater Seepage

Beginning in 1983, groundwater monitoring wells were installed and sampled during three phases of characterization of the upland portion of the Site (Harding Lawson Associates, 1986). Before 2013, groundwater samples had not been collected at the site since the mid-1980s. Additionally, the previous monitoring wells were widely spaced in some areas along the shoreline. The potential for DDT transport to the Lauritzen Channel through leaching of pesticide-contaminated soils under the upland cap and groundwater transport to the canal were re-evaluated as part of the Source Identification Study.

The 2013 evaluation found that the shallow aquifer of the upland area east of the Lauritzen Channel contributes total DDT mass to the Lauritzen Channel sediments. The estimated contribution of total DDT from groundwater (approximately 167 grams per year (g/year) is not of sufficient magnitude to account for the high levels of DDT present in channel sediments. This conclusion is consistent with the previous findings in the 1990 upland RI report (Levine Fricke, 1990). However, groundwater discharge will continue to contribute DDT to sediments, surface water and biota in the Lauritzen Channel if not controlled.

### 3.2.4 Wood Pilings

Samples were collected from six creosote-treated wood pilings evenly spaced along the eastern side of the Lauritzen Channel during the 1999 sediment recontamination study (Kohn and Gilmore, 2001). The wood samples were collected during a low tide as close as possible to the 0-foot MLLW on the pilings. Scrapings of selected pilings were collected to a depth of approximately 3 millimeters. High concentrations of DDT were found in four of the six wood piling samples (50,000 to 200,000 µg/kg).

Kohn and Gilmore (2001) noted that the pilings could contribute to sediment contamination through mechanical weathering, which includes a range of ablative effects from anthropogenic activity, resulting in particle deposition to the sediment. Mechanical weathering of the pilings is an ongoing source of DDT-contaminated particles to the sediment bed and potentially to biota. DDT is not likely to desorb from the pilings into the sediment and water of the channel. If the pilings are not removed or cut off, the DDT-contaminated wood particles will continue to accumulate in sediments, increasing sediment DDT concentrations and potentially being incorporated into the food web.

### 3.2.5 Stormwater Outfall Discharges

Two components to the storm drain system were evaluated: the City of Richmond municipal storm drain system and the stormwater management system on the LRTC property. The City of Richmond municipal outfall at the head of the Lauritzen Channel cannot be fully evaluated as an ongoing source of contamination to the Lauritzen Channel until the DDT-contaminated residual sediments within the storm drain system are removed. This outfall will be sampled after the drains have been cleaned to verify that the system is no longer acting as an active contaminant transport pathway from the former plant site to the Lauritzen Channel.

The stormwater monitoring data collected for the storm drain system that serves the upland cap on the LRTC property indicates that the system is functioning as designed, with only infrequent direct discharges to the Lauritzen Channel. Low levels of pesticides have been periodically detected in stormwater samples from the interceptors.

### 3.2.6 Non-site-related Sources

No non-site-related sources of DDT and dieldrin to the Lauritzen Channel or the rest of Richmond Inner Harbor have been identified. The RI report concluded that the main source of total DDT and dieldrin to the Lauritzen Channel was waste discharges during pesticide processing activities at the Site (White et al., 1994). The total DDT concentration gradients measured during the RI strongly suggested that the Lauritzen Channel was the source of pesticides to the rest of Richmond Inner Harbor. Total DDT concentrations in sediment decreased by two orders of magnitude from the Lauritzen Channel to the Santa Fe Channel, and by another order of magnitude from the Santa Fe Channel to the Inner Harbor Channel. Additionally, the analysis of water-sediment ratios in the ERA also indicated that the Lauritzen Channel was the source of contamination to the other channels (Lee et al., 1994).

Ambient sediment concentrations for San Francisco Bay have been developed based on a statistical evaluation of chemical concentrations in surface sediments collected from the bay (Gandesbery and Hetzel, 1998). The “ambient” stations were located away from point and non-point pollution sources. The ambient threshold values for dieldrin and total DDT are:

- Total DDT—2.8 µg/kg for sediments with less than 40 percent fines and 7 µg/kg for sediments dominated by fines
- Dieldrin—0.18 µg/kg for sediments with less than 40 percent fines and 0.44 µg/kg for sediments dominated by fines

A sediment sample collected at biomonitoring station 303.1 in Richmond Inner Harbor in 2008 had a total DDT concentration of about 7 µg/kg (average of field duplicates) (CH2M HILL, 2008a), which is close to the ambient threshold concentration for fine-grained sediments in San Francisco Bay. Dieldrin was not detected, although the detection limit was higher than the ambient threshold concentration.

## 3.3 Nature and Extent of Contamination

The present-day nature and extent of sediment contamination in the Lauritzen Channel were assessed using the 2013 sediment sampling data described in Section 2.10.2. The 2013 sample locations are shown in Figure 3-1. Sediment core and grab sample results are provided in Tables 3-1 and 3-2, respectively.

### 3.3.1 Statistical Summaries

Statistical summaries for total DDT and dieldrin are provided in Tables 3-3 and 3-4, respectively. [4] Box-and-whisker plots of the sample results are provided in Figures 3-2 through 3-4. The 2013 sample results show the following general trends:

- The average total DDT concentration in the Younger Bay Mud is several orders of magnitude higher in the Lauritzen Channel than in the Santa Fe Channel
- The Older Bay Mud is uncontaminated except where disturbed by dredging or other anthropogenic activity (e.g. anchoring)
- Dieldrin concentrations show similar trends

[4] Total DDT is the sum of the detected concentrations of the six 2,4’- and 4,4’- isomers of DDT, DDD, and DDE. A value of one-half the detection limit was used for non-detected results for dieldrin in data analyses. The maximum concentration of each field duplicate pair was used for data analyses.

Within the Lauritzen Channel, total DDT and dieldrin concentrations in the Younger Bay Mud show the following trends:

- The average concentrations are highest near the former plant site, followed by the northern portion of the channel. The average concentrations in the east and west subareas are an order of magnitude lower.
- The average total DDT concentrations in surface sediment in all subareas are above the 1994 RG of 590 µg/kg.

As shown in Figure 3-5, total DDT and dieldrin tend to co-occur ($R^2$ = 0.76).

### 3.3.2 Spatial Distribution

Figures 3-6 and 3-7 show the distribution of surface sediment and core maximum total DDT concentrations, respectively. Surface sediment concentrations are highest along the Lauritzen Channel embankment, particularly near the former plant site, former train scale area, and at the head of the channel. Mid-channel concentrations are higher in northern half of the channel compared to the southern half. The core maximum concentrations show the same spatial patterns, but concentrations are higher at depth than at the surface.

Fine-interval cores were collected from two locations in the northern part of the Lauritzen Channel (SD13-05 and SD13-09). The total DDT profiles in these two cores are shown in Figure 3-8. These profiles both have lower DDT concentrations at the surface than at depth, suggesting progressive burial by and mixing with relatively cleaner sediment at these locations. The coarse-interval profiles for the remaining cores are provided in Appendix F. Some of these cores show higher concentrations at depth, some show higher concentrations at the surface, and several show no discernable trend with depth.

### 3.3.3 DDT Composition

DDT naturally degrades in the aquatic environment through various physical, chemical and biological processes (Horsak et al., 2006). Degradation rates and pathways for DDT vary widely depending on environmental conditions such as pH, availability of various nutrients and oxygen, temperature, and nature of the microbial populations. DDT undergoes goes aerobic and anaerobic degradation. Under anaerobic conditions, DDT typically degrades to DDD and its breakdown products, whereas DDE and its breakdown products are more typically found in aerobic systems (Walker et al., 2004; Yu et al., 2011).

The degradation rates of DDT in the Lauritzen Channel sediments are not known and cannot be determined without additional site-specific studies. However, high concentrations of DDT and its metabolites persist in sediment even though the pesticide processing activities at the site ended in 1966. Figure 3-9 shows the relative contributions of 4,4'-DDT, 4,4'-DDD, and 4,4'-DDE in surface sediment by subarea. Samples collected near the former plant site have the highest proportions of 4,4'-DDT (approximately 65 percent), indicating relatively non-degraded DDT deposits. For comparison, technical-grade DDT contains 65-80 percent 4,4'-DDT (Metcalf, 1995). The most abundant metabolite in the northern head and west side of the channel is 4,4'-DDD (approximately 50 percent), indicating a more degraded contaminant mix, with degradation occurring under mostly anaerobic conditions. A notable exception is samples SD13-01 and SD13-02, which were collected from the embankment at the northwest corner of the channel (Figure 3-1). This area is believed to be affected by runoff from a soil stockpile that was formerly located in this area (Appendix B).

## 3.4 Sediment Transport Process Summary

The Lauritzen Channel is a low-energy, protected region with tidal velocities that are not likely to result in sediment resuspension. The low energy coupled with sediment input from San Francisco Bay result in a net sediment accumulation in the channel. Ongoing vessel operations in the channel are responsible for localized sediment bed resuspension (up to approximately 10 cm deep) and sediment transport modeling indicated that resuspended sediment is primarily deposited locally within the channel within a few hundred

meters from where it was resuspended. The Tier 2 study modeling indicated, on average, approximately 3.5 percent of resuspended sediment may be tidally dispersed into the Santa Fe Channel.

The largest amount of sediment accumulation is observed in the berth on the east side of the Lauritzen Channel. The observed accumulation is occurring in the deep dredged region where currents are likely the lowest, causing the berth to behave as a sediment trap. Conversely, generally low accumulation of Younger Bay Mud is observed in the west side of the channel, which experiences the highest vessel activity in relatively shallow regions. Finally, the northern head of the channel with low energy shallow water and moderate barge activity exhibits a moderate Younger Bay Mud accumulation and a mix of potential erosion and deposition. The general boundaries of these three regions (Northern Head Area, Eastern Area, and Western Area) are illustrated in Figure 3-1.

Vessel resuspension is responsible for the mixing of surface sediment, redistribution of sediment within the channel, and loss of sediment to the Santa Fe Channel. The Tier 2 modeling indicated that in areas with sufficient water depth to allow for typical unimpeded vessel movements, vessel scour depth averages about 1.4 cm, with a maximum depth of about 10 cm (SEI, 2014b). As discussed in Section 3.1, the bathymetric and side-scan sonar surveys also identified more significant scour and sediment redistribution features in both the northern head and deeper dredged areas, which are typical of vessel propellers or the keel of a vessel dragging along the bottom sediment. Furthermore, "crater" features near the Manson Construction facility are likely the result of large vertical spuds from crane barges being dropped into the sediment to anchor the barges in place, and likely results in sediment resuspension and redistribution.

The wake caused by a vessel also has the potential of mobilizing sediment near or under piers and in shoreline areas throughout the channel as a whole; however, the mass of sediment suspended along the shorelines is very low in comparison to the sediment suspended behind a vessel.

The modeling simulations in the Tier 2 sediment transport analysis indicated that sediment deposition was negligible outside of the Lauritzen Channel one day after resuspension due to vessel activity. The results indicated that on average 96.5 percent of the sediment was deposited within Lauritzen Channel, resulting in an average loss of 3.5 percent of resuspended sediment mass. Although the modeled sediment loss from the Lauritzen Channel is small, due to the relatively high concentrations of sediment-associated DDT contamination, the site acts as a potential DDT source to the San Francisco Bay.

## 3.5 DDT Fate and Transport

The DDT fate and transport study report is provided in Appendix E. The objectives of the study were to develop a quantitative contaminant fate and transport CSM and DDT mass balance for the Lauritzen Channel, and to assess trends in DDT mass and concentration in the channel. Figures 3-10 and 3-11 present conceptual diagrams of average annual sources and losses of DDT and sediment respectively to the Lauritzen Channel. The DDT mass balance model shows that Younger Bay Mud total DDT concentrations are projected to decrease, even when accounting for uncertainty in the magnitude of the ongoing sources to the system. The projected Younger Bay Mud total DDT concentrations remain over 2,000 µg/kg in the year 2050 despite a +/- 50 percent variation in DDT mass input. The magnitudes of sources and losses of DDT investigated in the mass balance support the conclusions of the source identification study that ongoing sources are relatively small compared to the DDT mass in channel sediments. The findings lead to the conclusion that dredge residuals are responsible for the primary DDT mass in the Lauritzen Channel.

## 3.6 Human Health and Ecological Risks

The HHRA for the Site indicated that the consumption of whole fish or fish fillets contaminated with DDT and dieldrin posed an unacceptable human health risk (ICF Technology, 1994). An updated evaluation of risks and hazards from fish consumption was performed in 2010 using the 2008 fish tissue data (CH2M HILL, 2010a). The updated risk calculations indicated that total DDT and dieldrin concentrations in fish tissue from the Lauritzen Channel could pose unacceptable risk to people consuming fish. The risks and hazards

associated with fish caught in the Parr Canal, Santa Fe Channel, and Richmond Inner Harbor were within USEPA's risk management range or below the noncancer threshold (CH2M HILL, 2010a).

The ERA performed for the RI concluded that DDT and dieldrin at the Site posed an unacceptable risk to benthic (bottom-dwelling) organisms, water column organisms, and sensitive fish-eating birds (Lee et al., 1994). Given the elevated levels of total DDT and dieldrin consistently measured in Site sediment and biota in the years after completion of remedial actions in 1999, the ongoing presence of unacceptable ecological risk needs no further demonstration or proof. Therefore, the technical memorandum presenting the reassessment of ecological RGs did not include an updated evaluation of ecological risk beyond that required to set new RGs (CH2M HILL, 2010b).

## 3.7 Key Findings and Implications for Future Actions

The source identification study did not identify a single ongoing source of contamination to the Lauritzen Channel of sufficient magnitude to account for the high DDT concentrations seen throughout the channel sediments. Dredging residuals and undredged inventory (including contaminated embankment sediments) that were not removed during either the upland or marine remedial actions, appear to be responsible for the majority of the DDT mass currently found in the channel. However, other ongoing sources of contamination are still active and may lead to the recontamination of channel sediments, surface water, and biota in the future if not controlled or remediated. The initial marine remedy conducted from 1996 through 1997 did not include any substantive shoreline or source control measures; the remedial alternatives developed as part of this FFS include both shoreline and source control measures as critical remedy components.

In addition, over the past 10 years, the need for increased quality control during dredging has been highlighted by the scientific community, which resulted in USEPA Sediment Remediation Guidance (2005) and the U.S. Army Corps of Engineer's 2008 report on "The Four R's of Environmental Dredging: Resuspension, Release, Residual, and Risk." Sophisticated tools are available for dredging quality control, including highly accurate dredging systems that are integrated with real time kinetic - global positioning systems for precise vertical and horizontal controls, as well as high-resolution bathymetry for pre- and post-dredging surveys. Future actions at United Heckathorn Superfund Site will have the benefit of using these tools, as well as lessons learned from other large dredging projects implemented subsequent to the initial marine remedial action in the Lauritzen Channel, to ensure effective removal and/or capping of the contaminated sediments is achieved.

SECTION 4

# Remedial Action Objectives and Remediation Goals

This section presents the RAOs, RG, and remediation areas for the Lauritzen Channel within the Site. The RAOs are a general description of what the cleanup is expected to accomplish. The RAOs provide the basis for developing numerical remediation goals, which are used to identify the extent of the cleanup (i.e., the remediation area) needed to achieve the RAOs. This section also describes the potential ARARs that must be met by the cleanup.

Remedial actions at CERCLA sites must be protective of human health and the environment. For the Site, numerical RGs were developed for fish tissue, sediment, and surface water. RGs for fish tissue and sediment are based on the site-specific risk assessments rather than ARARs because there are no promulgated federal or California fish tissue or sediment cleanup standards. RGs for surface water are based on ambient water quality criteria (AWQC) for protection of human health and aquatic life. The RAOs are based on the findings of the ERA and HHRA and specify (1) the contaminants of concern, (2) the exposure route(s) and receptor(s), and (3) an acceptable contaminant level (or range of levels) for each exposure route. USEPA Sediment Remediation Guidance (2005) states the following:

> When developing RAOs, project managers should evaluate whether the RAO is achievable by remediation of the site or if it requires additional actions outside the control of the project manager…the RAOs should reflect objectives that are achievable from the site cleanup.

This FS presents a summary of the 1994 ROD, the reassessment of ecological and human health RGs, the amended RAOs, the amended RGs, potential ARARs, and the remediation footprint based on the application of the amended RGs.

## 4.1 1994 Record of Decision

A ROD was issued in 1994 (USEPA, 1994) that identified the remedy for the upland part of the site as excavation and offsite disposal of soils, and capping of the Site with concrete and asphalt. The remedy for the marine part of the Site, which included the Lauritzen Channel and Parr Canal, was dredging of the sediments and offsite disposal. A summary of the risk assessments providing the basis for the action is described below.

### 4.1.1 Human Health Risk

The human health risk was summarized as follows in the 1994 ROD, page 13:

> The results [of the baseline HHRA] indicate that among the various potential exposure pathways for Site contaminants, only the consumption of fish poses risks that are above USEPA's acceptable risk range.

### 4.1.2 Ecological Risk

The ecological was summarized as follows in the 1994 ROD, page 18:

> Overall, the results [of the ERA] indicate that the gross contaminant levels in the Lauritzen Channel threaten a variety of ecological receptors at various trophic levels, including benthic and water-column organisms and fish-eating birds. It is clear from the results above that the most sensitive ecological receptors to sediment organochlorines in Richmond Harbor are likely to be fish-eating marine birds.

### 4.1.3 Remedial Action Objective

The RAO was defined in the 1994 FS report (Lincoff et al., page iv) as follows:

> The primary remedial action objective identified for the site is the attainment of the USEPA water quality criteria and equivalent state objectives for bay waters, which are applicable, or relevant and appropriate requirements (ARARs) of federal and state environmental laws. This objective is expected to be achieved by the remediation of contaminated sediment in the Lauritzen Channel and Parr Canal. Another remedial action objective is to prevent the erosion and transport of upland soils into the Lauritzen Channel.

### 4.1.4 Remediation Goals

The final remediation levels identified in the 1994 ROD are presented in Table 4-1. For surface water the final remediation levels were 0.00059 microgram per liter (µg/L; or 0.59 nanogram per liter [ng/L])[5] for DDT and 0.00014 µg/L (0.14 ng/L) for dieldrin. The final remediation level for sediment was 590 µg/kg average based on achieving the human health AWQC for consumption of organisms. It was determined that attainment of human health AWQC for the consumption of organisms would also result in protection of ecological receptors. The sediment RG was derived from site-specific data collected for the risk assessments that were documented in the 1994 ROD.

## 4.2 Summary of 2010 Reassessment of Ecological and Human Health RGs

A reassessment of the 1994 remediation levels present in the 1994 ROD was conducted in 2010 and is described below.

### 4.2.1 Human Health RGs

The updated human health risk evaluation (CH2M HILL, 2010a) indicated that most of the fish caught in the Lauritzen Channel in 2008 would pose an unacceptable cancer risk and noncancer hazard if consumed at the assumed rates. In general, consumption of fish caught in the Parr Canal, Santa Fe Channel, and Richmond Inner Harbor pose risks that are within USEPA's generally accepted risk management range for cancer risks and hazard indices are below the non-cancer threshold of 1.0.

Risk-based concentrations (RBCs) for fish tissue were developed using the same assumptions for potential exposure that were used in the updated human health risk evaluation. Local survey data for fish consumption rates and USEPA default recommendations for exposure frequency and duration (i.e., 350 days per year for 30 years) were used to derive RBCs for fish tissue (CH2M HILL, 2010a). The RBCs for fish tissue are presented in Table 4-2. Fish tissue RBCs for total DDT ranged from 0.012 to 1.2 mg/kg wet weight. Fish tissue RBCs for dieldrin ranged from 0.00025 to 0.086 mg/kg wet weight.

Sediment RBCs for the fish consumption pathway were calculated based on site-specific empirical relationships between sediment and fish tissue. Table 4-3 presents the sediment RBCs. Sediment RBCs for total DDT ranged from 0.74 to 730 µg/kg. Sediment RBCs for total dieldrin ranged from 1.5 to 23 µg/kg.

### 4.2.2 Ecological RGs

The updated ecological evaluation (CH2M HILL, 2010b) developed a range of ecological RGs using site-specific empirical sediment-tissue relationships and modeling. RBCs were calculated for invertebrates, 18 fish, three bird species (surf scoter, double-crested cormorant, and Fosters' tern) and one mammal species (harbor seal). Sediment RBCs for dieldrin and total DDT are summarized in Figures 4-1 and 4-2.

[5] The 1994 ROD established surface water RGs with units of nanograms per liter (ng/L) and current evaluations use micrograms per liter (µg/L). In order to facilitate comparison to present day values, the original RGs are shown above using both units.

Sediment RBCs for ecological receptors for total DDT ranged from 400 to 24,000 µg/kg; the lowest RBC was based on the surfperch and the highest RBC was based on a male harbor seal. Sediment RBCs for ecological receptors for dieldrin ranged from 66 to 1,600 µg/kg; the lowest RBC was based on the surfperch and the highest RBC was based on a male harbor seal.

## 4.3 Amended RAOs

The chemicals and pathways driving unacceptable risk for the marine portion of the Site have not changed since the 1994 ROD. However, the RAOs and RGs were updated for the FFS to be consistent with USEPA Sediment Remediation Guidance (2005) and approaches used more recently at similar contaminated sediment sites. The proposed revised RAOs and RGs are summarized below. In all cases, total DDT refers to the sum of the 4,4' and 2,4' isomers of DDT, DDD, and DDE.

- **RAO 1:** Reduce to acceptable levels the risks to human health from the consumption of fish contaminated with total DDT and dieldrin.
- **RAO 2**: Reduce to acceptable levels the risks from total DDT and dieldrin to ecological receptors, including benthic invertebrates, water column organisms, and fish-eating marine birds.
- **RAO 3:** Reduce concentrations of total DDT and dieldrin in surface waters to levels that meet USEPA ecological and human health AWQC.
- **RAO 4:** Control remaining active sources of total DDT and dieldrin to the Lauritzen Channel to reduce the potential for recontamination of marine sediments.

## 4.4 Amended Remediation Goals

Tables 4-2, 4-3, and 4-4 summarize the proposed RGs for fish tissue, sediment, and surface water, respectively. These RGs were developed to meet the four RAOs for the Site.

The proposed RG for fish tissue for DDT is 0.12 mg/kg wet weight (human health RBC) and for dieldrin is 0.0025 mg/kg wet weight (human health RBC). These RGs represent the total concentration of the chemical ingested in tissue regardless of whether the concentration is ingested from fish fillet or whole-bodied fish. The proposed RGs for fish tissue correspond to the most restrictive criterion between a target excess lifetime cancer risk (ELCR) of $1x10^{-5}$ and a noncancer hazard quotient (HQ) of 1.

The proposed RG for sediment for DDT is 400 µg/kg (ecological RBC) and for dieldrin is 4.3 µg/kg (human health RBC). The ecological RBC was chosen for the proposed RG for DDT in sediment because it is less than the proposed human health RBC for DDT in sediment of 450 µg/kg. The primary purpose of the sediment RG is to define the remediation area. If the total DDT sediment RG was based on the human health sediment RBC for DDT associated with an ELCR of $1x10^{-5}$ (23 µg/kg) then the remediation area would extend into the Santa Fe Channel. However, the updated human health risk evaluation for consumption of fish caught in the Santa Fe Channel and Richmond Inner Harbor indicated that in general, cancer risks are within USEPA's risk management range of $1x10^{-4}$ to $1x10^{-6}$ and noncancer hazards are below the threshold of 1 (i.e., the HQ does not exceed 1 for concentrations of total DDT in sediment at or below 450 µg/kg). As a result, remediation of the Santa Fe Channel is not expected to be necessary to achieve the total DDT fish tissue RG of 0.12 mg/kg wet weight, which is based on an ELCR of $1x10^{-5}$. The noncancer, human health-based total DDT RBC for sediment of 450 µg/kg corresponds to an ELCR between $1x10^{-5}$ and $1x10^{-4}$, which is within USEPA's risk management range. This level is higher than the sediment concentration corresponding to the $1x10^{-5}$ ELCR for fish tissue (23 µg /kg for DDT).

The proposed sediment RGs for total DDT and dieldrin are higher than the ambient threshold concentrations for San Francisco Bay (Gandesbery and Hetzel, 1998). The proposed sediment RG for total DDT (400 µg/kg]) corresponds to a target ELCR between $1x10^{-5}$ and $1x10^{-4}$ and a noncancer HQ less than 1. The proposed sediment RG for dieldrin (4.3 µg/kg) corresponds to a target ELCR of $1x10^{-5}$and noncancer HQ of less than 1.

Additionally, the proposed RGs for sediment will be protective of all identified ecological receptors (Figures 4-1 and 4-2). Risks to green sturgeon were not evaluated; however, based on the limited habitat and site use potential of Richmond Inner Harbor and Lauritzen Channel, it can be assumed that if other benthic fishes are protected, then sturgeon would also be protected. For fish-eating birds, the U.S. Fish and Wildlife Service (USFWS) advised USEPA that evaluating the brown pelican and Forster's tern would be appropriate. The Forster's tern was included in the 2010 updated ecological evaluation. A cormorant was also included in the 2010 updated evaluation, and the cormorant evaluation is considered to be protective of the brown pelican.

The proposed RG for surface water for DDT is 0.00022 µg/L (human health endpoint) and for dieldrin is 0.000054 µg/L (human health endpoint). The proposed surface water RGs correspond to the lowest criterion between the ecological and human health endpoints (Table 4-4).

RAO 4 would be achieved by taking the following measures:

- Remediate the channel sediments and prevent the erosion and transport of DDT-contaminated embankment soils into the Lauritzen Channel.
- Prevent identified and potential unidentified pipes and conveyances from serving as DDT transport pathways from the former plant site to the Lauritzen Channel.
- Minimize the seepage of DDT-contaminated groundwater into the Lauritzen Channel.
- Remove residual DDT-contaminated sediments from the City of Richmond municipal storm drain system and verify that the cleaned storm drains do not act as DDT transport pathways from the former plant site to the Lauritzen Channel.

## 4.5 Potential ARARs

Section 121(d) of CERCLA requires that remedial alternatives attain ARARs unless they are waived in accordance with CERCLA. ARARs are regulations, standards, criteria, or limitations promulgated under federal or more-stringent state laws. An ARAR may either be "applicable" or "relevant and appropriate" to the remedial activities, but it cannot be both. NCP defines applicable, relevant and appropriate, and to-be-considered (TBC) criteria as follows:

- Applicable requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal or state law that directly and fully address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.
- Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated federal or state law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar (relevant) to those encountered at a CERCLA site that their use is well suited (appropriate) to the site.
- TBC criteria are advisories, criteria, or guidance developed by USEPA, other federal agencies, or states that may be useful in developing CERCLA remedies. They are neither promulgated nor independently enforceable; however, they may be used to set protective cleanup level targets.

To qualify as a state ARAR under CERCLA and the NCP, a state requirement must be (1) a standard, requirement, citation, or limitation under a state environmental or facility citing law; (2) promulgated (of general applicability and legally enforceable); (3) substantive (not procedural or administrative); (4) more stringent than the federal requirement; (5) identified by the state in a timely manner; and (6) consistently applied.

"Onsite" CERCLA response actions must comply with the substantive but not the administrative requirements of environmental laws and regulations. Substantive requirements are those pertaining directly to actions or conditions in the environment.

Administrative requirements are mechanisms that facilitate the implementation of the substantive requirements of environmental law or regulation. In general, administrative requirements prescribe methods and procedures (fees, permitting, inspection, reporting requirements, etc.) by which substantive requirements are made effective for the purposes of a particular environmental or public health program. Offsite actions must comply with all legally applicable requirements, both substantive and administrative.

Specifically, the onsite components of the developed remedial alternatives are evaluated in this FS on the basis of whether they can be designed to meet substantive requirements. For example, dredging in waters of the US onsite would require compliance with substantive requirements of Section 404 of the Clean Water Act, however submittal of a Preconstruction Notification would be considered an administrative requirement. All active alternatives include dredging of sediment from the channel off-site disposal, capping of shoreline sediments along the embankment as part of source control measures, long-term monitoring, and institutional controls. Some alternatives also include sediment capping in the channel,

ARARs are grouped into three types: chemical-specific, action-specific, and location-specific. Table 4-5 provides the chemical-specific, action-specific, and location-specific ARARs and TBCs that may apply to remedial actions at the Site.

Chemical-specific ARARs include laws and requirements that define health-or risk-based numerical values or methodologies applied to site-specific conditions that can be used to establish remediation goals. Many potential ARARs associated with specific remedial actions can be characterized as action-specific but include numerical values or methodologies to establish them, so they fit both into chemical- and action-specific categories.

Action-specific ARARs apply to specific actions or technologies under consideration, including the management of regulated materials.

Location-specific ARARs relate to the geographical location of the site. State and federal laws and regulations applying to the protection of wetlands, dredging in waters of the US, and protection of endangered species are examples of location-specific ARARs.

## 4.6 Remediation Areas

To identify the remediation areas, the 2013 total DDT sediment concentrations were compared with the total DDT sediment RG of 400 µg/kg. Figure 4-3 shows the range of total DDT sediment concentrations in Younger Bay Mud. Based on the comparison of the sediment concentrations with the sediment RG, the entire Lauritzen Channel was identified for remediation. Concentrations of total DDT in the Santa Fe Channel are below the sediment RG, indicating the contamination is confined to the area within the Lauritzen Channel (Figure 4-6). Concentrations of total DDT in Older Bay Mud collected from locations within the Lauritzen Channel are generally below the sediment RG with most concentrations more similar to the RMP Central Bay Maximum of 30 µg/kg and the San Francisco Bay ambient threshold of 7 µg/kg (Figure 4-6). A complete exposure pathway for subsurface sediment does not exist for ecological receptors; however, a clean subsurface layer could not be identified within the sediment column to limit the remediation area to a depth less than the Older Bay Mud.

Figures 4-4 and 4-5 indicate that the surface water RGs should be attainable in the future based on comparisons of the site concentrations with the ambient bay concentrations derived from the RMP data for the San Francisco Bay.

SECTION 5

# Identification and Screening of Remedial Technologies

This section presents the process by which potential remedial technologies for the Site sediments are identified and screened. The process comprises three steps:

1. Identify general response actions that can accomplish the RAOs identified in Section 4
2. Establish the process for initial screening of potential remedial technologies and evaluation criteria
3. Identify and screen potential remedial technologies against the evaluation criteria and in consideration of the nature and extent of contamination and other site-specific factors

General response actions are broad categories of action that, with the exception of the No Action alternative, can be expected to accomplish the RAOs. General response actions may be used in combination with one another. The No Action alternative is included because it is required by the NCP (Code of Federal Regulations (CFR), Title 40, § 300.430(e)), as a baseline alternative against which all other alternatives are compared.

The general response actions selected to address the RAOs were developed from nine primary remediation strategy categories in USEPA Sediment Remediation Guidance (2005). Table 5-1 lists the general response actions that are appropriate for consideration at the Site.

## 5.1 Technology Screening Process and Evaluation Criteria

Technology screening was conducted following the USEPA RI/FS Guidance. In addition, the technologies identified and screened are consistent with the USEPA Sediment Remediation Guidance (2005). Potential remedial technologies and process options were screened according to the following three established criteria:

- Technical effectiveness
- Implementability
- Cost

Each technology was evaluated on a scale of 1 to 4 for each of the established screening criteria, with 1 being the lowest ranking and 4 being the highest ranking. The qualitative definitions for each screening criterion are presented in Table 5-2 and the technology rankings are presented in Table 5-3. The ranking numbers are qualitative only and were not used as the basis of screening (i.e., whether a technology/process option is retained or not).

### 5.1.1 Technical Effectiveness

The technical effectiveness of a technology/process option was evaluated based on its ability to meet the RAOs under the conditions and limitations present at the Site. The technical effectiveness criterion was used to determine which remedial technologies would be effective based on the nature and extent of contamination, site characteristics, and other engineering considerations. The NCP defines effectiveness as the “degree to which an alternative reduces toxicity, mobility, or volume through treatment, minimizes residual risks and affords long-term protection, complies with ARARs, minimizes short-term impacts, and how quickly it achieves protection.”[40 CFR §300.430(e)(7)(i)]. Remedial technologies that are not likely to be effective for addressing sediment contamination at the Site were screened out and not retained for further evaluation.

### 5.1.2 Implementability

"Implementability" refers to the relative degree of difficulty anticipated in implementing a particular technology/process option under the regulatory and technical constraints posed at the Site. Implementability is evaluated in terms of the technical and administrative feasibility of constructing, operating, and maintaining the technology/process option, as well as the availability of services and materials. Technical feasibility refers to the ability to construct, reliably operate, and comply with regulatory requirements during implementation of the technology/process option. Technical feasibility also refers to the future operation, maintenance, and monitoring after the technology/process option has been completed. Administrative feasibility refers to the ability to coordinate with and obtain approvals and permits from regulatory agencies. Availability of services and materials may include the availability and capacity of treatment, storage, and disposal services; the availability of bulk materials; and the requirements for and availability of specialized equipment and technicians. Remedial technologies that cannot be implemented at the Site were screened out and not retained for further evaluation.

### 5.1.3 Cost

The primary purpose of the cost-screening criterion is to allow for a comparison of rough costs associated with the technologies/process options. The cost criterion addresses costs to implement the technology/process option and long-term costs to operate and maintain the remedy. At this stage of the process, the cost criterion is qualitative and used for rough comparative purposes only. However, no technologies were screened out based solely on disproportionately higher costs.

## 5.2 Summary of Technology Screening Results

The initial screening process evaluated the remedial technologies and process options for effectiveness, implementability, and cost. Remedial technologies and process options that would not effectively address sediment contamination at the Site were eliminated. Table 5-4 summarizes the results of the screening and the technologies and representative process options that were retained and carried forward for the development of the remedial alternatives discussed in Section 6.

As described in USEPA Sediment Remediation Guidance (2005), three potential remedy approaches should be evaluated at every sediment site: dredging, in situ capping, and monitored natural recovery (MNR). Dredging and in situ capping are viable process options for the Site and were retained for alternative development and cost estimating. However, MNR was not retained; although the Tier 2 sediment transport analysis (SEI, 2014) showed relatively clean sediment from San Francisco Bay is accumulating within the Lauritzen Channel, the rate of decrease in sediment concentration is not sufficient to meet RAOs within an acceptable timeframe. As discussed earlier in Section 3.5, the DDT mass balance model projects that Younger Bay Mud total DDT concentrations will remain over 2,000 µg/kg in 2050, well above the RG for total DDT of 400 µg/kg. The magnitudes of sources and losses of DDT investigated in the mass balance suggest that dredge residuals are responsible for primary DDT mass in the channel.

SECTION 6

# Development and Analysis of Remedial Alternatives

This section of the FFS discusses the development and evaluation of a limited number of new remedial alternatives that will address the amended RAOs for the Site. The remedial alternatives were developed by assembling the remedial technologies and process options discussed in Section 5. This section defines the criteria to be used in screening and evaluating alternatives, describes the alternatives, and evaluates them using criteria established by the NCP.

## 6.1 Evaluation Process and Criteria

The NCP defines nine criteria—classified as threshold, balancing, or modifying—to be used for the evaluation and analysis of remedial alternatives. The definitions of these criteria from the USEPA RI/FS Guidance are presented below. The alternatives were also qualitatively evaluated with respect to sustainability and green remediation metrics.

For the alternatives developed, the detailed analysis was performed using a two-step process. During the first step, each alternative was evaluated individually against the NCP criteria and the sustainability/green remediation metrics. In the second step, a comparative analysis was performed using the same criteria to identify key differences between alternatives. The detailed analysis discussed below presents the significant components of each alternative, the assumptions used, and the uncertainties associated with the assessment.

### 6.1.1 NCP Threshold Criteria

To be eligible for selection, an alternative must meet the threshold criteria described below, or in the case of compliance with ARARs, a waiver, if necessary, must be justified.

#### 6.1.1.1 Overall Protection of Human Health and the Environment

This criterion evaluates whether an alternative can protect human health and the environment. This criterion draws on the analyses performed for other evaluation criteria, particularly long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs. Evaluation of overall protection of human health and the environment offered by each alternative focuses on the following:

- Determining whether an alternative achieves adequate protection
- Considering how site risks associated with each exposure pathway are either eliminated, reduced, or controlled through treatment, engineering, or institutional controls
- Determining if an alternative will result in any unacceptable short-term or cross-media effects

#### 6.1.1.2 Compliance with ARARs

This evaluation criterion is used to determine whether an alternative meets the substantive portions of the federal and state ARARs defined in Section 4. Under CERCLA, permits are not required for actions conducted onsite; however, the substantive requirements of the associated ARARs must be met.

CERCLA authorizes the waiver of an ARAR with respect to a remedial alternative if any of the following bases exist (USEPA, 1988):

- The alternative is an interim measure that will become part of a total remedial action that will attain the ARAR.

- Compliance with the requirement will result in greater risk to human health and the environment than other alternatives.
- Compliance with the requirement is technically impracticable from an engineering perspective.
- The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method.
- With respect to a state requirement, the state has not consistently applied, or demonstrated the intention to consistently apply, the promulgated requirement in similar circumstances at other remedial actions within the state.
- For Superfund-financed response actions only, an alternative that attains the ARAR will not provide a balance between the need for protection of human health and the environment at the site and the availability of Fund monies to respond to other sites.

## 6.1.2 NCP Balancing Criteria

Alternatives meeting the threshold criteria are further evaluated using the following five primary balancing criteria.

### 6.1.2.1 Long-term Effectiveness and Permanence

The assessment against this criterion evaluates the long-term effectiveness of alternatives in maintaining consistent protection of human health and the environment. A key component of this evaluation is to consider the extent and effectiveness of controls that may be required to manage risk posed by treatment residuals and/or untreated waste. The long-term effectiveness of an alternative is assessed by considering the following two factors:

- **Magnitude of residual risk** assesses the residual risk remaining from untreated waste or treatment residuals at the conclusion of the remedial activities.
- **Adequacy and reliability of controls** evaluates the capability and suitability of controls, if any, that are used to manage treatment residuals or untreated wastes that remain at the site.

### 6.1.2.2 Reduction of Toxicity, Mobility, or Volume through Treatment

This evaluation criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies resulting in the permanent and significant reductions of toxicity, mobility, or volume of the hazardous substances as their principal element. This preference is satisfied when treatment is used to reduce the principal threats at a site through destruction of toxic contaminants, irreversible reduction in contaminant mobility, or reduction of total volume of contaminated media. The following six factors are considered when evaluating alternatives against this criterion:

- The treatment processes the remedy will employ and the materials they will treat
- The amount of hazardous materials that will be destroyed or treated (including how the principal threat(s) will be addressed)
- The degree of expected reduction in toxicity, mobility, or volume measured as a percentage of reduction (order of magnitude)
- The degree to which the treatment is irreversible
- The type and quantity of treatment residuals remaining following treatment
- Whether the alternative satisfies the statutory preference for treatment as a principal element

Of particular importance in evaluating this criterion is the assessment of whether treatment is used to reduce principal threats, including the extent to which toxicity, mobility, or volume is reduced either alone or in combination.

#### 6.1.2.3 Short-term Effectiveness

This criterion assesses the effects of an alternative during its construction and implementation until the RAOs are met. Alternatives are evaluated with respect to potential effects on human health and the environment during their implementation. The following factors are considered when evaluating alternatives against this criterion:

- **Protection of the community during remedial actions** addresses any risk resulting from the remedy implementation. Examples include dust from excavations, transportation of hazardous materials, and air-quality impacts.
- **Protection of workers during remedial actions** assesses threats potentially posed to workers and the effectiveness and reliability of protective measures that would need to be taken.
- **Environmental impacts** considers the environmental impacts potentially resulting from the construction and implementation of the alternative and assesses the reliability of available mitigation measures for preventing or reducing those impacts.
- **Time until RAOs are achieved** includes an estimate of the time required to achieve protection for either the entire site or individual elements associated with specific site areas or threats.

#### 6.1.2.4 Implementability

The implementability criterion assesses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during the remedy implementation. The following factors are considered when evaluating alternatives against this criterion:

- Technical feasibility includes the following:
  - **Construction and operation** relates to the technical difficulties and unknowns associated with a technology.
  - **Reliability of technology** focuses on the likelihood that technical problems associated with the implementation will result in schedule delays.
  - **Ease of undertaking additional remedial action** includes a discussion of what, if any, future remedial actions may need to be performed and how difficult it would be to implement those actions.
  - **Monitoring considerations** addresses the ability to monitor the effectiveness of the remedy and includes an evaluation of exposure risk should monitoring be insufficient to detect a failure.
- **Administrative feasibility** assesses the activities required to coordinate with other offices and agencies (e.g., access, right-of-way).
- **Availability of services and materials** includes an evaluation of the availability of appropriate offsite treatment, storage capacity, and disposal services; necessary equipment and specialists; services and materials (including the potential for competitive bidding); and the availability of prospective technologies.

#### 6.1.2.5 Cost

This criterion includes all the engineering, construction, and operations and maintenance (O&M) costs incurred over the life of the project. The evaluation of cost consists of three principal components:

- **Capital costs** include direct (construction) and indirect (non-construction and overhead) costs. Equipment, labor, and materials required for the installation of the remedy are considered direct costs. Indirect costs consist of those expenses related to the engineering, financial, and other services necessary to complete the remedy installation but are not part of the actual installation or construction activities.

- **Annual O&M costs** refers to post-construction expenditures required to ensure continued effectiveness of the remedial action. Components of annual O&M costs include auxiliary materials, monitoring expenses, equipment or material replacement, and 5-year review reporting.
- **Present-worth analysis** is a method of evaluating expenditures such as construction and O&M costs that occur over different lengths of time. This allows costs for remedial alternatives to be compared by discounting all costs to the year that the alternative is implemented. The present worth of a project represents the amount of money, which if invested in the initial year of the remedy and disbursed as needed, would be sufficient to cover all costs associated with the remedial action.

The level of detail required to analyze each alternative with respect to the cost criteria depends on the nature and complexity of the site, the types of technologies and alternatives being considered, and other project-specific considerations. The analysis is conducted in sufficient detail to understand the significant aspects of each alternative and to identify the uncertainties associated with the evaluation.

The cost estimates presented for each alternative have been developed for the purpose of comparing the alternatives. The final costs of the selected remedy will depend on actual labor and material costs, competitive market conditions, final project scope, the implementation schedule, and other variables. The cost estimates are order-of-magnitude estimates with an intended accuracy range of plus 50 to minus 30 percent. The range applies only to the alternatives as they are described in this report and does not account for changes in the scope of the alternatives.

### 6.1.3 NCP Modifying Criteria

The two modifying criteria are state acceptance and community acceptance. The evaluation of these criteria is typically not completed until state and public comments are received on the Proposed Plan.

### 6.1.4 Sustainability

The USEPA Office of Solid Waste and Emergency Response (OSWER) has a goal to implement sustainable and/or green practices as part of remedial actions, where practicable. The USEPA Office of Superfund Remediation and Technology Innovation document titled *Superfund Green Remediation Strategy* (USEPA, 2010) includes the following initiatives for green remediation practices during remediation:

- Maximize the use of renewable energy and identify methods for increasing energy efficiency.
- Reduce the use of natural resources and energy during remedial actions.
- Integrate clean, renewable, and innovative energy sources and advanced diesel technologies and encourage operational practices that minimize total emissions.
- Establish mechanisms to track and increase water conservation, reuse of treated water, and recharge of aquifers.
- Identify additional onsite or offsite uses of materials or energy otherwise considered waste.

The USEPA *Methodology for Understanding and Reducing a Project's Environmental Footprint* (USEPA, 2012) presents the agency's methodology for assessing and reducing potential negative environmental effects that could be associated with site remediation. This document cites five core elements of green remediation: materials and waste, energy, air and atmosphere, water, land and ecosystems. The specific metrics used to evaluate each of these core elements are follows:

- Materials and Waste: Refined materials used onsite; unrefined materials used onsite; onsite hazardous and non-hazardous waste generated; and percentage of total onsite waste that is recycled or reused
- Water: Onsite water use
- Energy: Total energy use; energy derived by from renewable resources

- Air: Onsite and total nitrogen and sulfur oxide and particulate emissions, greenhouse gas (GHG) emissions, and hazardous air pollutant (HAP) emissions
- Land and Ecosystems: Qualitative description

USEPA Region 9 also has a *Greener Cleanups Policy* (USEPA, 2009), which directs the Region to "strive to integrate sustainability practices into its cleanup actions" by implementing the following practices:

- Reduce air emissions, including GHG emissions, by using clean diesel technology and alternative fuels.
- Conserve natural resources and energy through efficient energy use by using renewable energy technologies.
- Minimize overall virgin material use and waste generation as well as reuse and recycle existing resources.
- Minimize toxics in materials and products.
- Minimize impacts to water quality and water resources by water conservation and efficiency measures.

The NCP defines nine criteria for the evaluation of remedial alternatives and subsequent selection of a remedy, however, the alternatives considered in the FFS were also evaluated qualitatively with respect to the five core elements of green remediation cited by USEPA (2012). Although sustainability is not one of the nine criteria, these core elements capture the Region 9 objectives, and the intent of this evaluation is to highlight key differences among the alternatives with respect to sustainability and green practices or elements. The results of this evaluation are provided as part of the comparative analysis discussion in Section 6.4.

## 6.2 Description of Alternatives

In addition to the no action alternative, three remedial alternatives were developed to address the affected sediment within Lauritzen Channel at the Site. The operational areas for the alternatives are depicted in Figures 6-1 and described in further detail below.

**Channel Areas:**

- **East Side Area—**located along the eastern shoreline and occupied by the LRTC facility. This area has historically been dredged to allow for access to the berthing area along the pier.
- **West Side Area—**located along the western shoreline and occupied by Manson Construction Co. This area has high boat traffic.
- **Northern Head Area—**characterized by shallower water depths and does not allow for unimpeded boat operations.

**Source Control Area:**

- **North End Area—**located along the northern head of the channel.
- **Northern Piles Area—**located along the north section of the eastern shoreline of the Lauritzen Channel and is characterized by the presence of former pier pilings in the water.
- **Southern Piles Area—**located south of the Northern Piles Area along the eastern shoreline of the Lauritzen Channel. This area differs from the Northern Piles Area because a portion of the former pier remains and in the southern part of this area, the railroad tracks extend over the water (this portion of the tracks is stilled actively used).
- **LRTC Pier Area—**located beneath the northern end of the LRTC pier. This area has been characterized as a hot spot.

### 6.2.1 Overview

The following sections provide a descriptive summary of each alternative; additional assumptions used to develop the cost estimates are detailed in Appendix G. The major components of each alternative are presented in Table 6-1.

- Alternative 1: No Action
- Alternative 2: Dredge East Side and West Side Areas, Cap Northern Head Area, Implement Source Control Measures, Offsite Landfill Disposal, Long-Term Monitoring, and Institutional Controls
- Alternative 3: Dredge East Side Area, West Side Area, and Portion of Northern Head Area, Cap Portion of Northern Head Area, Implement Source Control Measures, Utilize Offsite Landfill Disposal, Implement Long-term Monitoring, and Implement Institutional Controls
- Alternative 4: Dredge East Side, West Side, and Northern Head Areas, Implement Source Control Measures, Utilize Offsite Landfill Disposal, Implement Long-term Monitoring, and Implement Institutional Controls

To achieve the RAOs for the Site, each alternative, except the No Action alternative, comprises a combination of remedial technologies selected from technologies that were retained in the screening evaluation process (see Section 5). In the short-term, sediment concentrations will be significant reduced down to the clean sand or armor used to backfill dredged areas and cover capped areas, respectively. In the long-term, deposition of sediment from San Francisco Bay will result in concentrations equivalent to ambient concentrations. As discussed in Section 3.2.6, ambient threshold values for total DDT are 2.8 µg/kg for sediments with less than 40 percent fines and 7 µg/kg for sediments dominated by fines. The corresponding values for dieldrin are 0.18 µg/kg for sediments with less than 40 percent fines and 0.44 µg/kg for sediments dominated by fines. These ambient values are well below the sediment RGs for total DDT and dieldren of 400 µg/kg and 4.3 µg/kg, respectively.

USEPA Sediment Remediation Guidance (2005) identifies NCP remedy expectations and their potential application to contaminated sediments. The factors summarized below were considered in the development of remedial alternatives, with the exception of the no action alternative, for Lauritzen Channel:

- **Use treatment to address principal threats wherever practicable**. In situ and ex situ treatment options were incorporated into the alternatives for the channel.
- **Use engineering controls such as containment for waste that poses a relatively low long-term threat or where treatment is impractical**. Active capping and sheet piling were incorporated into the remedial alternatives for the channel to address contaminated soil and sediments that cannot be removed or effectively treated.
- **Use a combination of methods, as appropriate, to achieve protection of human health and the environment**. The remedial alternatives for the channel comprise various combinations of dredging, and capping, in conjunction with source control options, long-term monitoring, and institutional controls.
- **Use institutional controls as needed to supplement engineering controls to prevent or limit exposure.** Institutional controls will be incorporated into the remedy for the channel as needed to assist in maintaining the long-term integrity of the active cap and sheet piling.
- **Prevent further migration of groundwater plumes and exposure to contaminants in groundwater**. Source control measures along sections of the shoreline will address potential migration of dissolved-phase contaminants in groundwater into the channel.

Each of the alternatives (except No Action) has dredging and capping components. Active capping is proposed as a source control component along sections of the shoreline and as a remediation technology for the Northern Head Area. The dredging and capping alternatives were combined with the shoreline

source control measures to create a complete remedial alternative. A capping-only remedy was not considered to be consistent with future use of the site, which includes commercial vessel use and associated maintenance dredging to maintain sufficient vessel draft. Also, in other areas the amount of sediment that would need to be removed to accommodate the thickness of the cap (e.g., armor layer required to protect against commercial vessel traffic scour, anchoring, and keel/anchor drag) could result in removal of the majority of the contaminated Younger Bay Mud, thus negating the need for a cap.

In order for any of the proposed remedial alternatives to be effective, upland sources of contamination must be controlled. The source control measures need to be coordinated and implemented in concert with the selected sediment remedy to prevent recontamination of the channel following remedy implementation. All of the alternatives rely on the successful implementation of source control measures along sections of the shoreline; therefore, they were included as a component in all the alternatives.

## 6.2.2 Alternative 1

In accordance with the NCP requirement, the No Action alternative is carried through the entire FS process as the baseline condition against which the performance of the remaining alternatives is evaluated.

## 6.2.3 Alternative 2

### 6.2.3.1 Mechanical Dredging

Alternative 2 includes mechanical dredging of sediment down to the native Older Bay Mud sediment surface (i.e., removal of contaminated Younger Bay Mud) using barge-mounted dredging equipment equipped with an environmental bucket. A post-dredge residual sand cap (6 inches) would be placed on the native Older Bay Mud surface. An estimated 58,000 $yd^3$ of sediment would be dredged under this alternative, representing 100 percent of the East and West Side Areas of Lauritzen Channel. The estimated breakdown of dredging surface areas and sediment volumes is as follows (Figure 6-1b):

- West Side: 3.0 acres (132,000 square feet [$ft^2$]), 17,000 $yd^3$
- East Side: 4.0 acres (175,000 $ft^2$), 41,000 $yd^3$

The dredge volumes are equal to estimated volume of Younger Bay Mud within the footprint of a given of each area (see area delineations presented in Figure 6-1). Younger Bay Mud thickness values are determined from coring efforts and corrected for less than 100% core recovery. These data are manually contoured at 1-foot intervals and interpolated within the channel. The volume of Younger Bay Mud is calculated by multiplying total Younger Bay Mud thickness by the area of each interpolated cell within a given footprint.

Dredged material and debris, assumed to be removed concurrently with sediment as it is encountered, would be transported from the dredge site via haul barge or other vessel to the onsite off-loading dock and transferred to watertight trucks for transport to the upland onsite dewatering cell. If a near-shore upland site is available for dewatering operations, direct offloading would be implemented and eliminate the need for upland transport via watertight trucks. Dredged sediment from near-shore locations, if close enough, would be transferred onshore by the same mechanical dredge and barge directly into watertight trucks. Before sediment dewatering/stabilization begins, debris and piles would be segregated from the dredged sediment and stockpiled for subsequent offsite disposal. Dredged sediment would be passively dewatered onsite using a dewatering cell sized to provide sufficient capacity to match the production rate of the dredge. The dewatering cell would be sloped to drain the water to the onsite water collection and treatment area. The dewatered sediment would be solidified/stabilized (e.g., addition of fly ash, Portland cement, or other additives) within the dewatering cell or barge before transport offsite. It was assumed that transport to the offsite disposal facility would occur by rail and the stabilized sediment would be disposed of at an out-of-state Resource Conservation and Recovery Act (RCRA) Subtitle D landfill. Treated water would be discharged back to the channel. Specific treatment options will be determined during remedial design. After completion of dredging activities, a 6-inch sand layer would be placed throughout the dredged areas.

#### 6.2.3.2 Capping

An active cap (activated carbon or modified clay) would be placed over 100 percent of the Northern Head Area of Lauritzen Channel (approximately 1.4 acres [61,000 $ft^2$], Figure 6-1b) to stabilize and prevent resuspension of the contaminated sediment, and to effectively reduce potential upwelling of contaminated groundwater and/or diffusive flux of contaminants in sediment, into the water column. The cap would isolate contaminated sediments from the overlying water column and prevent exposure of receptors via direct contact. Bulk cap material would be placed on the existing sediment (i.e., no pre-dredging of the area) using a clamshell bucket. The active cap would include a layer of activated carbon and/or modified clay to isolate and sequester contaminants present in sediment and groundwater. For purposes of the cost estimate, a 3-inch active layer (activated carbon) and up to 6-inch sand layer was assumed based on experience at other sites. A 12-inch protective armor layer would be placed on top of the isolation layer to provide protection against propeller wash and potential erosion from municipal outfall discharges (required cap layer thicknesses will be determined during the remedial design). Institutional controls in the form of land use restrictions would be required in the Northern Head Area to prevent damage to the sediment cap from vessel activity (e.g., propeller scour, keel drag, and anchoring spuds). In addition, long-term monitoring would be performed to evaluate cap integrity and performance. The monitoring would include physical inspections and surveys, and collection of sediment and/or surface water samples. Cap repairs (e.g., material replacement) would be performed as needed. See Appendix G for additional details regarding long-term monitoring and maintenance.

#### 6.2.3.3 Source Control Measures

The source control measures included in this FFS go beyond the typical source control measures for addressing point discharges and include capping as a component of the remediation. The embankment soil and sediment data indicate that DDT contamination is widespread along the eastern, northern, and northwestern shorelines of the Lauritzen Channel. Although the shoreline is largely armored with rip rap and sheetpile, fine-grained sediments are present in pockets in the riprap and soils are eroding from under the sheetpile in some areas.

According to USEPA Sediment Remediation Guidance, at sites with differing characteristics or uses (such as the embankment area versus the main channel at United Heckathorn Superfund Site), alternatives that combine a variety of approaches are frequently the most promising. For this reason, the remedial alternatives and proposed source control measures were designed to address contaminated sediments using multiple components and technologies including an active cap along the shoreline.

Several source control measures would be implemented along sections of the shoreline in concert with the selected sediment remedy to prevent recontamination of the channel from potential upland sources (e.g., contaminated groundwater and embankment soils). Figure 6-1 presents these subareas with representative photographs. These source control measures are generally depicted in Figure 6-2 and summarized below:

- Permanent sheet piling along sections of the shoreline to control sediment that is not removed by dredging and embankment soils. Sheet piling would be keyed into native sediment to cut-off groundwater migration and direct flow upward to the active cap (see Figure 6-2). Water would be allowed to flow on both sides of the sheet pile to provide stability.
- Active cap (activated carbon or modified clay) on landward side of sheet piling to isolate sediment from the overlying water column, prevent direct contact with sediment, and control sediment erosion and groundwater upwelling and seepage.
- Removal and/or sealing of non-functional pipes and outfalls along the eastern shoreline to control groundwater seepage.
- One-time removal of sediment from the City of Richmond storm drain system to control trapped residual sediment.

North End Shoreline Area

In addition to capping, the source control measures along the North End Shoreline Area (approximately 125 feet) would include barge-based dredging and filling to remove shallow near-shore sediments and prepare the slope for capping from approximately 30 feet off the shoreline to the top of the bank. Once the shallow sediments are removed, the area would be graded with a smooth slope over existing riprap down to a new toe bench. Sheet pile would be permanently installed approximately 30 feet off the shoreline using barge-mounted equipment to contain contaminated soil and sediment. An active cap (activated carbon and/or modified clay) would be placed on the slopes using a clamshell bucket (barge-mounted or land-based). The active layer would be covered with a geotextile, followed by riprap, increasing in gradation (i.e., smaller diameter stone at base overlain by larger diameter stone), to hold active cap material in place and provide erosion control.

Northern Piles Area

In addition to capping, the source control measures along the Northern Piles Area (approximately 300 feet) would include removal and/or cutting (1-foot recess below grade) of vertical timber piles to clear the slope. Cutting of timber piles would likely require commercial divers. Sheet pile would be installed along the former outer row of timber piles to contain contaminated soil and sediment on the slope down to the channel bottom. An active cap would be placed as indicated for the North End Shoreline Area.

Southern Piles Area

In addition to capping, the source control measures along the Southern Piles Area (approximately 400 feet) would include removal and/or cutting (1-foot recess below grade) of vertical timber piles to clear the slope, with the exception of structural pier piles that if removed, would undermine the stability of the embankment. Cutting of timber piles would likely require commercial divers. The former pier section located at Bent -7 to Bent -8 would be removed. Sheet pile would be installed along the outer row of timber piles to contain contaminated soil and sediment on the slope down to the channel bottom. An active cap would be placed as indicated for the North End Shoreline Area.

Levin Pier Shoreline Area

For source control measures along the Levin Pier Shoreline Area (approximately 300 feet), structural pier piles would be left in place because this is an active pier. In addition to capping, source control measures on the Levin Pier Shoreline Area would include installation of sheet pile along the outer row of timber piles to contain contaminated soil and sediment on the slope down to the channel bottom. An active cap (activated carbon and/or modified clay) would be placed on slopes using a barge-mounted broadcast spreader, followed by riprap, increasing in gradation (i.e., smaller diameter stone at base overlain by larger diameter stone), to hold cap material in place and provide erosion control. Sheet pile depth, and the site-specific materials and thicknesses of the multiple cap layers described (i.e. active and subsequent armor layers) will be determined during remedial design.

The source control measures would also include addressing discharges to the channel from unpermitted, non-functional, pipes and outfalls along the eastern shoreline. These structures would be removed and/or sealed. In addition, a one-time removal of sediment from the City of Richmond storm drain system would be performed to prevent future discharge of potentially contaminated sediment to the channel. It is estimated that approximately 100 tons of sediment would be removed from the storm drain system, which discharges to the channel through an outfall located at the north end of the channel.

#### 6.2.3.4 Institutional Controls and Long-Term Monitoring

Institutional controls and long-term monitoring would be performed as part of the shoreline source control measures to provide cap and sheet piling integrity and performance. The monitoring would include physical inspections and surveys, and collection of sediment and/or surface water samples. Repairs would be performed as needed. During dredging, capping, debris/pile removal, and installation of sheet piling, silt curtains would be installed to mitigate the release of resuspended sediment and contaminants outside of

the remediation areas. Short-term water quality (e.g., turbidity) and air monitoring (as needed) would be implemented to support the remediation activities.

### 6.2.4 Alternative 3

Alternative 3 is similar to Alternative 2, with the exception of how the Northern Head Area would be remediated (Figure 6-1c). In Alternative 3, rather than placing an active cap over the entire Northern Head Area, only a portion of the Northern Head Area would be capped and the remaining portion would be dredged. Alternative 3 would be less restrictive than Alternative 2 and would allow for more of the Northern Head Area to be used as it currently is for commercial vessel traffic. An estimated 64,000 $yd^3$ of sediment would be dredged under this alternative, representing 100 percent of the East and West Side Areas of Lauritzen Channel and 75 percent of Northern Head Area of Lauritzen Channel. The estimated breakdown of dredging surface areas and sediment volumes is as follows (Figure 6-1c):

- West Side: 3.0 acres (132,000 $ft^2$), 17,000 $yd^3$
- East Side: 4.0 acres (175,000 $ft^2$), 41,000 $yd^3$
- Northern Head: 1.0 acre (44,000 $ft^2$), 6,000 $yd^3$

An active cap (activated carbon or modified clay) would be placed over 25 percent of the Northern Head Area of Lauritzen Channel (approximately 0.4 acre [17,000 $ft^2$]). All source control measures along the shoreline and other components of this alternative are identical to Alternative 2 including placing a 6-inch sand-layer throughout all dredged areas.

### 6.2.5 Alternative 4

Alternative 4 is similar to Alternative 2, with the exception of how the Northern Head Area would be remediated (Figure 6-1d). In Alternative 4, no capping would be performed in the Northern Head Area; rather, this area would be dredged. This alternative would have the least potential restriction on commercial vessel traffic. An estimated 66,000 $yd^3$ of sediment would be dredged under this alternative, representing 100 percent of the East and West Side Areas of Lauritzen Channel and 100 percent of Northern Head Area of Lauritzen Channel. The estimated breakdown of dredging surface areas and sediment volumes is as follows (Figure 6-1d):

- West Side: 3.0 acres (132,000 $ft^2$), 17,000 $yd^3$
- East Side: 4.0 acres (175,000 $ft^2$), 41,000 $yd^3$
- Northern Head: 1.4 acre (61,000 $ft^2$), 8,000 $yd^3$

All source control measures along the shoreline and other components of this alternative are identical to Alternative 2 including placing a 6-inch sand-layer throughout all dredged areas.

## 6.3 Detailed Analysis of Alternatives

Table 6-3 presents the detailed analysis of the alternatives against the NCP criteria defined in Section 6.1 and includes net present-worth costs for comparison purposes. Detailed cost estimates are provided in Appendix G.

## 6.4 Comparative Analysis of Alternatives

Alternative 1, the No Action alternative, does not meet the first threshold criterion (overall protection of health and the environment), but was retained for comparison as required by the NCP. The remaining alternatives (Alternatives 2, 3, and 4) meet both threshold criteria (protection of human health and the environment and compliance with ARARs). The following sections explain the relative performance of alternatives against five of the seven balancing criteria as described in the NCP. Table 6-4 summarizes the comparative analysis and presents each remedial alternative with rankings of its relative performance to each of the five balancing criteria. A sustainability criteria evaluation was also performed and is discussed

herein. Two of the modifying criteria (state and community acceptance) will subsequently be evaluated in the ROD amendment.

### 6.4.1 Overall Protection of Human Health and the Environment

Alternative 1, No Action, would not provide overall protection of human health and the environment and would not achieve the RAOs for the channel. As discussed in Section 3.5, the DDT mass balance model projects that bulk Younger Bay Mud DDT concentrations will remain over 2,000 µg/kg in 2050, well above the RG for total DDT of 400 µg/kg. Contaminated sediment would remain onsite and would continue to pose a potential risk to human health and the environment. Potential migration of contaminated groundwater via upwelling and seepage from unpermitted, non-functional, pipes and outfalls along the shoreline into the channel would continue, and the potential for contaminated embankment soils to erode into the channel would remain.

Alternatives 2, 3, and 4 would provide protection to human health and the environment and would meet the RAOs upon completion of the remedy. These alternatives would effectively mitigate long-term exposure to contaminated sediment via dredging and/or capping, and source control measures would mitigate potential upland sources of contamination (e.g., groundwater and embankment soils). As discussed in Section 6.2.1, in the short-term, sediment concentrations will be significant reduced down to the clean sand or armor used to backfill dredged areas and cover capped areas, respectively. In the long-term, deposition of sediment from San Francisco Bay will result in concentrations equivalent to ambient concentrations, which are well below the sediment RGs for total DDT and dieldren.

### 6.4.2 Compliance with ARARs

Because no action is taken under it, Alternative 1 would not meet ARARs since water at the site currently exceeds ambient water quality standards. Alternatives 2, 3, and 4 would be designed to comply with the ARARs.

### 6.4.3 Long-term Effectiveness and Permanence

Alternative 1 would not result in any significant change in risk associated with contaminated sediment. This alternative received a low ranking for this criterion.

Alternatives 2 and 3 would provide a moderate to high level of long-term effectiveness and permanence through removal of contaminated sediment, placement of an active cap over contaminated sediment in the Northern Head Area, placement of sheet piling along the shoreline and an active cap on the landward side of the wall, and disposal of dredged sediment and debris in an offsite landfill. Dredging and removal of sediment would significantly and permanently reduce potential human health and ecological risks associated with contaminated sediment and improve surface water quality by eliminating contact between surface water and contaminated sediment. Capping in the Northern Head Area would reduce and control potential human health and ecological risks associated with contaminated sediment, improve surface water quality by preventing contact between surface water and contaminated sediment, and reduce of the flux of dissolved contaminants into the water column. Capping would provide long-term control of the risks associated with contaminated sediment provided that appropriate institutional controls and long-term cap monitoring and maintenance plans are implemented.

Because Alternative 4 would include dredging and removal of all contaminated sediment within the Northern Head Area, rather than capping, this alternative is not as dependent on institutional controls and long-term monitoring to ensure performance of the remedy. Therefore, it provides greater certainty in long-term effectiveness and permanence than Alternatives 2 and 3.

### 6.4.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 1 does not include a treatment component and therefore was ranked low for this criterion.

Alternatives 2, 3, and 4, were ranked moderate for this criterion due to reduction in contaminant mobility that would be achieved through the active layer of the cap and solidification of dredged material. Active

capping materials would immobilize both sediment bound and dissolved phase contaminants. Dredged material mobility would be reduced via solidification and subsequent placement into a permitted landfill. In all cases there would be reduction in mobility; however, there would be no reduction in toxicity or volume.

### 6.4.5 Short-term Effectiveness

The short-term effectiveness of Alternative 1, No Action, was considered to be low because RAOs for the site would not be achieved.

Alternatives 2, 3, and 4 would present comparable short-term risks to workers and the surrounding community during implementation and were ranked moderate to high. There would be a risk of some adverse short-term impacts to human health and the environment during the construction period due to resuspension of sediment; however, these potential risks can generally be mitigated and controlled through the use of floating turbidity curtains and industry standard best management practices (BMPs) for mechanical dredging, as follows:

- The bucket is raised and lowered slowly through the water column to reduce the washing effect of the water on the bucket.
- All precautions are taken to not overfill the bucket on each bite.
- Excess water is allowed to slowly decant from the bucket at the surface
- Scows are filled evenly, but not overfilled so water does not drain off scows back into the river.
- Dredge material is dug from the top of the slope to the toe, across each cut, reducing the amount of material falling into areas previously dredged.
- Crane swing speed is controlled
- Bucket bites overlap each other enough to assure that all existing dredge material is removed to grade.

Alternatives 2, 3, and 4 have a post-dredge sand cover for residuals control is an effective means of preventing short-term impacts from resuspension of sediment from the dredging activities.

### 6.4.6 Implementability

Alternative 1 was considered to be readily implementable (high ranking) because no remedial actions would be performed; however, this alternative would not meet any of the RAOs for the site.

Alternatives 2, 3, and 4 have comparable rankings for implementability and were all ranked high. Dredging and capping are established, field-proven technologies; however, pilot testing may be required to select the most suitable cap placement methods in the presence of obstructions for the source control measures along the shoreline. In addition, permanent institutional controls would be required for capping in the Northern Head and the shoreline measures, and commercial boating access would be restricted in the capped areas of the Northern Head.

### 6.4.7 Cost

A summary of the estimated cost for each alternative is provided in Table 6-3. Appendix G presents the detailed cost estimates and associated assumptions. The alternative components discussed in Section 6-3 provide the basis of the cost estimate; additional detailed costing assumptions are provided in Appendix G. The cost estimates have been prepared to compare the relative cost of the alternatives from the information available at the time of the estimate. The final cost of the project will depend on many factors including actual labor and material costs, competitive market conditions, implementation schedule, and field conditions. As a result, the final project costs will vary from the estimates presented herein. Based on estimated total costs, Alternative 1 would be the least expensive, followed in order by Alternatives 2 ($21.7 million), 3 ($22.6 million), and 4 ($22.7 million). The differences between Alternatives 2 and 4, however, are approximately 5 percent.

### 6.4.8 Sustainability

The five core elements of green remediation evaluations are materials and waste, energy, air and atmosphere, water, land and ecosystems. Based on the scope of the alternatives developed, the water and land and ecosystems elements are not anticipated to be markedly different between the alternatives. Site water affected by the dredging would be treated and discharged, resulting in no net damage to the resource. The spatial extent of the remedy would be the same for all three alternatives and there would be minimal, if any, difference among the alternatives with respect to land and ecosystems. Relatively small differences are anticipated among the alternatives related to materials and waste. The removal volumes for Alternatives 2 through 4 range from approximately 58,000 $yd^3$ to 66,000 $yd^3$, respectively. The amount of capping material used ranges from approximately 776 tons for Alternative 2 to 281 tons for Alternative 4.

The two categories anticipated to show significant differences among alternatives are air emissions and energy use. The estimates for emissions and energy use were used to approximate the environmental footprint of Alternatives 2 through 4. The emissions estimates are presented graphically in Figure 6-3 and the energy use estimates are provided in Figure 6-4. The energy use associated with the dredging and dredge material handling (i.e., the diesel use) is comparable among all three alternatives because the volumes are relatively similar. More pronounced differences between alternatives are observed in the emissions and energy use associated with primarily the powdered activated carbon (PAC) in the AquaGate material used in the capping and shoreline controls. Overall, Alternative 4 is expected to have the lowest environmental footprint due to the lower amount of AquaGate used in the remedy.

The AquaGate footprint was estimated assuming a composition of 70 percent limestone, 15 percent bentonite, 10 percent PAC and 5 percent polymer. USEPA's Spreadsheet for Environmental Footprint Analysis (SEFA) was used to assign characterization factors for diesel, PAC (using virgin granular activated carbon—coal based as a proxy) and polymer (using treatment materials and chemicals as a proxy).Characterization factors for specific materials such as AquaGate were not readily available; therefore, values of AquaGate components were used as proxies for this analysis.

The footprint of the selected alternative should be further evaluated in the design phase using the ASTM International *E2893-13 Standard Guide for Greener Cleanup* (2013) and/or the 2012 USEPA *Methodology for Understanding and Reducing a Project's Environmental Footprint* to explore opportunities to optimize the environmental footprint of the project and integrate sustainable remediation best practices in the design, construction, and operation of the alternative.

## 6.5 Summary and Next Steps in CERCLA Process

Following completion of the FFS, the next step in the CERCLA process is the preparation of a Proposed Plan. The Proposed Plan will document the USEPA's preferred remedy for the United Heckathorn Superfund Site in Richmond, California and will allow for evaluation of the last two NCP criteria, State and Community acceptance (also referred to as the modifying criteria). A public comment period will be held to obtain comments on the Proposed Plan in accordance with the NCP. This includes a public meeting held in the community to allow public comments to be given verbally and recorded for the public record. The USEPA's responses to comments received on the Proposed Plan during the public comment period will be presented in a Responsiveness Summary that is included in the Amended Record of Decision. The Amended Record of Decision documents the chosen remedial alternative. The Remedial Design is then developed to provide detailed engineering of specific components (i.e. water treatment, sheet pile and cap design, etc.) for the chosen remedial alternative. For the United Heckathorn Superfund Site, the remedial design will need to account for specific factors such as sea-level rise to ensure the long-term effectiveness of the chosen remedy.

SECTION 7

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# Tables

TABLE ES-1
**Detailed Evaluation of Alternatives**
*United Heckathorn Superfund Site, Richmond, California*

| Summary of Alternatives | Alternative 1No Action | Alternative 2<br>Dredge East Side and West Side, Cap Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-Term Monitoring, and Institutional Controls | Alternative 3<br>Dredge East Side, West Side, and Portion of Northern Head, Cap Portion of Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls | Alternative 4<br>Dredge East Side, West Side, and Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls |
|---|---|---|---|---|
| **Key Differentiating Elements** | NA | • Dredge: 100% of East and West Side areas of Lauritzen Channel (58,000 cy)<br>• Active cap (activated carbon or modified clay): 100% of Northern Head area of Lauritzen Channel (1.4 acres / 61,000 $ft^2$) | • Dredge: 100% of East and West Side areas of Lauritzen Channel and 75% of Northern Head area of Lauritzen Channel (64,000 cy)<br>• Active cap (activated carbon or modified clay): 25% of Northern Head area of Lauritzen Channel (0.4 acre / 17,000 $ft^2$) | • Dredge: 100% of East and West Side areas of Lauritzen Channel and 100% of Northern Head area of Lauritzen Channel (66,000 cy) |
| **Additional Elements Common to all Alternatives (Except No Action)** | NA | • Source control measures along sections of shoreline:<br>– Sheet piling<br>– Active cap (activated carbon or modified clay) on landward side of sheet piling<br>– Remove and/or seal non-functional pipes and outfalls along the eastern shoreline<br>– One time removal of sediment from the City of Richmond storm drain system<br>• Offsite landfill disposal of dredged material and debris/piles via rail<br>• Long-term monitoring to evaluate cap and sheet pile integrity and performance<br>• Institutional controls to ensure physical integrity of cap and sheet piling<br>• Onsite handling of dredged material and debris/piles:<br>– Segregation and stockpiling of debris/piles<br>– Dewatering and/or solidification/stabilization of dredged material<br>• Short-term monitoring and engineering controls during dredging, capping, and debris/piles removal activities | | |
| ***Threshold Criteria*** | | | | |
| **Overall protection of human health and the environment** | Alternative would not provide protection of human health and the environment.<br>• RAOs would not be achieved.<br>• Potential human health and ecological risks associated with contaminated sediment and surface water would not be reduced or controlled. | Alternative would provide protection of human health and the environment.<br>• Surface water and sediment RAOs would be achieved soon after completion of the remedy through dredging and capping of contaminated sediment.<br>• Dredging of contaminated sediment would result in significant reduction of potential human health and ecological risk by permanently removing the contaminated sediment.<br>• Capping of sediment would result in significant reduction of potential human health and ecological risk by physical isolation and stabilization of the contaminated sediment, preventing resuspension and transport to other sites, and reduction of the flux of dissolved contaminants into the water column. However, long-term effectiveness of capping relies on adequacy of institutional controls to protect cap integrity and implementation of monitoring and maintenance of the cap, as necessary. | Same as Alternative 2. | Same as Alternative 2 (and 3); however, this alternative would provide greater certainty of long-term effectiveness because all areas would be dredged (i.e., contaminated sediment in the Northern Head would be removed rather than capped). Removal of the sediment significantly and permanently reduces potential human health and ecological risks associated with contaminated sediment. |
| **Compliance with ARARs** | Alternative would not be in compliance with ARARs. | Alternative can be designed to comply with substantive requirements of the ARARs. | Same as Alternative 2 (and 4). | Same as Alternative 2 (and 3). |

TABLE ES-1
**Detailed Evaluation of Alternatives**
*United Heckathorn Superfund Site, Richmond, California*

| Summary of Alternatives | Alternative 1No Action | Alternative 2<br>Dredge East Side and West Side, Cap Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-Term Monitoring, and Institutional Controls | Alternative 3<br>Dredge East Side, West Side, and Portion of Northern Head, Cap Portion of Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls | Alternative 4<br>Dredge East Side, West Side, and Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls |
|---|---|---|---|---|
| ***Balancing Criteria*** | | | | |
| **Long-term effectiveness and permanence** | Alternative would not result in any significant change in the potential human health and ecological risks associated with contaminated sediment. | Alternative would provide a moderate to high level of long-term effectiveness and permanence through dredging/removal of contaminated sediment, placement of a an active cap over contaminated sediment in the Northern Head, placement of sheet piling along the shoreline and an active cap on the landward side of the wall, and disposal of dredged sediment and debris in an offsite landfill.<br>• Dredging and removal of sediment would: (1) significantly and permanently reduce potential human health and ecological risks associated with contaminated sediment and (2) improve surface water quality by eliminating contact between surface water and contaminated sediment.<br>• Capping in the Northern Head area would: (1) reduce and control potential human health and ecological risks associated with contaminated sediment, (2) improve surface water quality by preventing contact between surface water and contaminated sediment, and (3) reduce of the flux of dissolved contaminants into the water column.<br>• Placing sheet piling along sections of the shoreline and an active cap on the landward side of the sheet pile wall would: (1) reduce and control potential human health and ecological risks associated with contaminated sediment, (2) prevent erosion of contaminated sediment and embankment soil into the adjacent marine area, (3) improve surface water quality by preventing contact between surface water and contaminated sediment and embankment soil, and (4) reduce of the flux of dissolved contaminants into the water column. | Same as Alternative 2. | Same as Alternative 2 (and 3); however, this alternative would provide a high level of long-term effectiveness and permanence through dredging/removal of contaminated sediment. There is greater certainty in the long-term effectiveness and permanence because the alternative is not dependent upon institutional controls and long-term monitoring to maintain cap integrity and performance in the Northern Head area of the channel. |
| Magnitude of residual risk | The magnitude of residual risks essentially remains the same. | Dredged sediment would be removed and transferred to an offsite landfill, and no residual risk would be associated with those materials. Residual risk would be associated with sediment that could not be removed by dredging; however, this risk would be mitigated with sediment capping and shoreline measures, and the RAOs would still be met. | Same as Alternative 2; however, this alternative would provide an incrementally lower level of residual risk because more sediment would be dredged and removed from the site. | Same as Alternative 2 (and 3); however, this alternative would provide a lower level of residual risk because all areas would be dredged (i.e., contaminated sediment in the Northern Head would be dredged rather than capped). This alternative would not depend on institutional controls and long-term monitoring to maintain cap integrity and performance in the Northern Head area of the channel. |
| Adequacy and reliability of controls | Does not include any controls for exposures or long-term management measures. | • Dredging:<br>- Mechanical dredging is an established technology and would be implemented to meet the performance specifications for the removal component of the alternative.<br>- Physical surveys would be conducted to confirm that removal depths were achieved. Confirmation samples would be collected to confirm that cleanup goals were met.<br>• Capping:<br>- Capping is an established technology and would be designed, constructed, and maintained in accordance with the specifications established for long-term isolation of the contaminated sediment and reduction of dissolved contaminants into the water column.<br>- Capping performance would be contingent upon enforcement of institutional controls and long-term monitoring and maintenance to assure cap integrity.<br>- Long term monitoring would be performed to assure sheet piling integrity.<br>- Physical surveys and the collection of samples would be needed to assess cap layer thickness, cap performance and integrity, contaminant movement, and/or recontamination concerns.<br>- Cap repairs would be performed as needed.<br>• Sheet piling: | Same as Alternative 2 | Same as Alternative 2 (and 3), except capping would not be performed in the Northern Head under this alternative. Capping would only be implemented as part of the source control measures along portions of the shoreline. |

TABLE ES-1
**Detailed Evaluation of Alternatives**
*United Heckathorn Superfund Site, Richmond, California*

| Summary of Alternatives | Alternative 1No Action | Alternative 2<br>Dredge East Side and West Side, Cap Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-Term Monitoring, and Institutional Controls | Alternative 3<br>Dredge East Side, West Side, and Portion of Northern Head, Cap Portion of Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls | Alternative 4<br>Dredge East Side, West Side, and Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls |
|---|---|---|---|---|
| | | - Sheet piling is an established engineering control and would be installed as part of the shoreline measures to prevent erosion of contaminated sediment and embankment soil into the adjacent marine area.<br>- Sheet piling repairs would be performed as needed.<br>• Disposal in an offsite landfill is an established means of disposal for contaminated sediment. Offsite landfill disposal would provide adequate long-term controls for the dredged sediment. | | |
| **Reduction of toxicity, mobility, or volume through treatment** | Alternative does not include a treatment component. | • Dredged sediment would be treated onsite by dewatering and/or solidification/stabilization to reduce leachability of contaminants. | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |
| Reduction in toxicity, mobility, or volume through treatment | | • Dredging does not reduce toxicity, mobility, or volume through treatment.<br>• Reduction in contaminant mobility would be achieved through the active layer of the cap (activated carbon) by immobilizing sediment bound and dissolved phase contaminants.<br>• Onsite treatment of the dredged sediment would include dewatering and/or solidification/stabilization to reduce leachability of the sediment-bound contaminants ultimately to be placed in an offsite landfill. | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |
| Irreversibility | | Solidification/stabilization would be considered irreversible if the material is placed into a controlled environment (i.e., permitted landfill). | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |
| Type and quantity of treatment residuals and associated risks | | Offsite disposal would not result in treatment residuals other than solidified sediment that would be disposed into a landfill. Residual risks would low because the material would be contained in a controlled environment (i.e., permitted landfill). | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |
| **Short-term effectiveness** | No construction activities are performed; therefore, this alternative would not have any adverse short-term effects that could pose risk to the community, workers, or the environment. | There would be a risk of some adverse short-term impacts to human health and the environment during the construction period due to resuspension of sediment, however these potential risks can generally be mitigated and controlled through industry standard BMPs. | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |
| Risks to community, workers, and the associated controls | | • Potential risks to the community would include increased levels of traffic, dust, noise, and odors during the dredging, capping, and handling of contaminated sediment. Engineering controls and BMPs can mitigate most potential risks and would include the following:<br>- Access to the active work and support zones would be prohibited.<br>- Notification of schedule for remedy implementation would be provided to the property owners and tenants.<br>- Dust, noise, and odor levels would be monitored.<br>- Work periods may be restricted to specific timeframes for especially noisy operations (e.g., sheet pile installation).<br>• Potential risks to workers would include physical hazards associated with general construction, potential exposure to and direct contact with dredged sediment, surface water, noise, odors, dust, and vapors. These would be mitigated through actions including the following:<br>- Engineering controls and BMPs<br>- Compliance with appropriate health and safety plans and site management plans<br>- Use of appropriate personal protective equipment | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |

TABLE ES-1
**Detailed Evaluation of Alternatives**
*United Heckathorn Superfund Site, Richmond, California*

| Summary of Alternatives | Alternative 1No Action | Alternative 2<br>Dredge East Side and West Side, Cap Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-Term Monitoring, and Institutional Controls | Alternative 3<br>Dredge East Side, West Side, and Portion of Northern Head, Cap Portion of Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls | Alternative 4<br>Dredge East Side, West Side, and Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls |
|---|---|---|---|---|
| Environmental Impacts of Remedy and Controls | | Short-term environmental effects during implementation may include turbidity increases within the channel and releases of some sediment-associated contamination, resulting in potential loss of benthic community in the short-term. However, these impacts can generally be mitigated and controlled through industry standard BMPs including turbidity and water column monitoring, silt curtains, and use of an enclosed environmental clamshell bucket for dredging. | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |
| Duration of short-term risks | | The duration of the short-term risks would be the time required to complete the dredging, capping (Northern Head), and shoreline measures (sheet piling and capping) and remedial action objectives are met, which is estimated to be less than 1 year. | The duration of the short-term risks would be the time required to complete the dredging, capping (Northern Head), and shoreline measures (sheet piling and capping) and remedial action objectives are met, which is estimated to be less than 1 year. | The duration of the short-term risks would be the time required to complete the dredging and shoreline measures (sheet piling and capping) and remedial action objectives are met, which is estimated to be less than 1 year. |
| **Implementability** | Not applicable; no actions are taken under this alternative. | Alternative would be implementable from both technical and administrative standpoints. | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |
| Technical feasibility | | • Alternative would be technically implementable and dredging and capping are established, field-proven technologies; however, pilot testing may be required to determine the most suitable cap placement methods in the presence of obstructions.<br>• Dredging and capping would be performed from barges using standard construction equipment.<br>• The short- and long-term monitoring requirements can be performed using standard practices and technologies. | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |
| Administrative feasibility | | • Alternative would require coordination between regulatory agencies, potentially responsible parties, property owners along the channel, and other stakeholders.<br>• Permanent institutional controls would also be required for capping in the Northern Head and for the shoreline measures.<br>• Commercial boating access would be restricted in the capped areas of the Northern Head. | Same as Alternative 2 | Same as Alternative 2 (and 3), except capping would not be performed in the Northern Head area under this alternative. |
| Availability of services and materials | | • Equipment and specialists required for the sheet piling installation, dredging, and capping would be commercially available.<br>• Commercial suppliers of capping amendments (activated carbon and/or modified clay) have been identified.<br>• Offsite landfill facilities that can accept the dredged sediment have been identified. | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |
| **Cost ($ Million)** | ___ | 21.7 | 22.6 | 22.7 |

Notes:
ARAR = applicable or relevant and appropriate requirement
BMP = best management practice
cy = cubic yards
$ft^2$ = square feet
NA = not applicable
RAO = remedial action objective

TABLE ES-2
**Comparative Analysis of Alternatives**
*United Heckathorn Superfund Site, Richmond, California*

| CERCLA Evaluation Criteria[1] | Threshold Criteria | | Balancing Criteria | | | | |
|---|---|---|---|---|---|---|---|
| | Overall Protection of Human Health and the Environment | Compliance with ARARs | Long-term Effectiveness and Permanence | Reduction of Toxicity, Mobility, or Volume through Treatment | Short-term Effectiveness | Implementability | Cost ($ Million) |
| **Alternative 1**<br>No Action | ○ | ○ | ○ | ○ | ● | ● | — |
| **Alternative 2 – Dredge East Side and West Side, Cap Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls**<br>• Dredge: 100% of East and West Side areas of Lauritzen Channel (58,000 $yd^3$)<br>• Active cap (activated carbon or modified clay): 100% of Northern Head Area of Lauritzen Channel (1.4 acres / 61,000 $ft^2$) | ● | ● | ◔ | ◑ | ◔ | ● | 21.7 |
| **Alternative 3 - Dredge East Side, West Side, and Portion of Northern Head, Cap Portion of Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls**<br>• Dredge: 100% of East and West Side areas of Lauritzen Channel and 75% of Northern Head area of Lauritzen Channel (64,000 $yd^3$)<br>• Active cap (activated carbon or modified clay): 25% Northern Head area of Lauritzen Channel (0.4 acre / 17,000 $ft^2$) | ● | ● | ◔ | ◑ | ◔ | ● | 22.6 |
| **Alternative 4 - Dredge East Side, West Side, and Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls**<br>• Dredge: 100% of East and West Side areas of Lauritzen Channel and 100% of Northern Head area of Lauritzen Channel (66,000 $yd^3$) | ● | ● | ● | ◑ | ◔ | ● | 22.7 |

**Legend:**

**Threshold Criteria:**

○ Does not satisfy criterion

● Satisfies criterion

**Balancing Criteria:**

○ Low

◔ Low to Moderate

◑ Moderate

◕ Moderate to High

● High

**Notes:**

[1] Elements common to all alternatives (except no action), such as the source control measures, long-term monitoring, and institutional controls are detailed in Tables ES-1 and 6-2.

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act

$yd^3$ = cubic yards

$ft^2$ = square feet

TABLE 1-1
**Chronology of Site Events**
*United Heckathorn Superfund Site, Richmond, California*

| Event | Date |
|---|---|
| ***Prior to Remediation*** | |
| Site used to formulate and package pesticides, particularly DDT. | 1947-1966 |
| The Regional Water Quality Control Board inspected and cited the facility for the release of DDT-laden wastewater into the Lauritzen Channel. | 1960 |
| California Department of Fish and Game identified a discharge of wastewater overflow into the Lauritzen Channel and leakage from the pesticide settling tanks. | 1965 |
| California Department of Health Services investigated the Site as part of its Abandoned Site Project. | 1980 |
| California Department of Health Services designated the Site as a State Superfund Site. | March 1982 |
| Interim removal actions occurred at the upland portion of the Site. | 1982-1993 |
| Last recorded maintenance dredging performed to Lauritzen Channel prior to remediation. | 1985 |
| The 1984-1985 California State Mussel Watch (SMW) survey added Richmond Harbor for the first time and found levels of DDT and dieldrin "highest ever measured in mussels by the SMW program." | 1986 |
| Site listed on USEPA National Priorities List. | March 1990 |
| Pursuant to USEPA Removal Order 90-22, approximately 1,500 cubic yards of soil and visible pesticide residue containing up to 100 % DDT were excavated by several potentially responsible parties. | November 1990 |
| Approximately 1,800 cubic yards of residue and contaminated soil were excavated from the Site. | 1991 |
| Final soil removal action completed. | May 1993 |
| Remedial investigation of marine sediment completed (White et al., 1994). | February 1994 |
| Human health risk assessment (ICF Technology, 1994) and Ecological Risk Assessment (Lee et al., 1994) completed. | 1994 |
| California Department of Toxic Substances Control issued advisory against consuming any bottom fish from the Richmond Inner Harbor. | April 1994 |
| Feasibility study (Lincoff et al., 1994) completed. | July 1994 |
| Record of decision (USEPA, 1994) signed. | October 1994 |
| ***Sediment Remediation*** | |
| Remedial design/remedial action work plan (CWM, 1996) for sediment dredging submitted. | May 1996 |
| Consent Decree approved by U.S. District Court. | July 1996 |
| Remedial action at Parr Canal and Lauritzen Channel began (CWM, 1997). | August 1996 |
| Remedial action at Parr Canal and Lauritzen Channel ended (CWM, 1997). | April 1997 |
| Post-remediation biomonitoring began. | July 1997 |
| ***Post-sediment Remediation*** | |
| Remedial design/remedial action work plan (PES, 1998) for upland cap submitted. | April 1998 |
| Construction of upland area cap began. | July 1998 |
| Construction of upland area cap ended. | July 1999 |

TABLE 1-1
**Chronology of Site Events**
*United Heckathorn Superfund Site, Richmond, California*

| Event | Date |
|---|---|
| Post-remediation Biomonitoring of Pesticides in Marine Waters Near the United Heckathorn Superfund Site, Year 1 Report (Antrim and Kohn, 2000a) prepared. | September 1998; revised July 2000 |
| Post-remediation Biomonitoring, Year 2 Report (Antrim and Kohn, 2000b) prepared. | October 1999; revised July 2000 |
| Post-remediation Biomonitoring, Year 3 Report (Kohn and Kropp, 2001a) prepared. | November 2000 |
| Post-remediation Biomonitoring, Year 4 Report (Kohn and Kropp, 2001b) prepared. | December 2001 |
| First Five-Year Review Report (USEPA, 2001) prepared. | September 2001 |
| Post-remediation Biomonitoring, Year 5 Report (Kohn and Kropp, 2002) prepared. | August 2002 |
| Phase I Source Investigation Report (Kohn and Evans, 2002) completed. | December 2002 |
| Conceptual site conceptual model (CH2M HILL, 2003) updated. | December 2003 |
| Post-remediation Biomonitoring, Year 6 and Phase II Source Investigation Report (Kohn and Evans, 2004) completed. | March 2004 |
| Phase III Fluid Mud and 2004 Water Quality Investigation Report (Wakemen, 2004) completed. | December 2004 |
| Lauritzen Channel Sediment Density Study (Welp, 2005) completed. | October 2005 |
| Second Five-Year Review Report (USEPA, 2006) prepared. | September 2006 |
| Focused Feasibility Study Data Gaps Sampling and Analysis Plan (CH2M HILL, 2007) prepared. | August 2007 |
| Summary of Mussel, Water, and Sediment Sampling (CH2M HILL, 2008a) completed. | January 2008 |
| Summary of Fish Tissue Sampling and Analysis (CH2M HILL, 2008b) completed. | October 2008 |
| Phase 1 of MIT passive sampler investigation completed. | October 2009 |
| Reassessment of human health and ecological remediation goals completed (CH2M HILL, 2010a; 2010b). | February 2010 |
| Fish advisory for Lauritzen Channel and San Francisco Bay issued (OEHHA, 2011). | May 2011 |
| Third Five-Year Report (USEPA, 2011) prepared. | September 2011 |
| High resolution multibeam and side-scan sonar surveys. | December 2012 |
| Site survey of shoreline in support of source identification survey. | December 2012 |
| Tier 1 Sediment Transport Study completed (CH2M HILL and Sea Engineering, Inc., 2013). | April 2013 |
| Post-remediation biomonitoring and Phase 2 of MIT passive sampler investigation completed. | October 2013 |
| Fish tissue sampling in areas adjacent to Lauritzen Channel. | November 2013 |
| Tier 2 Sediment Transport Study (Sea Engineering, Inc., 2014a) completed. | February 2014 |
| Source Identification Study (CH2M HILL, 2014) completed. | March 2014 |
| DDT Fate and Transport Study completed (Sea Engineering, Inc., 2014b). | May 2014 |

TABLE 2-1

**Summary of Biomonitoring Program**

*United Heckathorn Superfund Site, Richmond, California*

| Year | Year Post-remedy | Stations | Mussels | | Water | |
|---|---|---|---|---|---|---|
| | | | Resident | Transplant | Total | Dissolved |
| 1998 | 1 | A | X | X | X | |
| 1999 | 2 | A | X | X | X | |
| 2000 | 3 | A | X | | X | |
| 2001 | 4 | A | X | | X | |
| 2002[1] | 5 | B | X | | X | X |
| 2003 | 6 | C | X | | X | X |
| 2007 | 10 | D | X | | X | X |
| 2009[1] | 12 | E | X | X | | |
| 2012[1,2] | 15 | F | X | X | | |
| 2013[1,3] | 16 | G | X | X | X | X |

**Notes**:

[1] Passive samplers were included in these events.

[2] Transplant mussels only at station 303.1; resident mussels only at station 303.6.

[3] Transplant mussels only at station 303.1.

A = 303.1, 303.2, 303.3, 303.4

B = 303.1, 303.2, 303.3, 303.4, 303.6

C = 303.1, 303.2, 303.3, 303.4, 303.6 (water only), 8-inch pipe, Manson ladder, seep, T+2.5

D = 303.1, 303.2, 303.3, 303.4, PCR, L01, L02, 03, L04

E = 303.1, 303.2, 303.3, 303.4, 303.6, 303.7

F = 303.1, 303.2, 303.3, 303.4, 303.6, 303.7 (1800), L01, L02, B1400

G = 303.1, 303.2, 303.3, 303.4, 303.6

TABLE 3-1

**Summary of Pesticide and Organic Carbon Results - 2013 Sediment Core Samples**

*United Heckathorn Superfund Site, Richmond, Californic*

| Location ID | Sample ID | Sample Type | Top Depth (ft) | Bottom Depth (ft) | Subarea | Sediment Type | Pesticides (µg/kg dry weight) | | | | | | | | Total Organic Carbon (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Dieldrin | 2,4'-DDD | 2,4'-DDE | 2,4'-DDT | 4,4'-DDD | 4,4'-DDE | 4,4'-DDT | Total DDT | |
| SD13-04 | SD13-04-0005 | N | 0.0 | 0.5 | North | YBM | 1,100 | 5,900 | 850 | 3.2 U | 33,000 | 1,100 | 2,000 | 42,850 | 25,300 |
| SD13-04 | SD13-04-0515 | N | 0.5 | 1.5 | North | YBM | 880 | 4,600 | 990 | 97 J | 31,000 | 1,200 | 11,000 | 48,887 | 32,900 |
| SD13-05 | SD13-05-0002 | N | 0.0 | 0.2 | North | YBM | 19 | 110 J | 3.2 U | 3.2 U | 600 | 120 | 200 | 1,030 | 37,600 |
| SD13-05 | SD13-05-0203 | N | 0.2 | 0.3 | North | YBM | 8.9 J | 60 J | 3.3 U | 22 J | 220 | 40 | 120 | 462 | 35,900 |
| SD13-05 | SD13-05-0305 | N | 0.3 | 0.5 | North | YBM | 24 | 74 | 3.3 U | 3.3 U | 360 | 79 | 220 | 733 | 36,900 |
| SD13-05 | SD13-05-0507 | N | 0.5 | 0.7 | North | YBM | 62 J | 150 J | 3.3 U | 140 J | 640 | 130 J | 440 | 1,500 | 38,900 |
| SD13-05 | SD13-05-0708 | N | 0.7 | 0.8 | North | YBM | 46 J | 110 J | 3 U | 3 U | 310 | 100 | 210 | 730 | 38,000 > |
| SD13-05 | SD13-05-0810 | N | 0.8 | 1.0 | North | YBM | 47 J | 210 | 240 | 500 | 940 | 420 | 1,100 | 3,410 | 38,000 > |
| SD13-05 | SD13-05-1020 | N | 1.0 | 2.0 | North | YBM | 110 | 700 | 1000 | 3.3 U | 2,700 | 1,100 | 2,300 | 7,800 | 38,100 |
| SD13-05 | SD13-05-2040 | N | 2.0 | 4.0 | North | YBM | 120 | 340 | 460 | 94 | 2,500 | 680 | 1,000 | 5,074 | 38,000 > |
| SD13-06 | SD13-06-0005 | N | 0.0 | 0.5 | North | YBM | 100 J | 320 | 3.2 U | 3.2 U | 1,200 | 260 | 1,300 | 3,080 | 31,200 |
| SD13-06 | SD13-06-0520 | N | 0.5 | 2.0 | North | YBM | 110 J | 380 | 3.3 U | 93 | 1,200 | 260 | 460 | 2,393 | 38,700 |
| SD13-06 | SD13-06-2040 | N | 2.0 | 4.0 | North | YBM | 120 J | 430 | 150 | 27 J | 1,700 | 160 | 190 | 2,657 | 14,200 |
| SD13-06 | SD13-06-4050 | N | 4.0 | 5.0 | North | YBM | 190 | 870 | 3.2 U | 1400 | 5,000 | 260 | 5,600 | 13,130 | 28,200 |
| SD13-08 | SD13-08-0005 | N | 0.0 | 0.5 | North | YBM | 23 J | 44 J | 3.3 U | 3.3 U | 150 J | 15 J | 130 J | 339 | 26,700 |
| SD13-08 | SD13-08-0520 | N | 0.5 | 2.0 | North | YBM | 41 J | 140 | 3.3 U | 3.3 U | 650 | 93 J | 850 | 1,733 | 28,100 |
| SD13-08 | SD13-92-0520 | FD | 0.5 | 2.0 | North | YBM | 14 J | 67 J | 3.3 U | 3.3 U | 490 | 36 J | 700 | 1,293 | -- |
| SD13-08 | SD13-08-2040 | N | 2.0 | 4.0 | North | YBM | 140 | 1,100 | 3.3 U | 95 | 5,800 | 310 | 8,000 J | 15,305 | 22,200 |
| SD13-08 | SD13-08-4655 | N | 4.6 | 5.5 | North | OBM | 3.3 U | 2 J | 3.3 U | 3.3 U | 8.1 | 3.3 U | 4.9 | 15 | 1,250 |
| SD13-09 | SD13-09-0002 | N | 0.0 | 0.2 | North | YBM | 5.7 J | 38 J | 3.3 U | 8.7 J | 260 | 22 J | 230 | 558.7 | 25,500 |
| SD13-09 | SD13-09-0203 | N | 0.2 | 0.3 | North | YBM | 15 J | 59 J | 3.3 U | 20 J | 390 | 39 J | 460 | 968 | 26,100 |
| SD13-09 | SD13-09-0305 | N | 0.3 | 0.5 | North | YBM | 9.2 J | 62 J | 3.2 U | 51 J | 460 | 33 J | 400 | 1,006 | 26,500 |
| SD13-09 | SD13-09-0507 | N | 0.5 | 0.7 | North | YBM | 26 J | 91 J | 3.3 U | 44 J | 500 | 63 J | 580 | 1,278 | 28,800 |
| SD13-09 | SD13-09-0708 | N | 0.7 | 0.8 | North | YBM | 27 J | 97 J | 3.3 U | 56 J | 350 | 47 J | 820 | 1,370 | 23,400 |
| SD13-09 | SD13-09-0810 | N | 0.8 | 1.0 | North | YBM | 21 J | 54 J | 3.2 U | 42 J | 160 | 25 J | 200 | 481 | 23,000 |
| SD13-09 | SD13-09-1020 | N | 1.0 | 2.0 | North | YBM | 31 J | 140 | 3.2 U | 34 J | 770 | 69 J | 730 | 1,743 | 25,600 |
| SD13-09 | SD13-09-2040 | N | 2.0 | 4.0 | North | YBM | 390 | 2,800 | 700 | 140 | 15,000 | 720 | 3,100 | 22,460 | 13,000 |
| SD13-09 | SD13-09-4055 | N | 4.0 | 5.5 | North | YBM/OBM | 150 | 1,300 | 250 | 91 | 7,400 | 180 | 2,200 | 11,421 | 4,150 |
| SD13-10 | SD13-10-0005 | N | 0.0 | 0.5 | North | YBM | 150 J | 610 | 140 J | 130 J | 3,500 | 580 | 590 | 5,550 | 20,600 |
| SD13-10 | SD13-10-0520 | N | 0.5 | 2.0 | North | YBM/OBM | 1,300 | 7,000 | 1,700 | 120 J | 29,000 | 2,000 | 5,200 | 45,020 | 33,000 |
| SD13-10 | SD13-10-2040 | N | 2.0 | 4.0 | North | YBM/OBM | 3.2 U | 26 | 3.2 U | 3.2 U | 110 | 20 | 13 | 169 | 7,000 |
| SD13-10 | SD13-10-4066 | N | 4.0 | 6.6 | North | OBM | 3.2 U | 6.2 | 3.2 U | 3.2 U | 15 | 2.2 J | 1 J | 24.4 | 5,500 |
| SD13-10 | SD13-10-6066 | N | 6.0 | 6.6 | North | OBM | 3.2 U | 2.1 J | 3.2 U | 3.2 U | 8.3 | 3.2 U | 3.2 U | 10.4 | -- |
| SD13-13 | SD13-13-0005 | N | 0.0 | 0.5 | West | YBM | 11 J | 72 J | 3.2 U | 200 | 160 | 37 J | 430 | 899 | 9,700 |
| SD13-13 | SD13-87-0005 | FD | 0.0 | 0.5 | West | YBM | 19 J | 44 J | 3.2 U | 38 J | 2,500 | 28 J | 360 | 2,970 | -- |
| SD13-13 | SD13-13-0520 | N | 0.5 | 2.0 | West | YBM/OBM | 26 | 46 | 3.2 U | 34 | 130 | 19 | 210 | 439 | 2,450 |
| SD13-13 | SD13-13-2025 | N | 2.0 | 2.5 | West | OBM | 3.2 U | 1.8 J | 3.2 U | 1.7 J | 7.7 | 1.1 J | 2.7 J | 15 | 970 |
| SD13-13 | SD13-87-2025 | FD | 2.0 | 2.5 | West | OBM | 3.2 U | 1.6 J | 3.2 U | 3.2 U | 6.2 | 3.2 U | 2.2 J | 10 | -- |
| SD13-14 | SD13-14-0005 | N | 0.0 | 0.5 | North | YBM | 140 | 1,000 | 230 | 120 J | 7,200 | 150 | 3,600 | 12,300 | 12,500 |
| SD13-14 | SD13-14-0509 | N | 0.5 | 0.9 | North | YBM | 110 | 900 | 230 | 90 J | 5,600 J | 140 J | 8,000 | 14,960 | 15,700 |
| SD13-14 | SD13-14-1020 | N | 1.0 | 2.0 | North | OBM | 3.2 U | 1.2 J | 3.2 U | 3.2 U | 1.5 J | 3.2 U | 1.5 J | 4.2 | 3,050 |
| SD13-14 | SD13-14-2040 | N | 2.0 | 4.0 | North | OBM | 8.2 | 54 | 3.2 U | 11 | 170 | 14 | 8.4 | 257.4 | 2,950 |
| SD13-15 | SD13-15-0005 | N | 0.0 | 0.5 | North | YBM | 86 | 300 | 50 | 660 | 1,200 J | 420 | 3,000 J | 5,630 | 19,200 |
| SD13-15 | SD13-15-0520 | N | 0.5 | 2.0 | North | YBM | 96 | 220 | 85 | 140 | 1,100 J | 270 | 7,900 | 9,715 | 7,700 |
| SD13-15 | SD13-15-2040 | N | 2.0 | 4.0 | North | OBM | 1.1 J | 2.4 J | 3.2 U | 3.2 U | 15 | 1.3 J | 4.4 | 23.1 | 2,350 |
| SD13-15 | SD13-15-4049 | N | 4.0 | 4.9 | North | OBM | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 5.1 | 3.2 U | 3.2 U | 5.1 | 580 |
| SD13-18 | SD13-18-0005 | N | 0.0 | 0.5 | West | YBM | 45 J | 170 | 3.2 U | 170 | 820 J | 74 J | 750 | 1,984 | 14,200 |
| SD13-18 | SD13-18-0510 | N | 0.5 | 1.0 | West | YBM | 280 | 1,300 | 330 | 400 | 4,900 | 270 | 4,400 | 11,600 | 10,100 |
| SD13-18 | SD13-18-1530 | N | 1.5 | 3.0 | West | OBM | 3.3 U | 3.3 U | 3.3 U | 3.3 U | 3.3 U | 3.3 U | 3.3 U | 0 U | 760 |
| SD13-18 | SD13-82-1530 | FD | 1.5 | 3.0 | West | OBM | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 2.3 J | 3.2 U | 1.4 J | 3.7 | -- |
| SD13-19 | SD13-19-0005 | N | 0.0 | 0.5 | East | YBM | 41 J | 140 | 3.3 U | 1,000 | 650 J | 69 J | 2,700 | 4,559 | 16,300 |
| SD13-19 | SD13-19-0520 | N | 0.5 | 2.0 | East | YBM | 95 | 440 | 3.2 U | 320 | 2,300 J | 130 | 8,600 | 11,790 | 10,100 |
| SD13-19 | SD13-19-2040 | N | 2.0 | 4.0 | East | YBM | 77 | 440 | 64 | 620 | 1,900 J | 100 | 2,500 | 5,624 | 1,350 |
| SD13-19 | SD13-19-4560 | N | 4.5 | 6.0 | East | OBM | 86 | 170 | 3.2 U | 240 | 820 J | 86 | 2,800 | 4,116 | 1,600 |

TABLE 3-1

**Summary of Pesticide and Organic Carbon Results - 2013 Sediment Core Samples**

*United Heckathorn Superfund Site, Richmond, Californic*

| Location ID | Sample ID | Sample Type | Top Depth (ft) | Bottom Depth (ft) | Subarea | Sediment Type | Pesticides (µg/kg dry weight) | | | | | | | | Total Organic Carbon (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Dieldrin | 2,4'-DDD | 2,4'-DDE | 2,4'-DDT | 4,4'-DDD | 4,4'-DDE | 4,4'-DDT | Total DDT | |
| SD13-20 | SD13-20-0005 | N | 0.0 | 0.5 | East | YBM | 3.3 U | 3.3 U | 3.3 U | 3.3 U | 3.3 U | 3.3 U | 2.8 J | 2.8 | 9,600 |
| SD13-20 | SD13-20-0520 | N | 0.5 | 2.0 | East | YBM | 110 | 400 | 3.2 U | 1,500 | 1,300 | 310 | 17,000 | 20,510 | 7,800 |
| SD13-20 | SD13-20-2040 | N | 2.0 | 4.0 | East | YBM | 100 | 600 | 3.2 U | 16,000 | 8,200 | 350 | 80,000 | 105,150 | 6,350 |
| SD13-20 | SD13-20-4052 | N | 4.0 | 5.2 | East | YBM | 320 | 1,200 | 98 J | 1,300 | 1,300 | 450 | 13,000 | 17,348 | 9,750 |
| SD13-23 | SD13-23-0005 | N | 0.0 | 0.5 | West | YBM | 180 | 740 | 3.2 U | 2,500 | 3,500 | 260 | 23,000 | 30,000 | 10,800 |
| SD13-23 | SD13-23-0520 | N | 0.5 | 2.0 | West | YBM | 360 | 1,600 | 390 | 1,000 | 8,200 J | 370 | 8,100 | 19,660 | 7,150 |
| SD13-23 | SD13-77-0520 | FD | 0.5 | 2.0 | West | YBM | 520 | 430 | 430 | 900 | 2,200 | 310 | 2,500 | 6,770 | -- |
| SD13-23 | SD13-23-2037 | N | 2.0 | 3.7 | West | YBM/OBM | 630 | 6,900 | 1600 | 1,900 | 2,300 | 1,300 | 3,500 | 17,500 | 13,600 |
| SD13-24 | SD13-24-0005 | N | 0.0 | 0.5 | East | YBM | 14 J | 51 J | 3.2 U | 36 J | 260 | 25 J | 770 | 1,142 | 17,100 |
| SD13-24 | SD13-24-0520 | N | 0.5 | 2.0 | East | YBM/OBM | 10 J | 55 J | 3.2 U | 15 J | 100 J | 20 J | 86 J | 276 | 4,050 |
| SD13-24 | SD13-24-2040 | N | 2.0 | 4.0 | East | YBM/OBM | 3.3 U | 17 | 3.3 U | 15 | 72 | 6.1 | 47 | 157.1 | 3,750 |
| SD13-24 | SD13-24-4060 | N | 4.0 | 6.0 | East | YBM/OBM | 40 | 350 | 79 | 210 | 1,700 | 100 | 4,700 | 7,139 | 6,200 |
| SD13-25 | SD13-25-0005 | N | 0.0 | 0.5 | East | YBM | 3.3 U | 31 J | 3.3 U | 41 J | 120 | 15 J | 740 | 947 | 21,100 |
| SD13-25 | SD13-25-0520 | N | 0.5 | 2.0 | East | YBM | 27 J | 110 | 3.2 U | 260 | 620 | 45 J | 2,800 | 3,835 | 20,700 |
| SD13-25 | SD13-25-2040 | N | 2.0 | 4.0 | East | YBM | 16 J | 140 | 3.2 U | 190 | 690 | 60 J | 3,600 | 4,680 | 24,300 |
| SD13-25 | SD13-75-2040 | FD | 2.0 | 4.0 | East | YBM | 20 J | 180 | 3.3 U | 650 | 730 | 86 J | 3,500 | 5,146 | -- |
| SD13-25 | SD13-25-4059 | N | 4.0 | 5.9 | East | YBM | 70 J | 110 | 92 J | 180 | 900 | 190 J | 3,100 | 4,572 | 12,300 |
| SD13-27 | SD13-27-0005 | N | 0.0 | 0.5 | West | YBM | 13 | 34 | 17 | 2.1 J | 210 | 13 | 97 | 373.1 | 5,950 |
| SD13-27 | SD13-27-0520 | N | 0.5 | 2.0 | West | YBM | 5 | 35 | 17 | 0.99 J | 240 | 15 | 8.4 | 316.39 | 1,550 |
| SD13-27 | SD13-27-2031 | N | 2.0 | 3.1 | West | YBM | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 4.9 | 3.2 U | 3.2 U | 4.9 | 570 |
| SD13-28 | SD13-28-0005 | N | 0.0 | 0.5 | East | YBM | 5.4 J | 25 J | 3.3 U | 15 J | 110 J | 12 J | 250 | 412 | 20,500 |
| SD13-28 | SD13-28-0520 | N | 0.5 | 2.0 | East | YBM | 4.5 J | 14 J | 3.3 U | 9.3 J | 220 | 7.8 J | 670 | 921.1 | 18,900 |
| SD13-28 | SD13-28-2040 | N | 2.0 | 4.0 | East | YBM | 9 | 46 | 3.2 U | 79 | 200 | 17 | 570 | 912 | 17,300 |
| SD13-28 | SD13-28-4060 | N | 4.0 | 6.0 | East | YBM | 52 | 290 | 160 | 85 | 1,600 | 93 | 2,900 | 5,128 | 19,600 |
| SD13-29 | SD13-29-0005 | N | 0.0 | 0.5 | East | YBM | 4.8 J | 14 J | 3.3 U | 18 J | 66 J | 8.1 J | 240 | 346.1 | 23,500 |
| SD13-29 | SD13-29-0520 | N | 0.5 | 2.0 | East | YBM | 14 J | 36 J | 3.2 U | 67 J | 100 J | 24 J | 500 | 727 | 24,300 |
| SD13-29 | SD13-71-0520 | FD | 0.5 | 2.0 | East | YBM | 12 J | 40 J | 3.2 U | 54 J | 130 | 24 J | 280 J | 528 | -- |
| SD13-29 | SD13-29-2040 | N | 2.0 | 4.0 | East | YBM | 3.3 U | 31 J | 3.3 U | 3.3 U | 150 J | 20 J | 120 J | 321 | 23,800 |
| SD13-29 | SD13-29-4060 | N | 4.0 | 6.0 | East | YBM | 3.3 U | 60 J | 16 J | 18 J | 230 | 35 J | 130 J | 489 | 23,300 |
| SD13-31 | SD13-31-0005 | N | 0.0 | 0.5 | West | OBM | 3.2 U | 1.2 J | 3.2 U | 3.2 U | 4.9 | 1 J | 4.9 | 12 | 1,700 |
| SD13-31 | SD13-31-0520 | N | 0.5 | 2.0 | West | OBM | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 1.5 J | 3.2 U | 3.2 U | 1.5 | 930 |
| SD13-31 | SD13-31-2040 | N | 2.0 | 4.0 | West | OBM | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 0.69 J | 0.69 | 810 |
| SD13-31 | SD13-69-2040 | FD | 2.0 | 4.0 | West | OBM | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 0.69 J | 0.69 | -- |
| SD13-32 | SD13-32-0005 | N | 0.0 | 0.5 | East | YBM | 3.2 U | 3.2 U | 3.2 U | 4.6 J | 24 | 3.2 U | 150 J | 178.6 | 17,100 |
| SD13-32 | SD13-32-0520 | N | 0.5 | 2.0 | East | YBM | 4.1 J | 18 J | 3.2 U | 23 J | 100 J | 8.6 J | 91 J | 240.6 | 16,700 |
| SD13-32 | SD13-32-2040 | N | 2.0 | 4.0 | East | YBM | 3.5 J | 24 J | 3.3 U | 17 J | 130 | 9.1 J | 170 J | 350.1 | 17,700 |
| SD13-32 | SD13-32-4060 | N | 4.0 | 6.0 | East | YBM | 33 J | 120 | 57 J | 48 J | 630 | 56 J | 1,000 J | 1,911 | 11,300 |
| SD13-33 | SD13-33-0005 | N | 0.0 | 0.5 | East | YBM | 5.5 J | 19 J | 3.2 U | 15 J | 68 J | 12 J | 91 J | 205 | 20,400 |
| SD13-33 | SD13-33-0520 | N | 0.5 | 2.0 | East | YBM | 3.2 U | 48 J | 3.2 U | 69 J | 120 | 29 J | 140 J | 406 | 20,400 |
| SD13-33 | SD13-33-2040 | N | 2.0 | 4.0 | East | YBM | 4.2 J | 12 J | 3.3 U | 18 J | 89 J | 11 J | 130 J | 260 | 25,300 |
| SD13-33 | SD13-33-4060 | N | 4.0 | 6.0 | East | YBM | 2.1 J | 14 J | 3.2 U | 3.2 U | 39 J | 6.4 J | 140 J | 199.4 | 24,500 |
| SD13-35 | SD13-35-0005 | N | 0.0 | 0.5 | West | YBM | 6.1 J | 22 J | 3.2 U | 8.1 J | 80 J | 11 J | 71 J | 192.1 | 14,200 |
| SD13-35 | SD13-65-0005 | FD | 0.0 | 0.5 | West | YBM | 1.7 J | 5.3 | 3.3 U | 2.4 J | 28 | 4.1 | 61 | 100.8 | -- |
| SD13-35 | SD13-35-0520 | N | 0.5 | 2.0 | West | YBM | 4.9 | 40 | 3.3 U | 3.3 U | 130 | 13 | 50 | 233 | 14,200 |
| SD13-35 | SD13-35-2040 | N | 2.0 | 4.0 | West | YBM | 16 | 86 | 26 | 3.2 U | 310 | 36 | 130 | 588 | 7,050 |
| SD13-35 | SD13-35-4058 | N | 4.0 | 5.8 | West | YBM | 15 | 120 | 38 | 3.2 U | 390 | 25 | 130 | 703 | 6,500 |
| SD13-36 | SD13-36-0005 | N | 0.0 | 0.5 | East | YBM | 3.3 U | 4.2 J | 3.3 U | 3.3 U | 16 J | 2.7 J | 33 J | 55.9 | 16,100 |
| SD13-36 | SD13-36-0520 | N | 0.5 | 2.0 | East | YBM | 5.1 | 53 | 19 | 18 | 270 | 15 | 330 | 705 | 16,500 |
| SD13-36 | SD13-36-2040 | N | 2.0 | 4.0 | East | YBM | 39 | 550 | 180 | 17 | 3,300 | 100 | 2,000 | 6,147 | 13,000 |
| SD13-36 | SD13-36-4065 | N | 4.0 | 6.5 | East | YBM | 3.2 U | 11 J | 3.2 U | 3.7 J | 73 J | 14 J | 56 J | 157.7 | 10,400 |
| SD13-37 | SD13-37-0005 | N | 0.0 | 0.5 | East | YBM | 3.2 U | 4.5 J | 3.2 U | 3.3 J | 28 J | 6.2 J | 31 J | 73 | 21,200 |
| SD13-37 | SD13-63-0005 | FD | 0.0 | 0.5 | East | YBM | 4.3 J | 10 J | 3.2 U | 1 J | 45 J | 6.5 J | 60 J | 122.5 | -- |
| SD13-37 | SD13-37-0520 | N | 0.5 | 2.0 | East | YBM | 3.2 U | 4.2 J | 3.2 U | 3.2 U | 24 J | 5.4 J | 21 J | 54.6 | 20,800 |
| SD13-37 | SD13-37-2040 | N | 2.0 | 4.0 | East | YBM | 6.3 J | 31 J | 27 J | 3.2 U | 160 | 34 J | 110 | 362 | 24,100 |

TABLE 3-1

**Summary of Pesticide and Organic Carbon Results - 2013 Sediment Core Samples**

*United Heckathorn Superfund Site, Richmond, Californic*

| Location ID | Sample ID | Sample Type | Top Depth (ft) | Bottom Depth (ft) | Subarea | Sediment Type | Pesticides (µg/kg dry weight) | | | | | | | | Total Organic Carbon (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Dieldrin | 2,4'-DDD | 2,4'-DDE | 2,4'-DDT | 4,4'-DDD | 4,4'-DDE | 4,4'-DDT | Total DDT | |
| SD13-37 | SD13-37-4060 | N | 4.0 | 6.0 | East | YBM | 3.2 U | **7 J** | 3.2 U | 3.2 U | **23 J** | **3.6 J** | **23 J** | **56.6** | **21,400** |
| SD13-39 | SD13-39-0005 | N | 0.0 | 0.5 | SFC | YBM | 3.2 U | 3.2 U | 3.2 U | 3.2 U | **12 J** | **2.4 J** | **8.6 J** | **23** | **16,400** |
| SD13-39 | SD13-39-0520 | N | 0.5 | 2.0 | SFC | YBM | 3.8 U | **4** | 3.8 U | 3.8 U | **26** | **5.2** | **23** | **58.2** | **17,300** |
| SD13-39 | SD13-39-2034 | N | 2.0 | 3.4 | SFC | YBM | 3.3 U | **7.9** | **3.5** | 3.3 U | **21** | **3.7** | **17** | **53.1** | **15,900** |
| SD13-39 | SD13-39-4049 | N | 4.0 | 4.9 | SFC | OBM | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 3.2 U | **1.1 J** | **1.1** | **4,050** |
| SD13-40 | SD13-40-0005 | N | 0.0 | 0.5 | SFC | YBM | **1.7 J** | **3.8 J** | **6.3 J** | 3.3 U | **24 J** | **3.6 J** | **11 J** | **48.7** | **15,400** |
| SD13-40 | SD13-40-0520 | N | 0.5 | 2.0 | SFC | YBM | **3.5 J** | **4.7 J** | 3.2 U | 3.2 U | **14 J** | **4.2 J** | **9.1 J** | **32** | **13,200** |
| SD13-40 | SD13-40-2040 | N | 2.0 | 4.0 | SFC | OBM | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 0 U | **1,350** |
| SD13-41 | SD13-41-0005 | N | 0.0 | 0.5 | SFC | YBM | 3.2 U | **2.5 J** | 3.2 U | 3.2 U | **9.3 J** | **3.7 J** | **8.4 J** | **23.9** | **18,100** |
| SD13-41 | SD13-41-0520 | N | 0.5 | 2.0 | SFC | YBM | **3.5 J** | **32 J** | **9 J** | **3.5 J** | **100 J** | **16 J** | **30 J** | **190.5** | **14,900** |
| SD13-41 | SD13-41-2040 | N | 2.0 | 4.0 | SFC | YBM | 3.2 U | **8.1 J** | 3.2 U | 3.2 U | **48 J** | **9.3 J** | **94 J** | **159.4** | **14,200** |
| SD13-41 | SD13-41-4049 | N | 4.0 | 4.9 | SFC | YBM/OBM | 3.2 U | 3.2 U | 3.2 U | 3.2 U | **2.4 J** | 3.2 U | 3.2 U | **2.4** | **1,400** |
| SD13-41 | SD13-59-4049 | FD | 4.0 | 4.9 | SFC | YBM/OBM | 3.2 U | 3.2 U | 3.2 U | 3.2 UJ | **3 J** | **0.78 J** | **1.7 J** | **5.48** | -- |
| SD13-41 | SD13-41-5565 | N | 5.5 | 6.5 | SFC | OBM | 3.2 U | 3.2 U | 3.2 U | 3.2 UJ | 3.2 U | 3.2 U | **1.2 J** | **1.2** | -- |

**Notes:**

**Bold** values indicate detected result.

Total DDT is the sum of the detected isomers.

> actual value is greater than result shown

µg/kg = micrograms per kilogram

DDD = dichlorodiphenyldichloroethane

DDE = dichlorodiphenyldichloroethylene

DDT = dichlorodiphenyltrichloroethane

FD = field duplicate

ft = feet

J = estimated value

mg/kg = milligrams per kilogram

N = normal sample

OBM = Older Bay Mud

SFC = Santa Fe Channel

U = not detected above reporting limit shown

YBM = Younger Bay Mud

TABLE 3-2

**Summary of Pesticide and Total Organic Carbon Results - 2013 Surface Sediment and Embankment Soil Samples**

*United Heckathorn Superfund Site, Richmond, Californic*

| Location ID | Sample ID | Sample Type | Top Depth (ft) | Bottom Depth (ft) | Subarea | Sediment Type | Pesticides (µg/kg dry weight) | | | | | | | | Total Organic Carbon (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Dieldrin | 2,4'-DDD | 2,4'-DDE | 2,4'-DDT | 4,4'-DDD | 4,4'-DDE | 4,4'-DDT | Total DDT | |
| SD13-01 | SD13-01-0005 | N | 0.0 | 0.5 | North | YBM | **140** | **1,500** | 3.2 UJ | **9,700** | **17,000** | **720** | **270,000** | **298,920** | **21,100** |
| SD13-02 | SD13-02-0005 | N | 0.0 | 0.5 | North | YBM | **78** | **700** | 3.3 UJ | **190** | **4,400** | **330** | **8,500** | **14,120** | **38,000 >** |
| SD13-03 | SD13-03-0005 | N | 0.0 | 0.5 | North | YBM | **130** | **430** | **160** | **230** | **790** | **390** | **290** | **2,290** | **38,000 >** |
| SD13-07 | SD13-07-0005 | N | 0.0 | 0.5 | North | YBM | **68 J** | **310** | 3.2 UJ | **150** | **1,600** | **290** | **580** | **2,930** | **31,200** |
| SD13-11 | SD13-11-0005 | N | 0.0 | 0.5 | North | YBM | **34 J** | **150 J** | 3.2 UJ | **81 J** | **630** | **98 J** | **490** | **1,449** | **9,700** |
| SD13-12 | SD13-12-0005 | N | 0.0 | 0.5 | North | YBM | **270** | **3,900** | **530** | **390** | **61,000** | **1,600** | **7,800** | **75,220** | **18,700** |
| SD13-16 | SD13-16-0005 | N | 0.0 | 0.5 | FPS | YBM | **180** | **430** | **97** | **670** | **1,300** | **860** | **4,200** | **7,557** | **11,300** |
| SD13-17 | SD13-17-0005 | N | 0.0 | 0.5 | FPS | YBM | **450** | **3,800** | **220 J** | **8,900** | **6,300** | **3,400** | **69,000** | **91,620** | **10,900** |
| SD13-21 | SD13-21-0005 | N | 0.0 | 0.5 | FPS | YBM | **310 J** | **2,300** | **74 J** | **2,400** | **7,000** | **420** | **28,000** | **40,194** | **8,250** |
| SD13-21 | SD13-79-0005 | FD | 0.0 | 0.5 | FPS | YBM | **270 J** | **2,300** | **120 J** | **3,400** | **21,000** | **670** | **50,000** | **77,490** | -- |
| SD13-22 | SD13-22-0005 | N | 0.0 | 0.5 | FPS | YBM | **170** | **890** | **22 J** | **3,100** | **1,900** | **200** | **8,800** | **14,912** | **7,150** |
| SD13-26 | SD13-26-0005 | N | 0.0 | 0.5 | FPS | YBM | **0.98 J** | **12 J** | **1.9 J** | **72 J** | **38 J** | **30 J** | **280** | **433.9** | **18,300** |
| SD13-30 | SD13-30-0005 | N | 0.0 | 0.5 | FPS | YBM | **21 J** | **53 J** | **13 J** | **250** | **220** | **360** | **1,500** | **2,396** | **10,700** |
| SD13-34 | SD13-34-0005 | N | 0.0 | 0.5 | East | YBM | **51** | **86** | **26 J** | **140 J** | **250** | **180** | **610** | **1,292** | **17,500** |
| SD13-38 | SD13-38-0005 | N | 0.0 | 0.5 | East | YBM | **68** | **63** | **19 J** | **420** | **140** | **320** | **1,400** | **2,362** | **12,200** |
| EMB13-01 | EMB13-01 | N | -- | -- | North | soil | **220 J** | **520** | 27 U | **110** | **2,100 J** | **370 J** | **11,000 J** | **14,100** | -- |
| EMB13-02 | EMB13-02 | N | -- | -- | North | soil | **170** | **430** | 22 U | **650** | **1,300** | **500** | **2,000** | **4,880** | -- |
| EMB13-03 | EMB13-03 | N | -- | -- | North | soil | **350** | **830** | 16 U | **820** | **2,600** | **1,100** | **2,700** | **8,050** | -- |
| EMB13-04 | EMB13-04 | N | -- | -- | North | soil | **380 J** | **560** | **63** | **1,400** | **1,600** | **1,800** | **5,300** | **10,723** | -- |
| EMB13-05 | EMB13-05 | N | -- | -- | North | soil | **27** | **74** | 13 U | **15 J** | **260** | **88** | **93** | **530** | -- |

**Notes:**

**Bold** values indicate detected result.

Embankment soils collected opportunistically from areas where thin layers of sediment were observed between pieces of rip-rap and shoreline armoring. Sediment depth was not recorded.

Total DDT is the sum of the detected isomers.

> actual value is greater than result shown

µg/kg = micrograms per kilogram

DDD = dichlorodiphenyldichloroethane

DDE = dichlorodiphenyldichloroethylene

DDT = dichlorodiphenyltrichloroethane

FD = field duplicate

FPS = former plant site

ft = feet

J = estimated value

mg/kg = milligrams per kilogram

N = normal sample

U = not detected above reporting limit shown

YBM = Younger Bay Mud

TABLE 3-3

**Statistical Summary of Total DDT Concentrations in Sediment**

*United Heckathorn Superfund Site, Richmond, California*

| Sample Group | Number of Detections | Number of Samples | Total DDT (µg/kg) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Minimum | Maximum | Mean | Standard Deviation | Median |
| ***Overall - YBM and OBM*** | | | | | | | |
| YBM, Lauritzen Channel | 100 | 100 | 2.8 | 298,920 | 11,742 | 34,523 | 1,617 |
| YBM, Santa Fe Channel | 9 | 9 | 5.5 | 191 | 66 | 64 | 49 |
| OBM | 15 | 16 | 0.7 | 4,116 | 281 | 1,025 | 8 |
| ***Lauritzen Channel - YBM*** | | | | | | | |
| Former Plant Site | 6 | 6 | 434 | 91,620 | 32,401 | 40,952 | 11,235 |
| North | 39 | 39 | 169 | 298,920 | 17,453 | 49,019 | 2,930 |
| East | 41 | 41 | 2.8 | 105,150 | 5,183 | 16,630 | 705 |
| West | 14 | 14 | 4.9 | 30,000 | 6,183 | 9,633 | 646 |
| ***Lauritzen Channel Surface Sediment - YBM*** | | | | | | | |
| Former Plant Site | 6 | 6 | 434 | 91,620 | 32,401 | 40,952 | 11,235 |
| North | 14 | 14 | 339 | 298,920 | 33,305 | 79,304 | 4,315 |
| East | 12 | 12 | 2.8 | 4,559 | 969 | 1,326 | 379 |
| West | 5 | 5 | 192 | 30,000 | 7,104 | 12,851 | 1,984 |

**Notes:**

Total DDT is the sum of the detected isomers.

For Dieldrin, a value of 1/2 the detection limit was used for non-detects.

For field duplicates, the sample with the higher concentration was used.

µg/kg = micrograms per kilogram

DDT = dichlorodiphenyltrichloroethane

OBM = Older Bay Mud

YBM = Younger Bay Mud; includes samples with mixed YBM/OBM

TABLE 3-4

**Statistical Summary of Dieldrin Concentrations in Sediment**

*United Heckathorn Superfund Site, Richmond, California*

| Sample Group | Number of Detections | Number of Samples | Dieldrin (µg/kg) Minimum | Maximum | Mean | Standard Deviation | Median |
|---|---|---|---|---|---|---|---|
| ***Overall - YBM and OBM*** | | | | | | | |
| YBM, Lauritzen Channel | 87 | 100 | 0.98 | 1,300 | 104 | 207 | 29 |
| YBM, Santa Fe Channel | 3 | 9 | 1.6 | 3.5 | 2.1 | 0.80 | 1.7 |
| OBM | 3 | 16 | 1.1 | 86 | 7.3 | 21 | 1.6 |
| ***Lauritzen Channel - YBM*** | | | | | | | |
| Former Plant Site | 6 | 6 | 0.98 | 450 | 182 | 166 | 175 |
| North | 38 | 39 | 1.6 | 1,300 | 165 | 286 | 86 |
| East | 30 | 41 | 1.6 | 320 | 31 | 56 | 5.5 |
| West | 13 | 14 | 1.6 | 630 | 114 | 188 | 18 |
| ***Lauritzen Channel Surface Sediment - YBM*** | | | | | | | |
| Former Plant Site | 6 | 6 | 1.0 | 450 | 182 | 166 | 175 |
| North | 14 | 14 | 5.7 | 1,100 | 167 | 277 | 93 |
| East | 8 | 12 | 1.6 | 68 | 17 | 23 | 5.1 |
| West | 5 | 5 | 6.1 | 180 | 53 | 73 | 19 |

**Notes:**

Total DDT is the sum of the detected isomers.

For Dieldrin, a value of 1/2 the detection limit was used for non-detects.

For field duplicates, the sample with the higher concentration was used.

µg/kg = micrograms per kilogram

DDT = dichlorodiphenyltrichloroethane

OBM = Older Bay Mud

YBM = Younger Bay Mud; includes samples with mixed YBM/OBM

TABLE 4-1

**Remediation Levels from the 1994 Record of Decision**

*United Heckathorn Superfund Site, Richmond, California*

| Final Remediation Levels | | | | |
|---|---|---|---|---|
| **Medium** | **Chemical** | **Level** | **Basis** | **ELCR** |
| Surface water | DDT | 0.00059 µg/L (0.59 ng/L[1]) | USEPA human health AWQC for the consumption of organisms | $1x10^{-6}$ |
| | Dieldrin | 0.00014 µg/L (0.14 ng/L[1]) | | $1x10^{-6}$ |
| Sediment | DDT | 590 µg/kg average | Site-specific; based on achieving human health AWQC for consumption of organisms | $1x10^{-6}$ |

**Notes**:

[1] USEPA AWQC for DDT and dieldrin were updated in 2002; criteria for consumption of organisms are now 0.00022 µg/L (0.22 ng/L) for DDT and 0.000054 µg/L (0.054 ng/L) for dieldrin based on a target ELCR of $1x10^{-6}$

µg/kg = micrograms per kilogram
µg/L = micrograms per liter
AWQC = ambient water quality criteria
DDT = dichlorodiphenyltrichloroethane
ELCR = excess lifetime cancer risk
ng/L = nanogram per liter
USEPA = U.S. Environmental Protection Agency

TABLE 4-2
**Proposed Remediation Goals for Fish Tissue (RAO 1)**
*United Heckathorn Superfund Site, Richmond, California*

| Endpoint | $RBC_{fish}$ Total DDT[1] (mg/kg wet weight) | $RBC_{fish}$ Dieldrin[1] (mg/kg wet weight) |
|---|---|---|
| **Human Health** | | |
| HQ = 1 | 0.86 | 0.086 |
| ELCR = $1x10^{-4}$ | 1.2 | 0.025 |
| ELCR = $1x10^{-5}$ | 0.12 | 0.0025 |
| ELCR = $1x10^{-6}$ | 0.012 | 0.00025 |
| **Proposed RG** | **0.12** | **0.0025** |

**Notes**:

[1] Represents the total concentration of chemical ingested in tissue regardless of whether concentration is ingested from fish fillet or whole-bodied fish.

DDT = dichlorodiphenyltrichloroethane
ELCR = excess lifetime cancer risk
HQ = hazard quotient
mg/kg = milligram per kilogram
RAO = remedial action objective
$RBC_{fish}$ = risk-based concentration for fish tissue
RG = remediation goal

TABLE 4-3
**Proposed Remediation Goals for Sediment (RAO 1 and RAO 2)**
*United Heckathorn Superfund Site, Richmond, California*

| | Sediment Concentration (µg/kg) | |
|---|---|---|
| **Endpoint** | **Total DDT** | **Dieldrin** |
| **Human Health (RAO 1)** | | |
| $1x10^{-6}$ ELCR | 0.74 | 1.5 |
| $1x10^{-5}$ ELCR | 23 | 4.3 |
| $1x10^{-4}$ ELCR | 730 | 13 |
| Noncancer Hazard HQ = 1 | 450 | 23 |
| Proposed human health $RBC_{sed}$ | 450 [1] | 4.3 |
| **Ecological (RAO 2)** | | |
| Range of RBCs for ecological receptors | 400 – 24,000 | 66 – 1600 |
| Proposed ecological $RBC_{sed}$ | 400 | 66 |
| San Francisco Bay ambient threshold [2] | 7 | 0.44 |
| **Proposed RG** | 400 | 4.3 |

**Notes**:

[1] The primary purpose of the sediment RG is to define the remediation target area. A total DDT sediment RG based on an ELCR of $1x10^{-5}$ (23 µg/kg) would extend the remediation target area into the Santa Fe Channel. However, the updated human health risk evaluation indicated that in general, cancer risks are within USEPA's risk management range of $1x10^{-4}$ to $1x10^{-6}$ for consumption of fish caught in the Santa Fe Channel and Richmond Inner Harbor, and hazards are below the non-cancer threshold of 1 (i.e., the HQ does not exceed 1 for concentrations of total DDT in sediment that are 450 µg/kg and below). Remediation of the Santa Fe Channel is not expected to be necessary to achieve the total DDT fish tissue RG, which is based on an ELCR of $1x10^{-5}$. The noncancer, human health-based total DDT $RBC_{sed}$ of 450 µg/kg corresponds to an ELCR between $1x10^{-5}$ and $1x10^{-4}$, which is within USEPA's risk management range.

[2] From Gandesbery and Hetzel (1998) for sediments with greater than 40 percent fines.

µg/kg = micrograms per kilogram
DDT = dichlorodiphenyltrichloroethane
ELCR = excess lifetime cancer risk
HQ = hazard quotient
RAO = remedial action objective
$RBC_{sed}$ = risk-based concentration for sediment
RG = remediation goal

TABLE 4-4
**Proposed Remediation Goals for Surface Water (RAO 3)**
*United Heckathorn Superfund Site, Richmond, California*

| | USEPA AWQC (µg/L) | |
|---|---|---|
| **Endpoint** | **Total DDT** | **Dieldrin** |
| **Human Health** | 0.00022 | 0.000054 |
| Protection of Human Health<br>Consumption of Organisms<br>Target ELCR = $1x10^{-6}$ | | |
| **Ecological** | 0.001 | 0.0019 |
| Protection of Aquatic Life<br>Saltwater Chronic | | |
| **Proposed RG** | 0.00022 | 0.000054 |

**Notes**:
µg/L = microgram per liter
AWQC = ambient water quality criteria
DDT = dichlorodiphenyltrichloroethane
ELCR = excess lifetime cancer risk
RAO = remedial action objective
USEPA = U.S. Environmental Protection Agency

TABLE 4-5

**Potential Applicable or Relevant and Appropriate Requirements (ARARs)**

*United Heckathorn Superfund Site, Richmond, California*

| Standard, Requirement, Criterion, or Limitation | ARAR Status | Description | Comment |
|---|---|---|---|
| **Potential Chemical-Specific ARARs** | | | |
| Clean Water Act, Section 304, 33 U.S. Code (U.S.C.) §1314 | Relevant and appropriate | Ambient Water Quality Criteria (AWQC) for marine aquatic life and human health (from fish consumption). | Marine Chronic AWQC:<br>Dichlorodiphenyltrichloroethane (DDT) = 1 ng/L<br>Dieldrin = 1.9 ng/L<br>Human health AWQC:<br>DDT = 0.59 ng/L<br>Dieldrin = 0.14 ng/L |
| National Academy of Sciences Action Level for DDT, 55 Federal Register 8745 | To be considered (TBCs) | National Academy of Sciences (NAS) saltwater action levels establish protection of fish-eating birds beyond the surface water ARARs for aquatic life.<br>The NAS saltwater action levels are TBCs, which provide an additional level of protection to fish-eating birds beyond the level that is the basis of the surface water ARARs for aquatic life. The NAS action level was retained as a TBC to help determine the protectiveness of remediation, since the U.S. Fish and Wildlife Service raised concerns that the EPA criteria for DDT might not be stringent enough for the protection of fish-eating birds.<br>Action levels also identified as protective of local species covered under the Endangered Species Act and the California Endangered Species Act. | NAS action level for DDT in fish = 0.05 mg/kg |
| California Code of Regulations, Title 22, Chapter 12, §§66262.11 and 66262.24(a)(2), and Chapter 14, Articles 9-12 | Applicable if hazardous waste generated | Establishes standards for generators of Resource Conservation and Recovery Act (RCRA) and California hazardous wastes, including those for hazardous waste determination, accumulation and disposal. The primary chemicals of concern for United Heckathorn – i.e., dieldrin and DDT – appear to be due to releases contained in waste streams from United Heckathorn's processes. Soils and sediments with chemical concentrations higher than Total Threshold Limit Concentration (TTLCs) and Soluble Threshold Limit Concentration (STLCs) would be classified as hazardous under California law if they are dredged or excavated at the site. | These regulations are applicable to activities that generate waste to determine if the waste is hazardous. Sediment, soil, etc. is generated when it is removed from the ground and taken outside of the area of contamination. |

TABLE 4-5

**Potential Applicable or Relevant and Appropriate Requirements (ARARs)**

*United Heckathorn Superfund Site, Richmond, California*

| Standard, Requirement, Criterion, or Limitation | ARAR Status | Description | Comment |
|---|---|---|---|
| **Potential Location-Specific ARARs** | | | |
| Coastal Zone Management Act, Section 307(c)(1), 16 U.S.C. §1456(c)(1) | Relevant and Appropriate | Coastal Zone Management Act Section 307 requires activities affecting the coastal zone to be "consistent to the maximum extent practicable with the enforceable policies of approved State management programs."<br>The San Francisco Bay Plan regulates development, filling and dredging of San Francisco Bay and the bay shoreline; promotes maintaining water surface area and volume, water quality and ecological integrity of the bay. Bay Plan policies that would likely apply at this project site include, but may not be limited to: Fish, Other Aquatic Organisms and Wildlife; Water Quality; Water Surface Area and Volume; Tidal Marshes and Tidal Flats; Subtidal Areas; Safety of Fills; Protection of the Shoreline; Dredging; Water Related Industry; Ports; Public Access; Fill in Accordance with the Bay Plan; Mitigation; and Navigational Safety and Oil Spill Prevention. In addition, this area is covered by the Bay Plan priority use designation as a Port Priority use and therefore is subject to San Francisco Bay Area Seaport Plan. | Activities will be conducted in a manner consistent with the substantive requirements of the San Francisco Bay Plan. |
| Regional Water Quality Control Board Basin Plan for the San Francisco Bay Basin<br>California Code of Regulations, Title 14, §§10110 through 11990 | Relevant and Appropriate | Reduce fill and disposal of dredged material in the Bay, maintain marshes and mudflats to the fullest extent possible to conserve wildlife, abate pollution, and protect the uses of beneficial uses of the Bay. | Substantive provisions apply to activities affecting the Bay and 100 feet landward of the shoreline. |
| Ocean Dumping Act, 33 U.S.C. §1404,<br>40 CFR Part 227 | Relevant and Appropriate | Prohibits the dumping of material into the ocean that would unreasonably degrade or endanger human health or the marine environment. | Dredged material must meet substantive federal testing guidelines before it can be approved for marine disposal. |
| Migratory Bird Treaty Act<br>16 U.S.C. §703 | Applicable if migratory birds are identified during the action | Prohibits the taking, possession, buying, selling, or bartering of any migratory bird, including feathers or other parts, nests eggs, or products, except as allowed by regulations. This includes disturbing nesting birds. | Migratory birds may pass over the area or be present on site. |

TABLE 4-5

**Potential Applicable or Relevant and Appropriate Requirements (ARARs)**

*United Heckathorn Superfund Site, Richmond, California*

| Standard, Requirement, Criterion, or Limitation | ARAR Status | Description | Comment |
|---|---|---|---|
| Endangered Species Act<br>16 U.S.C. §1536(a)(2) and (c) and 16 U.S.C. §1538(a)(1) | Applicable if listed species or critical habitat is identified | Prohibits actions that jeopardize the continued existence of any listed species, results in the destruction or adverse modification of designated critical habitat of such species (§1536) or results in a "taking" of any listed species (§1538). | Though on-site actions are not required to meet the administrative/procedural requirements of the Act (e.g., consultation), consultation will be completed as needed to verify compliance with substantive requirements if a listed species or critical habitat is identified. |
| Marine Mammal Protection Act, 16 U.S.C. §1372(a) | Applicable if marine mammals are identified at the site | Protects any marine mammal in the U.S. except as provided in international treaties from unregulated "take". | Marine mammals may pass through the area or be present near the site. Provisions are applicable if marine mammals are identified on site and if the selected response action constitutes a take. |
| California Fish & Game Code §2080 | Applicable if an endangered or threatened species is present on site | No person shall take any endangered or threatened species. | |

TABLE 4-5

**Potential Applicable or Relevant and Appropriate Requirements (ARARs)**

*United Heckathorn Superfund Site, Richmond, California*

| Standard, Requirement, Criterion, or Limitation | ARAR Status | Description | Comment |
|---|---|---|---|
| **Potential Action-Specific ARARs** | | | |
| Clean Water Act, Section 404, 33 U.S.C. §1344, and Rivers and Harbors Act, Section 10, 33 U.S.C. §403 | Relevant and appropriate | The determination of the acceptability of fill into waters of the United States is made under the Clean Water Act Section 404(b)(1) guidelines which were promulgated in 40 Code of Federal Regulations Part 230. The discharge of dredged or fill material is prohibited if there is a practicable alternative to the proposed discharge that would have less impact on the ecosystem, so long as the alternative does not have other significant adverse environmental consequences. | The substantive provisions of this requirement are relevant and appropriate requirements for dredging and capping that may affect navigable waters. |
| Resource Conservation and Recovery Act, California Code of Regulations, Title 22, §§66262.10(a) and 66262.11 | Applicable | Person who generates waste shall determine if waste is a RCRA hazardous waste. | These regulations are applicable to any operation that generates waste. Waste will be generated during dredging, and must be the subject of a RCRA hazardous waste determination at that time. |
| Resource Conservation and Recovery Act, California Code of Regulations, Title 22, §§66264.13(a) and (b) | Applicable | Requirements for analyzing waste for determining whether waste is hazardous. | These regulations are applicable to any operation that generates waste. Waste will be generated during dredging, and must be the subject of a RCRA hazardous waste determination at that time. |
| Resource Conservation and Recovery Act, California Code of Regulations, Title 22, §66262.34(a)(1)(A),(a)(2), and (a)(3) | Applicable if hazardous waste is generated | Accumulation times and marking requirements | Applicable if hazardous waste is generated. |
| National Pollutant Discharge Elimination System General Permit for Storm Water Discharges Associated With Construction and Land Disturbance Activities<br>ORDER NO. 2009-0009-DWQ<br>NPDES NO. CAS000002 | Relevant and Appropriate | Defines use of best management practices for effluent from management, erosion and sediment control plan, plans for minimizing discharge and erosion during and after construction, and other general provisions including best management practices, storm water controls, and monitoring, and other requirements for construction activities that would normally require National Pollutant Discharge Elimination System (NPDES) permitting by virtue of disturbing more than 1 acre of land. These actions are documented in a construction site best management practices plan. | Obtaining a NPDES permit is an administrative requirement and is not required for on-site activities. However, the requirements and best management practices associated with this general permit are relevant and appropriate for some of the proposed remedial actions and should be adhered to. |

TABLE 5-1

**General Response Actions**

*United Heckathorn Superfund Site, Richmond, California*

| Action | Description/Examples |
|---|---|
| No Action | Provides a baseline against which other remedial technologies are evaluated. The site is considered unchanged and represents the existing site conditions (i.e., no remedial activities would be implemented). |
| Institutional Controls | Administrative or legal controls such as fish consumption advisories, waterway use restrictions, site access restrictions, and environmental easements are implemented. The measures are intended to prevent or reduce human exposure to onsite contaminants. |
| Monitored Natural Recovery | MNR involves leaving the contaminated sediment in place and allowing natural processes (physical, chemical, and/or biological) to contain, destroy, alter, or reduce contaminant concentrations in sediment. Long-term monitoring is often a component of MNR and may include physical surveys as well as chemical and biological sampling to assess the extent to which ongoing natural recovery is occurring. |
| Enhanced Natural Recovery | ENR is the application of thin layers of clean material over areas where natural recovery processes already occur or to facilitate recovery in areas where contaminated sediments have been removed. Long-term monitoring is often a component of ENR. |
| Containment | Containment (e.g., capping and sheet piles) involves physically isolating and/or stabilizing contaminated sediments to reduce potential for exposure to contaminants and to minimize sediment resuspension and transport. Long-term monitoring and maintenance activities and institutional controls are often required for the long-term effectiveness of this remedial technology. |
| In Situ Treatment | In situ treatment (e.g., bioremediation and stabilization) involves treating contaminated sediment in place by applying various physical or chemical methods to contain chemical concentrations, reduce mobility, and reduce bioavailability. |
| Ex Situ Treatment | Ex situ treatments (e.g., thermal treatment and physical/chemical treatment) can be performed onsite or at an offsite treatment facility. The treatments are usually applied to meet final disposal requirements, reduce costs by generating material with less stringent disposal requirements, and/or create a beneficial use product. |
| Removal | This response action involves removal of impacted sediment (e.g., excavation and dredging) for treatment and/or onsite or offsite disposal. Factors that influence removal of sediment include site conditions, water depth, sediment characteristics (including water content), volumes to be removed, and accessibility. Removed sediment requires transport (e.g., barge, truck, and/or rail) for treatment and disposal. |
| Disposal | Removed sediment from the site is disposed of in a RCRA Subtitle D Landfill, an in-water CAD facility, or a CDF. |

**Notes**:

CAD = confined aquatic disposal
CDF = confined disposal facility
ENR = enhanced natural recovery
MNR = monitored natural recovery
RCRA = Resource Conservation and Recovery Act

TABLE 5-2

**Guidelines for Technology Screening Ranking**

*United Heckathorn Superfund Site, Richmond, California*

| Ranking Guidelines for the Technology Screening Scores in Table 5-3 | |
|---|---|
| **Technical Effectiveness** | |
| 1 | Would not be effective. |
| 2 | Would be only partially effective, or the effectiveness is unknown. |
| 3 | An innovative technology that may work and there have been some successful applications. |
| 4 | Effectiveness is more certain and there have been many successful applications. |
| **Implementability** | |
| 1 | Would cause a high amount of disruption in the project area and would require significant specialized equipment, technical knowledge, and/or administrative permits. |
| 2 | Would cause a modest amount of disruption in the project area and would require some specialized equipment, technical knowledge, and/or administrative permits. |
| 3 | Would cause a modest amount of disruption in the project area but would not require significant specialized equipment, technical knowledge, or administrative permits. |
| 4 | Could be readily implemented at the site with minimal equipment and would not disrupt the project area. |
| **Cost** | |
| 1 | High |
| 2 | Moderate |
| 3 | Low |
| 4 | No cost |

TABLE 5-3

**Technology Screening Evaluation**

*United Heckathorn Superfund Site, Richmond, California*

| General Response Action | Remedial Technology Type | Process Option | Description | Ranking[1] | | | Retained for Further Evaluation?[2] | Screening Comments |
|---|---|---|---|---|---|---|---|---|
| | | | | Effectiveness | Implementability | Cost | | |
| No action | None | Not applicable | No remedial actions such as removal, containment, treatment, engineering controls, or new institutional controls would be implemented. | 1 | 4 | 4 | Yes | No action would not be effective at reducing contaminant concentrations in sediments because remedial actions would not be implemented. No action is retained for further evaluation as a baseline for comparison with other alternatives in accordance with the NCP. |
| Institutional controls | Not applicable | Deed and use restrictions | Administrative or legal controls such as fish consumption advisories, waterway use restrictions, site access restrictions, and environmental easements would be implemented. Institutional controls are typically used in conjunction with other remedy components and not as a stand-alone remedy. | 2 | 4 | 3 | Yes | Institutional controls alone would not be an effective technology. However, they can be a useful approach to mitigate human exposures to contaminants and can be readily combined with various technologies to enhance the overall effectiveness of a remedy. Therefore, they are retained for further evaluation. |
| Monitored natural recovery (MNR) | MNR | MNR | MNR involves leaving the contaminated sediments in place and allowing natural processes (physical, chemical, and/or biological) to contain, destroy, alter or reduce contaminant concentrations in sediments. Long-term monitoring is often a component of MNR and may include physical surveys as well as chemical and biological sampling to assess the extent to which ongoing natural recovery occurs. | 2 | 4 | 3 | No | The Tier 2 sediment transport analysis (SEI, 2014) showed that the Lauritzen Channel is accumulating relatively clean sediment from San Francisco Bay. Although average contaminant concentrations in the sediment appear to be decreasing in the channel, the rate of decrease is not sufficient to meet the RAOs within an acceptable timeframe. In addition, scour from moving vessels and disturbance of sediment from mooring spuds may cause higher contaminant concentrations in the subsurface sediments to become exposed. Therefore, MNR is not retained for further evaluation. |
| Enhanced natural recovery (ENR) | ENR | ENR | ENR is the application of thin layers of clean material over areas where natural recovery processes are already occurring or to facilitate recovery in areas where contaminated sediments have been removed. Long-term monitoring is often a component of ENR and may include physical surveys as well as chemical and biological sampling to assess the extent to which ongoing enhanced natural recovery occurs. | 2 | 4 | 3 | No | As shown by the loss of the benthic sand layer after the 1997 remedy, scour from moving vessels and disturbance of sediment from mooring spuds would disturb the thin layer of clean material, severely limiting enhanced recovery. Therefore, ENR is not retained for further evaluation. |
| Containment | Capping | Isolation layer | Sand may be placed as separate layers or mixed with active materials to physically isolate and stabilize the contaminated sediments, preventing the exposure of biota to contaminants and sediment resuspension and transport. Long-term monitoring and maintenance activities are needed for the long-term effectiveness of this remedial technology. Additionally, institutional controls may be employed. | 3 | 3 | 3 | Yes | An isolation layer may be used in combination with other capping materials (e.g., reactive/adsorptive and armor) to address contaminated sediments. Therefore, it is retained for further evaluation. |
| Containment | Capping | Active layer | Active cap amendments may be placed as separate layers or mixed with the isolation layer. Addition of active layers allows for a thinner cap (compared to an isolation layer alone) as the amendments increase the cap's adsorptive capacity and extend the breakthrough time (time for contaminants to flow through the cap into the overlying water column). Long-term monitoring and maintenance activities are required for the long-term effectiveness of this remedial technology. Additionally, institutional controls may be employed. | 3 | 3 | 3 | Yes | A number of active materials are effective in sequestering dissolved-phase hydrophobic organic compounds and may be used to reduce/eliminate contaminant transport up through the cap into the overlying water column. Available active cap amendments include activated carbon and oleophilic clays as well as engineered products, such as AquaGate™ (an activated carbon based material developed by AquaBlok®). The active layer can be designed to create permeable and impermeable sediment caps. Geotextiles may also be incorporated into the cap in to serve as a filter between dissimilar graded materials and/or to isolate contaminated sediments from benthic organisms via bioturbation. Active cap materials are retained for further evaluation. |
| Containment | Capping | Armor layer | The armor layer is used to stabilize the underlying cap materials. This layer generally includes the placement of stone, gravel, riprap, or geotextiles over the primary capping material(s). Long-term monitoring and maintenance activities are required to ensure the long-term effectiveness of this remedial technology. Additionally, institutional controls may be employed. | 3 | 3 | 3 | Yes | Cap armoring may be used to protect the underlying cap materials (e.g., sand and active materials) from hydrodynamic forces (e.g., prop scour) within the channel and/or to stabilize the cap in sloped areas. Therefore, it is retained for further evaluation |
| Containment | Sheet pile | Sheet pile | Sheet pile walls are rigid vertical barriers that are driven into the soil or sediment surface. Sheet pile can be made from a variety of materials such as steel, vinyl, plastic, and fiberglass. The edges of the sheets fit together with interlocking joints to form a continuous wall. The sheets are generally installed by driving with impact or vibratory hammers hoisted from a crane assembly. | 3 | 4 | 3 | Yes | Sheet pile walls may be used for short-term applications such as sediment resuspension containment during environmental dredging operations or long-term containment of contaminated soils and sediment. Sheet pile has been retained for further evaluation as a technology for containing contaminated shoreline and embankment soils and sediments. |
| In situ treatment | Bioremediation | Enhanced biological oxidation/ reduction | Bioremediation uses natural microbiological processes to degrade or transform organic chemicals in the sediment environment. Nutrients and potential electron donors/acceptors are provided while controlling temperature and pH to stimulate existing microorganisms to grow and use chemicals as a source of food and energy. | 1 | 2 | 3 | No | In situ bioremediation of persistent and bioaccumulative chlorinated contaminants such as DDT and Dieldrin is not a proven technology for sediments and previous site studies do not indicate that natural biodegradation is occurring to a significant extent. Additional studies would be needed to evaluate this remedial technology. Therefore, it is not retained for further evaluation. |

TABLE 5-3
**Technology Screening Evaluation**
*United Heckathorn Superfund Site, Richmond, California*

| General Response Action | Remedial Technology Type | Process Option | Description | Ranking[1] | | | Retained for Further Evaluation?[2] | Screening Comments |
|---|---|---|---|---|---|---|---|---|
| | | | | Effectiveness | Implementability | Cost | | |
| In situ treatment | Stabilization | Vitrification | Contaminated sediments are heated to a molten state with electrical current, destroying the chemical constituents. | 1 | 1 | 1 | No | In situ vitrification is not appropriate in a saturated environment or high organic wastes containing little sand (e.g., soft sediments). In situ vitrification effectiveness is highly dependent upon site-specific conditions and is very energy intensive and costly. Special precautions would need to be implemented to capture and treat off-gas. Because in situ vitrification is not applicable to a saturated environment, it is not retained for further evaluation. |
| In situ treatment | Stabilization | Chemical treatment | This technology involves immobilizing contaminants by physically binding or enclosing the sediments within a stabilized mass, or chemically treating the contaminants. Portland cement, lime, or other additive is mixed with the sediments in situ to encapsulate the sediments and/or reduce the solubility, mobility, and toxicity of the contaminants. | 2 | 2 | 2 | No | In situ solidification/stabilization could potentially be used to immobilize chemical contaminants. However, bench and field-scale pilot testing would be needed to assess its applicability to the site. In addition, in-situ treatment methods could potentially reduce the navigation depths and thus interfere with use of the berth and other areas of the channel. Given that there are other remedial technologies that would not require testing before implementation and/or potentially impede navigation, in situ solidification/stabilization is not retained for further evaluation. |
| In situ treatment | Treatment | Chemical destruction/ oxidation | Chemical oxidants are injected into the subsurface sediments to oxidize organic contaminants. | 1 | 2 | 3 | No | Chemical destruction/oxidation would require the injection of oxidants to reduce contaminant concentrations in the sediments. However, bench-scale and field-scale pilot testing would be needed to assess its applicability to the site, because site conditions (e.g., sediment properties) may inhibit the ability to achieve adequate delivery and distribution of the oxidants. Given that there are other remedial technologies that would not require testing before implementation and the effectiveness of in situ solidification/stabilization under conditions at the site is uncertain, it is not retained for further evaluation. |
| In situ treatment | Treatment | Adsorption | This technology is based on mixing activated carbon (e.g., granular, SediMite ™) into the biologically active sediment zone (typically the top 6 to 12 inches) to reduce the bioavailability of hydrophobic organic chemicals in sediment. Granular activated carbon may be mixed into the sediments using large-scale equipment. SediMite ™ is an agglomerate material that does not require mechanical mixing. It uses the activity of the benthic organisms in a bioturbation process to naturally mix the activated carbon into the top sediment layers over an extended time period. | 2 | 2 | 2 | No | Although activated carbon is a proven adsorbent for site contaminants, treatment using this remedial technology would be subject to scour from moving vessels and disturbance from mooring spuds, causing the adsorptive material to be displaced and the contaminated subsurface sediments to become exposed. Therefore, it is not retained for further evaluation. |
| Ex situ treatment | Biological treatment | Landfarming | Landfarming involves mixing sediment contaminated with organic chemicals with nutrients, water, and amendments and placing the mixture in an engineered treatment unit. | 1 | 2 | 2 | No | The application of landfarming would require additional studies to evaluate its applicability to the contaminants and concentrations found in site sediments. This technology also requires a large amount of land space, which is unavailable at the site. Therefore, it is not retained for further evaluation. |
| Ex situ treatment | Physical/ chemical treatment | Stabilization and solidification (ex situ) | Cementing or stabilization agents are mixed with contaminated sediments to immobilize contaminants by fixing the chemicals by physical or chemical reactions. | 4 | 2 | 2 | Yes | Stabilization and solidification techniques may be used to treat dredged sediments, to reduce their moisture content, and to prepare them for truck/rail transport to a disposal facility. Stabilized/solidified sediments could have potential beneficial use applications as engineered fill or structural/nonstructural concrete. The process would not reduce contaminant concentrations but would reduce the leachability of some contaminants. Bench-scale testing would need to be performed to evaluate the effectiveness of this technology and determine the type(s) and amount of reagent to be added to meet disposal requirements. This technology is retained for further evaluation. |
| Ex situ treatment | Thermal treatment | Thermal destruction | Thermal destruction technologies (e.g., Cement-Lock, co-generation electrical plant) destroy organic contaminants by heating the waste at very high temperatures (greater than 1,400ºC). Inorganic chemicals are concentrated in the ash generated during the incineration process. Beneficial use products may result from the thermal process (e.g., cement replacement or as a partial replacement for sand in concrete, electricity production). | 2 | 2 | 1 | No | This technology may be applied after reduction in the moisture content of the sediments. The acceptability of the sediments by the potential treatment facilities would need to be evaluated, and samples may need to be evaluated to determine whether they meet facility-specific acceptance criteria and to assess their potential beneficial use value. The application of this technology is limited to existing facilities because there is not sufficient sediment volume from this project to economically justify the investment in new facilities based solely or mainly for this project. Given the costs associated with thermal treatment and the availability of other effective remedial technology options, it is not retained for further evaluation. |
| Ex situ treatment | Thermal treatment | Ex situ vitrification | Ex situ vitrification (e.g., Minergy Glass Furnace Technology) involves melting dewatered sediment contaminated with organics and/or heavy metals at very high temperatures (greater than 1,400°C) and turning it into a glass aggregate. The vitrified sediment may be used beneficially in road construction projects and in the making of concrete, shingles, and ceramic floor tiles. | 1 | 1 | 1 | No | Vitrification would not be effective for site sediments because of insufficient sand content in the soft sediment. Moreover, the application of this technology is limited to existing facilities because there is not sufficient sediment volume from this project to economically justify the investment in new facilities based solely or mainly for this project. Given the costs associated with vitrification and the availability of other effective remedial technology options, it is not retained for further evaluation. |

TABLE 5-3
**Technology Screening Evaluation**
*United Heckathorn Superfund Site, Richmond, California*

| General Response Action | Remedial Technology Type | Process Option | Description | Ranking[1] | | | Retained for Further Evaluation?[2] | Screening Comments |
|---|---|---|---|---|---|---|---|---|
| | | | | Effectiveness | Implementability | Cost | | |
| Ex situ treatment | Thermal treatment | Thermal desorption | Thermal desorption technologies heat the sediment to temperatures ranging between 90 and 540ºC and the contaminants are condensed and collected as a liquid, captured on activated carbon, and/or destroyed in an afterburner. The treated materials may be used as landfill cover or for other beneficial uses. | 3 | 2 | 1 | No | This technology may be applied after reduction in the moisture content of the sediments. The acceptability of the sediments by the potential treatment facilities would need to be evaluated, and samples may need to be evaluated to determine whether they meet facility-specific acceptance criteria and to assess their potential beneficial use value. Given the costs associated with thermal desorption and the availability of other effective remedial technology options, it is not retained for further evaluation. |
| Ex situ treatment | Dewatering | Passive or mechanical dewatering and/or dewatering additives | Dewatering can be accomplished by passive or mechanical means. Passive dewatering uses passive drainage and evaporation to dry sediments. Common passive dewatering methods include dewatering beds and geotextile tubes. Mechanical systems such as belt presses and filter presses can be used to accelerate the dewatering process.<br>Dewatering additives (e.g., polymers, hydrated lime, and ferric sulfate) can be added to the dredged sediments after removal to aid in the dewatering process. | 4 | 2 | 2 | Yes | Dewatering would be used to remove water from dredged sediments prior to treatment and/or transport. Mechanical dewatering is the fastest method of dewatering and requires the least amount of space, but it is typically more expensive than passive dewatering. However, passive dewatering requires considerably more land area. This technology is needed to support the dredging operation and is retained as a supporting component to dredging. |
| Ex situ treatment | Particle size segregation | Particle size segregation | Particle size segregation uses vibrating or fixed screens, hydrocyclones, or gravity separation to segregate particle sizes in dredged sediment. The segregated particles may be used for fill materials. | 1 | 3 | 3 | No | Particle size segregation would not be applicable to the fine-grained soft sediments dredged from the channel. Therefore, this technology is not retained for further evaluation. |
| Ex situ treatment | Sediment washing | Sediment washing | Sediment washing (e.g., Biogenesis) is achieved by ex situ physical separation of fine and bulk sediment particles followed by chemical washing using a solvent to remove chemicals from sediment. It is assumed that chemicals sorb to the finer particles, which generally contain high levels of total organic carbon. The washed sediment may be used beneficially for fill materials. | 1 | 2 | 2 | No | The effectiveness of this technology for reducing contaminant concentrations in soft sediments is uncertain. Additionally, this technology would result in a large volume of wastewater to be treated, substantial equipment and energy use, and cost. Therefore, it is not retained for further evaluation. |
| Removal | Dry excavation | Mechanical excavation | Excavation includes the removal of sediment by using earthmoving equipment (e.g., excavator and backhoe) in dry conditions. The excavation area must first be dewatered. Temporary barriers may be installed to dewater and excavate the sediment. | 4 | 2 | 2 | No | Dry excavation could potentially be used in limited portions of the channel; however, the majority of the contaminated sediment volume is located in areas where water depths are too deep to allow for dewatering. Therefore, it is not retained for further evaluation. |
| Removal | Dredging | Mechanical dredging | Mechanical dredging typically consists of a suspended or manipulated bucket (e.g., clamshell or environmental) that collects the sediment and raises it to the surface via a cable, boom, or ladder. The sediment is deposited on a haul barge or other vessel for transport to a processing facility or disposal site. | 4 | 3 | 2 | Yes | Mechanical dredging may be an effective removal technology throughout the channel. Mechanical dredging tends to entrain less water than hydraulic dredging (described below), with a typical water entrainment ratio of approximately 2 parts water to 1 part dredged sediment. As a result, upland sediment processing and water treatment facilities generally require less area to handle mechanically dredged sediments than for hydraulic dredging. Therefore, mechanical dredging is retained for further evaluation. |
| Removal | Dredging | Hydraulic dredging | Hydraulic dredging removes sediments with hydraulic suction. The sediments are then pumped through a pipeline to a staging area (e.g., dewatering site). Common hydraulic dredges include cutterhead, horizontal augers, plain suction, pneumatic submersible pumps, specialty dredge heads, and diver assisted hand-held hydraulic suctions. | 4 | 2 | 2 | No | Hydraulic dredging may be an effective removal technology if a nearby staging area could be identified to support the process. However, the volume of the sediment slurry produced by hydraulic dredging would be significantly greater than the volume of sediments generated from mechanical dredging. This slurry would require significantly more dewatering and solidification than sediments produced from mechanical dredging prior to disposal. In addition, the presence of debris in previously undredged areas of the channel could substantially hinder productivity. Therefore it is not retained for further evaluation. |
| Removal | Dredging | Micro dredging | Micro dredging involves divers or remotely operated vehicles to remove small, precise volumes of sediment. | 1 | 2 | 2 | No | The removal of small, precise volumes of sediment is not necessary at this site because of the extent of the contamination present. The implementation of shoreline control measures will eliminate the need for micro dredging between pilings or under the Levin pier. Micro dredging would not be effective at removing the volume of contaminated sediment requiring remedial action and is not retained for further evaluation. |
| Disposal | Onsite disposal | CCAD | CAD cells are in-water disposal units that isolate contaminated sediments by placing them into a geochemically stable environment that limits the mobility of the contaminants. The CAD cell is capped after it is filled. Long-term monitoring and maintenance activities are required as part of this remedial technology. | 3 | 2 | 1 | No | A CAD may be an effective disposal option for contaminated sediments. Implementation of this option is a function of the available subsurface volume (e.g., below mean lower low water) within the channel. The available volume must also be able to accommodate sediment bulking (temporary increased sediment volume) due to dredged material placement and the CAD cell cap. Contaminated sediments placed in CADs are usually not treated; therefore, releases to the water column may occur during and after placement and prior to capping. In addition, significant administrative or regulatory impediments to implementation are often encountered. Therefore, it is not retained for further evaluation. |

TABLE 5-3
**Technology Screening Evaluation**
*United Heckathorn Superfund Site, Richmond, California*

| General Response Action | Remedial Technology Type | Process Option | Description | Ranking[1] | | | Retained for Further Evaluation?[2] | Screening Comments |
|---|---|---|---|---|---|---|---|---|
| | | | | Effectiveness | Implementability | Cost | | |
| Disposal | Onsite disposal | CCDF | A CDF is an extension of land or an island area designed for containment of contaminated dredged sediments that provides control of potential releases of contaminants to the environment. Dikes or other structures may be used to isolate the dredged materials placed in a CDF. Long-term monitoring and maintenance activities are required as part of this remedial technology. | 3 | 2 | 1 | No | An onsite CDF may be an effective disposal option for contaminated sediments. However, this technology requires a large area, which is unavailable at the site. In addition, significant administrative or regulatory impediments to implementation are often encountered. Therefore, it is not retained for further evaluation. |
| Disposal | Offsite disposal | Landfill | Disposal of contaminated sediments at an offsite landfill removes the chemicals of concern from the site. The removed sediments would be evaluated prior to disposal to identify the type of landfill that will accept the material. | 4 | 3 | 2 | Yes | Disposal of dredged sediments at an offsite, permitted disposal facility may be implemented in combination with treatment (e.g., dewatering and/or stabilization for truck/rail transport). The acceptability of the sediments by the disposal facility would need to be evaluated in greater detail during the remedial design. This option is retained for further evaluation. |
| Disposal | Offsite disposal | CCDF | A CDF is an extension of land or an island area designed for containment of contaminated dredged sediments that provides control of potential releases of contaminants to the environment. Dikes or other structures may be used to isolate the dredged materials placed in a CDF. Long-term monitoring and maintenance activities are required as part of this remedial technology. | 3 | 2 | 1 | No | There are currently no available CDFs in the area that could accept the contaminated sediments from the site. Construction of a new CDF would be difficult due to lack of available sites, environmental impacts, regulatory and public concerns, and lengthy site characterization and permitting processes. Therefore, offsite CDF disposal is not retained for further evaluation. |
| Disposal | Transportation | Barge, truck, and/or rail | Dredged sediment may be transported to a staging area or directly to a treatment and disposal facility by barge. From there, the sediment may need to be transported by truck and/or rail for further treatment. Dredged sediment may be placed directly on barges, after which the sediment would be transported to a staging area for dewatering/treatment prior to disposal. Dredged sediment would require dewatering/stabilization prior to transport by truck or rail. | 4 | 2 | 2 | Yes | After removal, sediments would need to be transported by barge to a facility where they would be prepared for further treatment and/or disposal. Neither truck nor rail transport would not apply for direct transport of sediments from the channel, because of the entrained water; however, truck and rail transport would apply to transport from the dewatering facility to the treatment/disposal facilities. These options are needed to support the overall remedy and are therefore retained as supporting components. Transport by rail is assumed to be the representative process option for alternative development. |

**Notes:**

[1]On scale of 1 (poorest) to 4 (best). See Table 5-2 for ranking guidelines.

[2]Shaded rows indicate technology was not retained for further evaluation.

°C = degrees Centigrade
CAD = confined aquatic disposal
CDF = confined disposal facility
ENR = enhanced natural recovery
MNR = monitored natural recovery
NCP = National Oil and Hazardous Substances Pollution Contingency Plan [Title 40 Code of Federal Regulations Section 300.430(e)]
RAO = remedial action objectives

TABLE 5-4

**Technology Screening Summary**

*United Heckathorn Superfund Site, Richmond, California*

| General Response Action | Remedial Technology Type | Process Options | Process Option Retained for Alternative Development | Comments |
|---|---|---|---|---|
| Institutional Controls | Not applicable | Deed and use restrictions | Deed and Use Restrictions | Institutional controls would be incorporated, as needed, into the development of remedial alternatives. |
| Containment | Capping | Isolation layer<br>Active layer<br>Armor layer<br>Sheet pile | All | All capping options and sheet pile are proposed as part of the remedial alternatives. Cap specifications will be developed during remedial design. |
| Monitored Natural Recovery (MNR) | MNR | MNR | None | Site conditions are not conducive to this technology. |
| Enhanced Natural Recovery (ENR) | ENR | ENR | None | Site conditions are not conducive to this technology. |
| In Situ Treatment | Bioremediation | Enhanced biological oxidation/reduction | None | Technology either unproven under site conditions and/or additional studies are needed for further evaluation. Other proven technologies are available; therefore, no in situ treatment technologies were retained for alternative development. |
| | Stabilization | Vitrification<br>Chemical treatment | | |
| | Treatment | Chemical destruction/oxidation<br>Adsorption | | |
| Ex Situ Treatment | Biological treatment | Landfarming | | |
| | Physical/chemical treatment | Stabilization and solidification (ex situ) | Stabilization and solidification (ex situ) | Ex situ stabilization/solidification of the dredged material is proposed to support transport of material under the disposal GRA. |
| | Thermal treatment | Thermal destruction<br>Ex situ vitrification<br>Thermal desporption | | |
| | Dewatering | Passive or mechanical dewatering and/or dewatering additives | Dewatering | Passive and mechanical dewatering are viable process options. Passive dewatering is retained as the representative process option for the purposes of developing remedial alternatives and cost estimating. |
| | Particle size segregation | Particle size segregation | | |

TABLE 5-4

**Technology Screening Summary**

*United Heckathorn Superfund Site, Richmond, California*

| General Response Action | Remedial Technology Type | Process Options | Process Option Retained for Alternative Development | Comments |
|---|---|---|---|---|
| | Sediment washing | Sediment washing | | |
| Removal | Dry excavation | Mechanical excavation | | Mechanical dredging is retained as the representative process option for the purposes of developing remedial alternatives and cost estimating. |
| | Dredging | Mechanical dredging<br>Hydraulic dredging<br>Micro dredging | Mechanical Dredging | |
| Disposal | Onsite disposal<br>Offsite disposal | CAD<br>CDF<br>Landfill | Landfill | RCRA Subtitle D Landfill disposal is retained as the representative process option for the purposes of developing remedial alternatives and cost estimating. |
| | Transportation | Barge, truck, and/or rail | Rail | All three process options are viable. Rail was retained as the representative process option under the disposal GRA, because onsite rail access is available. |

**Note**:
GRA = general response action

TABLE 6-1

**Major Components of the Remedial Alternatives**

*United Heckathorn Superfund Site, Richmond, California*

| | No Action | Mechanical Dredging | Active Capping within Northern Head Area | Long Term Monitoring of Cap within Northern Head Area | Source Control Measures Along Shoreline | Long Term Monitoring of Source Control Measures | Institutional Controls | Onsite Passive Dewatering of Dredged Material | Onsite Solidification of Dredged Material | Offsite Landfill Disposal via Rail |
|---|---|---|---|---|---|---|---|---|---|---|
| **No Action** | X | | | | | | | | | |
| **Alternative 2**<br>Dredge East Side and West Side, Cap Northern Head, Implement Source Control Measures, Utilize Offsite Landfill Disposal, Implement Long-Term Monitoring, and Implement Institutional Controls | | X | X | X | X | X | X | X | X | X |
| **Alternative 3**<br>Dredge East Side, West Side, and Portion of Northern Head, Cap Portion of Northern Head, Implement Source Control Measures, Utilize Offsite Landfill Disposal, Implement Long-term Monitoring, and Implement Institutional Controls | | X | X | X | X | X | X | X | X | X |
| **Alternative 4**<br>Dredge East Side, West Side, and Northern Head, Implement Source Control Measures, Utilize Offsite Landfill Disposal, Implement Long-term Monitoring, and Implement Institutional Controls | | X | | | X | X | X | X | X | X |

TABLE 6-2
**Detailed Evaluation of Alternatives**
*United Heckathorn Superfund Site, Richmond, California*

| Summary of Alternatives | Alternative 1<br>No Action | Alternative 2<br>Dredge East Side and West Side, Cap Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-Term Monitoring, and Institutional Controls | Alternative 3<br>Dredge East Side, West Side, and Portion of Northern Head, Cap Portion of Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls | Alternative 4<br>Dredge East Side, West Side, and Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls |
|---|---|---|---|---|
| **Key Differentiating Elements** | NA | • Dredge: 100% of East and West Side areas of Lauritzen Channel (58,000 cy)<br>• Active cap (activated carbon or modified clay): 100% of Northern Head area of Lauritzen Channel (1.4 acres / 61,000 $ft^2$) | • Dredge: 100% of East and West Side areas of Lauritzen Channel and 75% of Northern Head area of Lauritzen Channel (64,000 cy)<br>• Active cap (activated carbon or modified clay): 25% of Northern Head area of Lauritzen Channel (0.4 acre / 17,000 $ft^2$) | • Dredge: 100% of East and West Side areas of Lauritzen Channel and 100% of Northern Head area of Lauritzen Channel (66,000 cy) |
| **Additional Elements Common to all Alternatives (Except No Action)** | NA | • Source control measures along sections of shoreline:<br>– Sheet piling<br>– Active cap (activated carbon or modified clay) on landward side of sheet piling<br>– Remove and/or seal non-functional pipes and outfalls along the eastern shoreline<br>– One time removal of sediment from the City of Richmond storm drain system<br>• Offsite landfill disposal of dredged material and debris/piles via rail<br>• Long-term monitoring to evaluate cap and sheet pile integrity and performance<br>• Institutional controls to ensure physical integrity of cap and sheet piling<br>• Onsite handling of dredged material and debris/piles:<br>– Segregation and stockpiling of debris/piles<br>– Dewatering and/or solidification/stabilization of dredged material<br>• Short-term monitoring and engineering controls during dredging, capping, and debris/piles removal activities | | |
| ***Threshold Criteria*** | | | | |
| **Overall protection of human health and the environment** | Alternative would not provide protection of human health and the environment.<br>• RAOs would not be achieved.<br>• Potential human health and ecological risks associated with contaminated sediment and surface water would not be reduced or controlled. | Alternative would provide protection of human health and the environment.<br>• Surface water and sediment RAOs would be achieved soon after completion of the remedy through dredging and capping of contaminated sediment.<br>• Dredging of contaminated sediment would result in significant reduction of potential human health and ecological risk by permanently removing the contaminated sediment.<br>• Capping of sediment would result in significant reduction of potential human health and ecological risk by physical isolation and stabilization of the contaminated sediment, preventing resuspension and transport to other sites, and reduction of the flux of dissolved contaminants into the water column. However, long-term effectiveness of capping relies on adequacy of institutional controls to protect cap integrity and implementation of monitoring and maintenance of the cap, as necessary. | Same as Alternative 2. | Same as Alternative 2 (and 3); however, this alternative would provide greater certainty of long-term effectiveness because all areas would be dredged (i.e., contaminated sediment in the Northern Head would be removed rather than capped). Removal of the sediment significantly and permanently reduces potential human health and ecological risks associated with contaminated sediment. |
| **Compliance with ARARs** | Alternative would not be in compliance with ARARs. | Alternative can be designed to comply with substantive requirements of the ARARs. | Same as Alternative 2 (and 4). | Same as Alternative 2 (and 3). |
| ***Balancing Criteria*** | | | | |
| **Long-term effectiveness and permanence** | Alternative would not result in any significant change in the potential human health and ecological risks associated with contaminated sediment. | Alternative would provide a moderate to high level of long-term effectiveness and permanence through dredging/removal of contaminated sediment, placement of a an active cap over contaminated sediment in the Northern Head, placement of sheet piling along the shoreline and an active cap on the landward side of the wall, and disposal of dredged sediment and debris in an offsite landfill.<br>• Dredging and removal of sediment would: (1) significantly and permanently reduce potential human health and ecological risks associated with contaminated sediment and (2) improve surface water quality by eliminating contact between surface water and contaminated sediment.<br>• Capping in the Northern Head area would: (1) reduce and control potential human health and ecological risks associated with contaminated sediment, (2) improve surface water quality by | Same as Alternative 2. | Same as Alternative 2 (and 3); however, this alternative would provide a high level of long-term effectiveness and permanence through dredging/removal of contaminated sediment. There is greater certainty in the long-term effectiveness and permanence because the alternative is not dependent upon institutional controls and long-term monitoring to maintain cap integrity and performance in the Northern Head area of the channel. |

TABLE 6-2
**Detailed Evaluation of Alternatives**
*United Heckathorn Superfund Site, Richmond, California*

| Summary of Alternatives | Alternative 1<br>No Action | Alternative 2<br>Dredge East Side and West Side, Cap Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-Term Monitoring, and Institutional Controls | Alternative 3<br>Dredge East Side, West Side, and Portion of Northern Head, Cap Portion of Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls | Alternative 4<br>Dredge East Side, West Side, and Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls |
|---|---|---|---|---|
| | | preventing contact between surface water and contaminated sediment, and (3) reduce of the flux of dissolved contaminants into the water column.<br>• Placing sheet piling along sections of the shoreline and an active cap on the landward side of the sheet pile wall would: (1) reduce and control potential human health and ecological risks associated with contaminated sediment, (2) prevent erosion of contaminated sediment and embankment soil into the adjacent marine area, (3) improve surface water quality by preventing contact between surface water and contaminated sediment and embankment soil, and (4) reduce of the flux of dissolved contaminants into the water column. | | |
| Magnitude of residual risk | The magnitude of residual risks essentially remains the same. | Dredged sediment would be removed and transferred to an offsite landfill, and no residual risk would be associated with those materials. Residual risk would be associated with sediment that could not be removed by dredging; however, this risk would be mitigated with sediment capping and shoreline measures, and the RAOs would still be met. | Same as Alternative 2; however, this alternative would provide an incrementally lower level of residual risk because more sediment would be dredged and removed from the site. | Same as Alternative 2 (and 3); however, this alternative would provide a lower level of residual risk because all areas would be dredged (i.e., contaminated sediment in the Northern Head would be dredged rather than capped). This alternative would not depend on institutional controls and long-term monitoring to maintain cap integrity and performance in the Northern Head area of the channel. |
| Adequacy and reliability of controls | Does not include any controls for exposures or long-term management measures. | • Dredging:<br>- Mechanical dredging is an established technology and would be implemented to meet the performance specifications for the removal component of the alternative.<br>- Physical surveys would be conducted to confirm that removal depths were achieved. Confirmation samples would be collected to confirm that cleanup goals were met.<br>• Capping:<br>- Capping is an established technology and would be designed, constructed, and maintained in accordance with the specifications established for long-term isolation of the contaminated sediment and reduction of dissolved contaminants into the water column.<br>- Capping performance would be contingent upon enforcement of institutional controls and long-term monitoring and maintenance to assure cap integrity.<br>- Long term monitoring would be performed to assure sheet piling integrity.<br>- Physical surveys and the collection of samples would be needed to assess cap layer thickness, cap performance and integrity, contaminant movement, and/or recontamination concerns.<br>- Cap repairs would be performed as needed.<br>• Sheet piling:<br>- Sheet piling is an established engineering control and would be installed as part of the shoreline measures to prevent erosion of contaminated sediment and embankment soil into the adjacent marine area.<br>- Sheet piling repairs would be performed as needed.<br>• Disposal in an offsite landfill is an established means of disposal for contaminated sediment. Offsite landfill disposal would provide adequate long-term controls for the dredged sediment. | Same as Alternative 2 | Same as Alternative 2 (and 3), except capping would not be performed in the Northern Head under this alternative. Capping would only be implemented as part of the source control measures along portions of the shoreline. |
| **Reduction of toxicity, mobility, or volume through treatment** | Alternative does not include a treatment component. | • Dredged sediment would be treated onsite by dewatering and/or solidification/stabilization to reduce leachability of contaminants. | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |
| Reduction in toxicity, mobility, or volume through treatment | | • Dredging does not reduce toxicity, mobility, or volume through treatment.<br>• Reduction in contaminant mobility would be achieved through the active layer of the cap (activated carbon) by immobilizing sediment bound and dissolved phase contaminants. | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |

TABLE 6-2
**Detailed Evaluation of Alternatives**
*United Heckathorn Superfund Site, Richmond, California*

| Summary of Alternatives | Alternative 1<br>No Action | Alternative 2<br>Dredge East Side and West Side, Cap Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-Term Monitoring, and Institutional Controls | Alternative 3<br>Dredge East Side, West Side, and Portion of Northern Head, Cap Portion of Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls | Alternative 4<br>Dredge East Side, West Side, and Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls |
|---|---|---|---|---|
| | | • Onsite treatment of the dredged sediment would include dewatering and/or solidification/stabilization to reduce leachability of the sediment-bound contaminants ultimately to be placed in an offsite landfill. | | |
| Irreversibility | | Solidification/stabilization would be considered irreversible if the material is placed into a controlled environment (i.e., permitted landfill). | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |
| Type and quantity of treatment residuals and associated risks | | Offsite disposal would not result in treatment residuals other than solidified sediment that would be disposed into a landfill. Residual risks would low because the material would be contained in a controlled environment (i.e., permitted landfill). | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |
| **Short-term effectiveness** | No construction activities are performed; therefore, this alternative would not have any adverse short-term effects that could pose risk to the community, workers, or the environment. | There would be a risk of some adverse short-term impacts to human health and the environment during the construction period due to resuspension of sediment, however these potential risks can generally be mitigated and controlled through industry standard BMPs. | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |
| Risks to community, workers, and the associated controls | | • Potential risks to the community would include increased levels of traffic, dust, noise, and odors during the dredging, capping, and handling of contaminated sediment. Engineering controls and BMPs can mitigate most potential risks and would include the following:<br>- Access to the active work and support zones would be prohibited.<br>- Notification of schedule for remedy implementation would be provided to the property owners and tenants.<br>- Dust, noise, and odor levels would be monitored.<br>- Work periods may be restricted to specific timeframes for especially noisy operations (e.g., sheet pile installation).<br>• Potential risks to workers would include physical hazards associated with general construction, potential exposure to and direct contact with dredged sediment, surface water, noise, odors, dust, and vapors. These would be mitigated through actions including the following:<br>- Engineering controls and BMPs<br>- Compliance with appropriate health and safety plans and site management plans<br>- Use of appropriate personal protective equipment | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |
| Environmental Impacts of Remedy and Controls | | Short-term environmental effects during implementation may include turbidity increases within the channel and releases of some sediment-associated contamination, resulting in potential loss of benthic community in the short-term. However, these impacts can generally be mitigated and controlled through industry standard BMPs including turbidity and water column monitoring, silt curtains, and use of an enclosed environmental clamshell bucket for dredging. | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |
| Duration of short-term risks | | The duration of the short-term risks would be the time required to complete the dredging, capping (Northern Head), and shoreline measures (sheet piling and capping) and remedial action objectives are met, which is estimated to be less than 1 year. | The duration of the short-term risks would be the time required to complete the dredging, capping (Northern Head), and shoreline measures (sheet piling and capping) and remedial action objectives are met, which is estimated to be less than 1 year. | The duration of the short-term risks would be the time required to complete the dredging and shoreline measures (sheet piling and capping) and remedial action objectives are met, which is estimated to be less than 1 year. |
| **Implementability** | Not applicable; no actions are taken under this alternative. | Alternative would be implementable from both technical and administrative standpoints. | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |
| Technical feasibility | | • Alternative would be technically implementable and dredging and capping are established, field-proven technologies; however, pilot testing may be required to determine the most suitable cap placement methods in the presence of obstructions. | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |

TABLE 6-2
**Detailed Evaluation of Alternatives**
*United Heckathorn Superfund Site, Richmond, California*

| Summary of Alternatives | Alternative 1<br>No Action | Alternative 2<br>Dredge East Side and West Side, Cap Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-Term Monitoring, and Institutional Controls | Alternative 3<br>Dredge East Side, West Side, and Portion of Northern Head, Cap Portion of Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls | Alternative 4<br>Dredge East Side, West Side, and Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls |
|---|---|---|---|---|
| | | • Dredging and capping would be performed from barges using standard construction equipment.<br>• The short- and long-term monitoring requirements can be performed using standard practices and technologies. | | |
| Administrative feasibility | | • Alternative would require coordination between regulatory agencies, potentially responsible parties, property owners along the channel, and other stakeholders.<br>• Permanent institutional controls would also be required for capping in the Northern Head and for the shoreline measures.<br>• Commercial boating access would be restricted in the capped areas of the Northern Head. | Same as Alternative 2 | Same as Alternative 2 (and 3), except capping would not be performed in the Northern Head area under this alternative. |
| Availability of services and materials | | • Equipment and specialists required for the sheet piling installation, dredging, and capping would be commercially available.<br>• Commercial suppliers of capping amendments (activated carbon and/or modified clay) have been identified.<br>• Offsite landfill facilities that can accept the dredged sediment have been identified. | Same as Alternative 2 (and 4) | Same as Alternative 2 (and 3) |
| **Cost ($ Million)** | ___ | 21.7 | 22.6 | 22.7 |

Notes:
ARAR = applicable or relevant and appropriate requirement
BMP = best management practice
cy =cubic yards
$ft^2$ = square feet
NA = not applicable
RAO = remedial action objective

TABLE 6-3
**Comparative Analysis of Alternatives**
*United Heckathorn Superfund Site, Richmond, California*

| CERCLA Evaluation Criteria[1] | Threshold Criteria | | Balancing Criteria | | | | |
|---|---|---|---|---|---|---|---|
| | Overall Protection of Human Health and the Environment | Compliance with ARARs | Long-term Effectiveness and Permanence | Reduction of Toxicity, Mobility, or Volume through Treatment | Short-term Effectiveness | Implementability | Cost ($ Million) |
| **Alternative 1**<br>No Action | ○ | ○ | ○ | ○ | ● | ● | — |
| **Alternative 2 – Dredge East Side and West Side, Cap Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls**<br>• Dredge: 100% of East and West Side areas of Lauritzen Channel (58,000 $yd^3$)<br>• Active cap (activated carbon or modified clay): 100% of Northern Head Area of Lauritzen Channel (1.4 acres / 61,000 $ft^2$) | ● | ● | ◔ | ◑ | ◔ | ● | 21.7 |
| **Alternative 3 - Dredge East Side, West Side, and Portion of Northern Head, Cap Portion of Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls**<br>• Dredge: 100% of East and West Side areas of Lauritzen Channel and 75% of Northern Head area of Lauritzen Channel (64,000 $yd^3$)<br>• Active cap (activated carbon or modified clay): 25% Northern Head area of Lauritzen Channel (0.4 acre / 17,000 $ft^2$) | ● | ● | ◔ | ◑ | ◔ | ● | 22.6 |
| **Alternative 4 - Dredge East Side, West Side, and Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls**<br>• Dredge: 100% of East and West Side areas of Lauritzen Channel and 100% of Northern Head area of Lauritzen Channel (66,000 $yd^3$) | ● | ● | ● | ◑ | ◔ | ● | 22.7 |

**Legend:**

**Threshold Criteria:**

○ Does not satisfy criterion

● Satisfies criterion

**Balancing Criteria:**

○ Low

◔ Low to Moderate

◑ Moderate

◕ Moderate to High

● High

**Notes:**

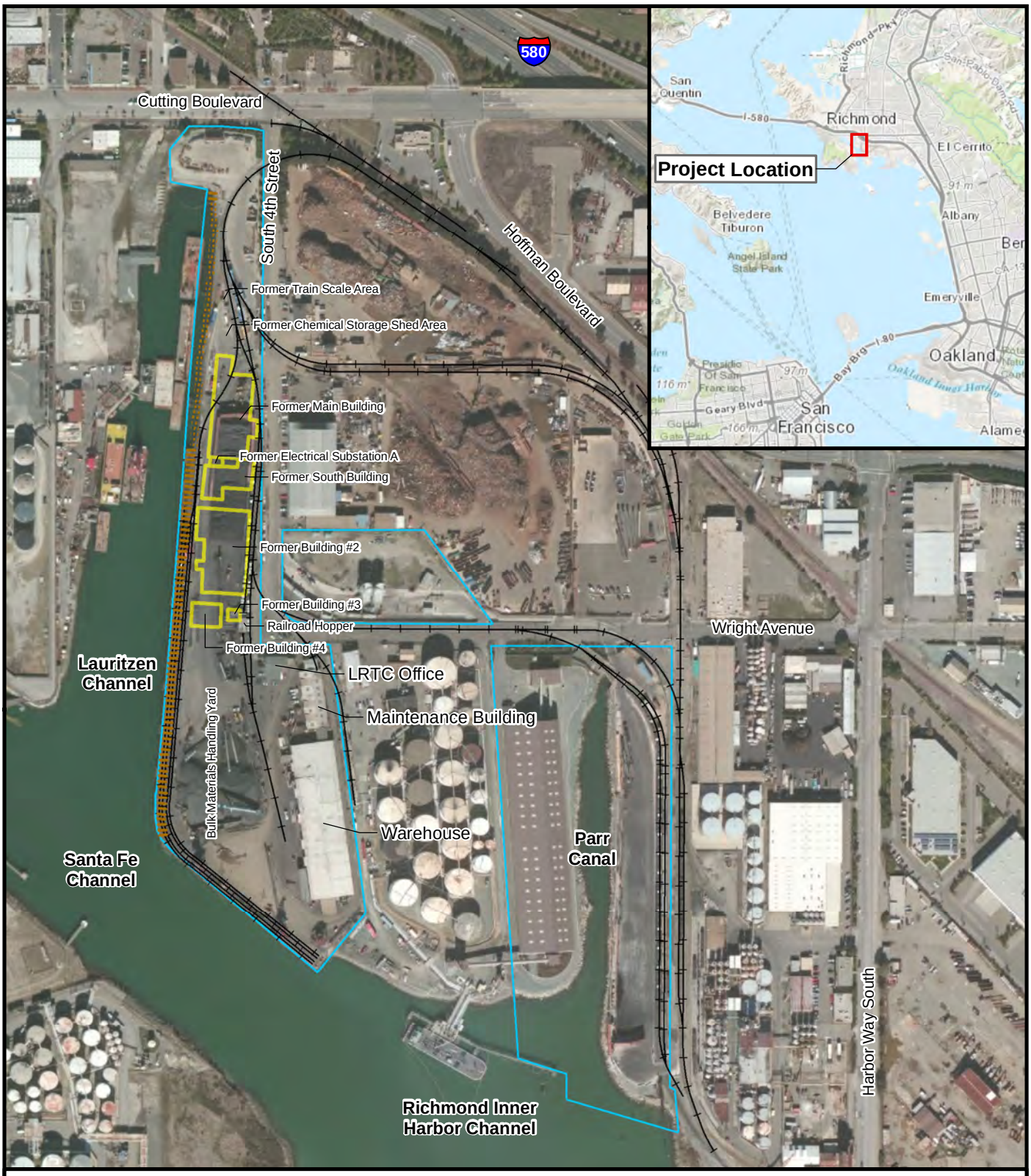
[1] Elements common to all alternatives (except no action), such as the source control measures, long-term monitoring, and institutional controls are detailed in Tables ES-1 and 6-2.

CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act

$yd^3$ = cubic yards

$ft^2$ = square feet

# Figures




**LEGEND**

- Former Pier Pilings
- Pier Pilings
- Railroad
- Former United Heckathorn Buildings
- LRTC Property Line

0 175 350 700 Feet

N

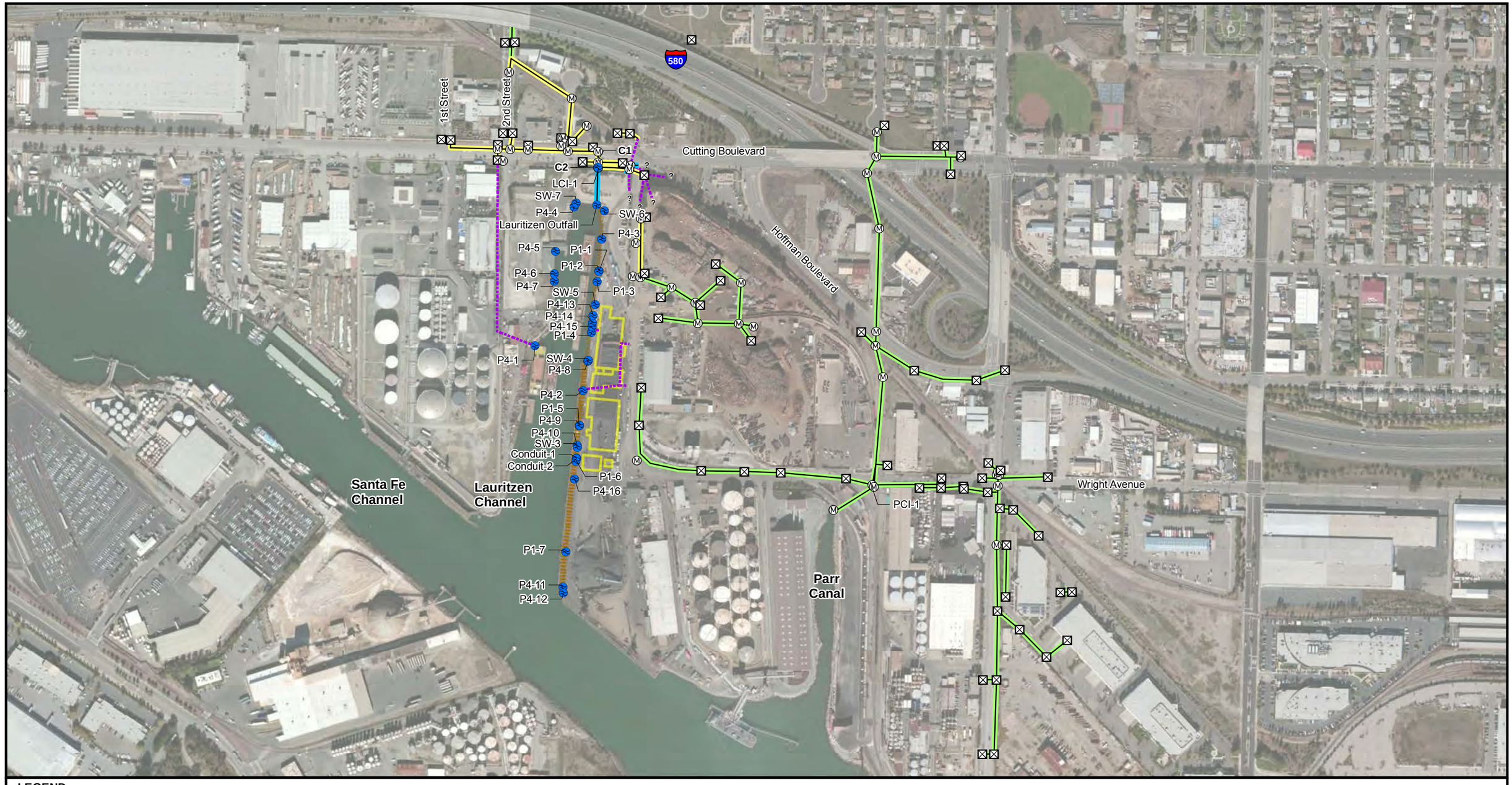
Imagery: October 26, 2010

**FIGURE 1-1**
**Site Location Map**

*United Heckathorn Superfund Site*
*Richmond, California*

CH2MHILL

BAO \\ZINFANDEL\PROJ\USENVIRONMENTALPROTE\340138UHFS\GIS\EPA_UNITED_HECKATHORN\MAPFILES\2014\FFS\FIGURE_1-1_SITELOCATION.MXD JCARR3 11/11/2014 7:49:52 AM




**LEGEND**

- Outfall Location
- Catch Basin
- Manhole
- Pier Pilings
- Former Pier Pilings
- Former Buildings

**Stormwater Mains**

- Assumed Hydraulically Connected - To Be Verified
- Hydraulically Connected
- Hydraulically Isolated
- Video Surveyed
- Unknown Status

Notes:
1. Manhole and catch basin system locations obtained from the City of Richmond, CA.
2. Pipes with "P4" and "SW" in the sample name were identified during the site survey activities conducted on November 29 and December 12, 2012.

N

0 250 500 1,000 Feet

Imagery: October 26, 2010

**FIGURE 1-2**
**Stormwater System Map**
*United Heckathorn Superfund Site*
*Richmond, California*

CH2MHILL

BAO \\ZINFANDEL\PROJ\USENVIRONMENTALPROTE\340138UHFS\GIS\EPA_UNITED_HECKATHORN\MAPFILES\2014\FFS\FIGURE_1-2_STORMWATERSYSTEM.MXD JCARR3 11/11/2014 9:55:38 AM

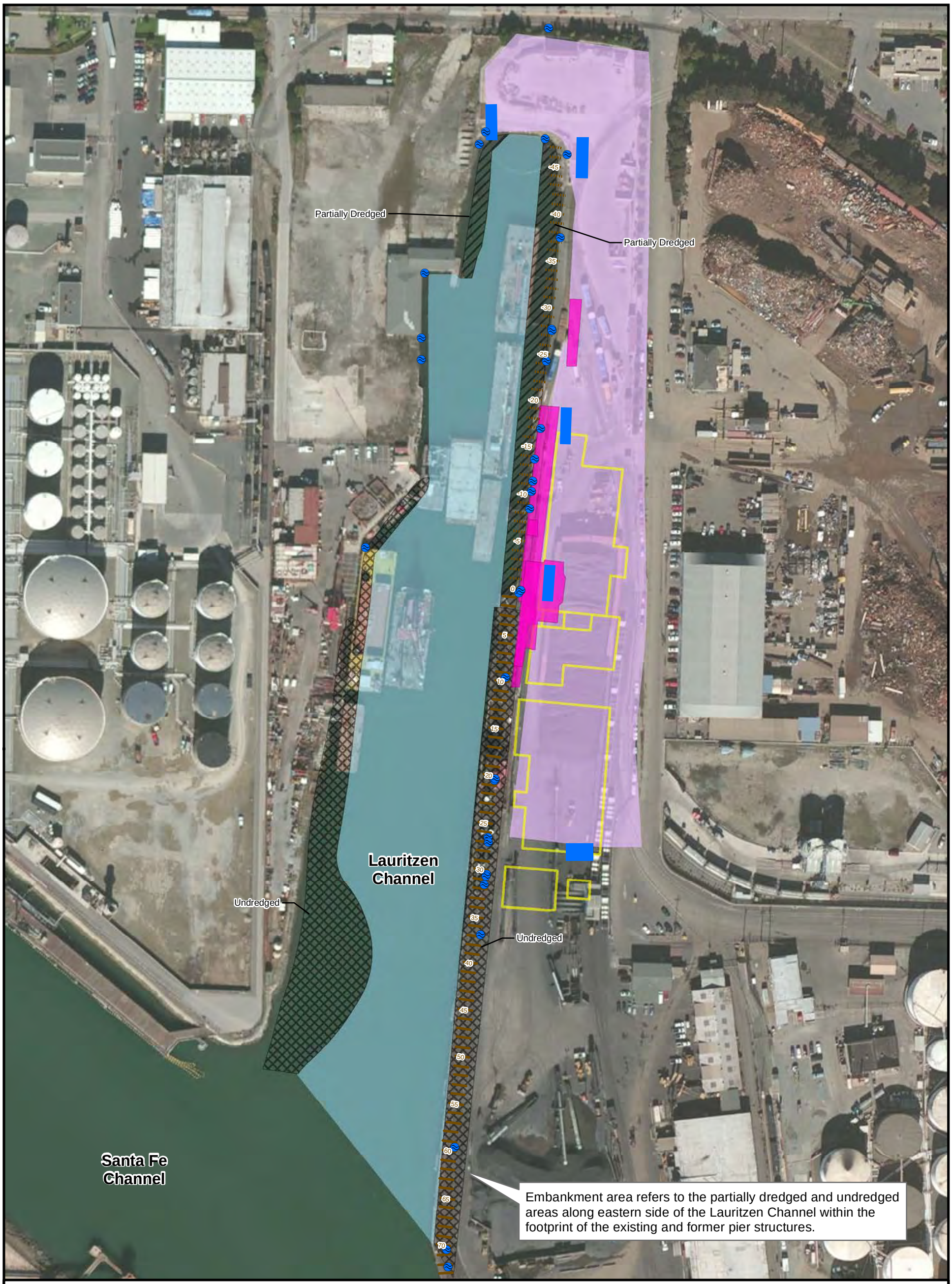



**FIGURE 1-3**
**Dredged Areas**
*United Heckathorn Superfund Site*
*Richmond, California*

CH2MHILL

\\Zinfandel\proj\USEnvironmentalProte\340138UHFS\GIS\EPA_United_Heckathorn\MapFiles\2014\FFS\Figure_1-3_DredgeAreas.mxd

**LEGEND**

- Biomonitoring Locations Established in ROD
- Supplemental Sampling Locations
- Former Buildings
- Former Excavation Area (1990 - 1991)

0 250 500 1,000 Feet

N

**Note:**
Table 2-1 summarizes the biomonitoring program by year.

Imagery: October 26, 2010

**FIGURE 2-1**
**Biomonitoring Locations**
*United Heckathorn Superfund Site, Richmond, California*

**LEGEND**

- Outfall Location
- Former Pier Pilings
- Pier Pilings
- Former Buildings
- Approximate Extent of Upland Cap
- Sampling Grid
- Dredged Area
- Partially Dredged Area
- Undredged Area

**Result Concentration (µg/kg)**

- 0 - 590 (1994 Remediation Goal)
- 591 - 2,950 (5 x RG)
- 2,951 - 29,500 (50 x RG)
- 29,501 - 295,000 (500 x RG)
- 295,001 - >590,000 (1,000 x RG)

**Sample Depth**

- 0 - 6"
- 7" - 2 feet
- 2.1 - 4 feet
- > 4 feet

**Sample Year**

- 1999
- 2003
- 2007

Results reported by Stanford et al. (2007). ∑DDT reported values are the sum of the 2,4' and 4,4' isomers of DDT and DDD and the 4,4' isomer of DDE and DDMU

Remediation goals noted are from the 1994 Record of Decision

N

0 30 60 120

Feet

Imagery: October 26, 2010

# FIGURE 2-2
# DDT Results in the Lauritzen Channel (Northern End)

*United Heckathorn Superfund Site*
*Richmond, California*

**LEGEND**

- Outfall Location
- Former Pier Pilings
- Pier Pilings
- Former Building
- Approximate Upland Cap Area
- Sampling Grid
- Dredged Area
- Undredged Area

**Sample Depth**

- 0 - 6"
- 7" - 2 feet
- 2.1 - 4 feet
- > 4 feet

**Sample Year**

- 1999
- 2003
- 2007

**Result Concentration (µg/kg)**

- 0-590 (1994 Remediation Goal)
- 591-2,950 (5 x RG)
- 2,951 - 29,500 (50 x RG)
- 29,501 - 295,000 (500 x RG)
- 295,001 - >590,000 (1,000 x RG)

Results reported by Stanford. ∑DDT reported values are the sum of the 2,4' and 4,4' isomers of DDT and DDD and the 4,4' isomer of DDE and DDMU.

0 45 90 180 Feet

N

Remediation goals noted are from the 1994 Record of Decision

Imagery: October 26, 2010

# FIGURE 2-3
# DDT Results in the Laurtizen Channel (Southern End)

*United Heckathorn Superfund Site*
*Richmond, California*

CH2MHILL

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EMB13-01
EMB13-03
EMB13-02
SD13-02
SD13-01
SD13-03
EMB13-05
SD13-04
SD13-06
EMB13-04
SD13-05
SD13-07
SD13-09
SD13-08
SD13-10
SD13-11
SD13-12
-10
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-20
SD13-13
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SD13-31
SD13-32
SD13-33
SD13-34
-40
-40
SD13-35
SD13-36
SD13-37
SD13-38
SD13-39
-35
-30
-25
-20
-15
-10
Santa Fe
Channel
-40
SD13-40
-30
SD13-41

**LEGEND**

- Sediment Grab Sample Location
- Vibracore Sample Location
- Embankment Soil Grab Sample Location

**Bathymetry**

1 ft

44 ft

-40 Bathymetric Contour (5-foot Interval)

Contour Depth Label

- LRTC Stormwater Outfalls
- Municipal Stormwater Outfall
- Other Pipe and Seep Locations
- Former Buildings

**Channel and Shoreline Areas**

- Northern Piles Area
- Southern Piles Area
- LRTC Pier Area
- North End Area
- East Side
- Northern Head
- West Side

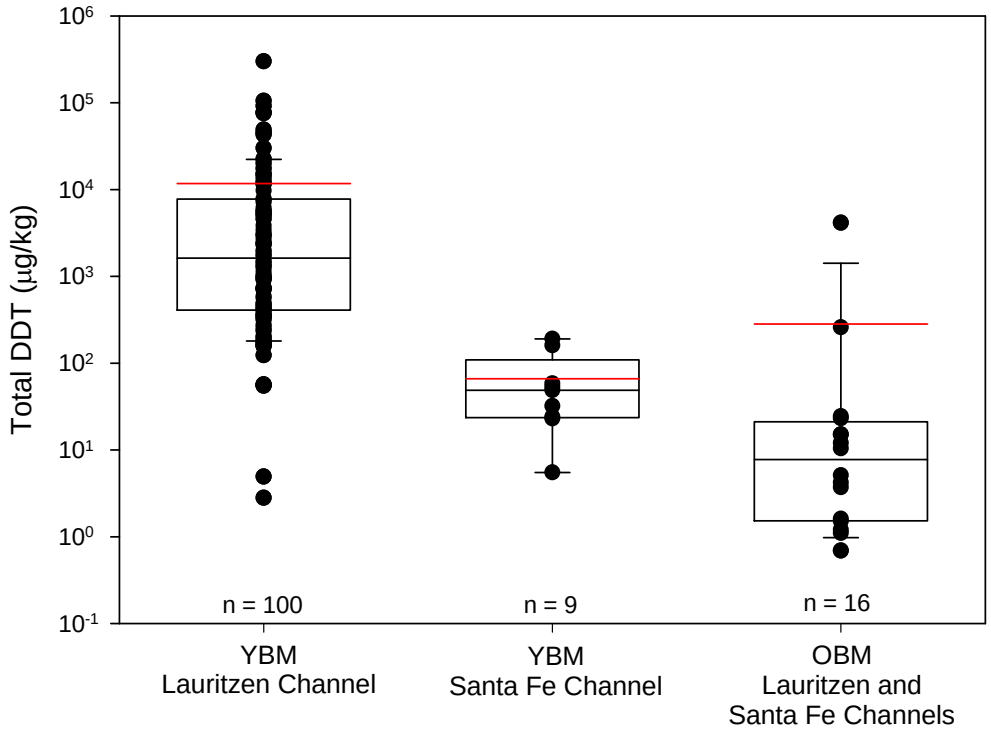
N

0 60 120 240 Feet

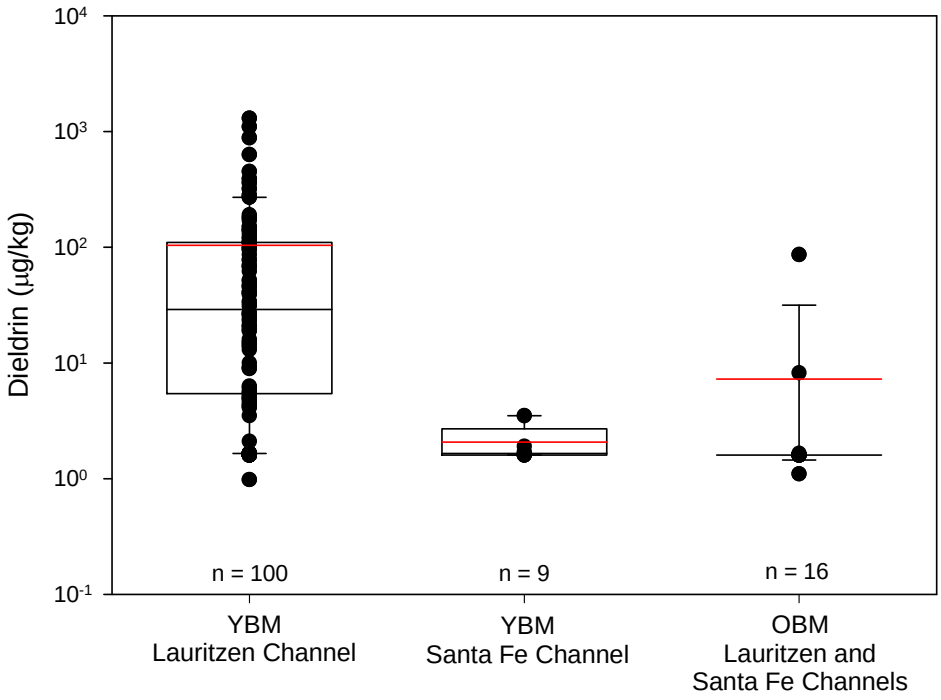
Imagery: October 26, 2010

**FIGURE 3-1**
**2013 Sediment Sample Locations**
*United Heckathorn Superfund Site*
*Richmond, California*

CH2MHILL




**a. Total DDT**

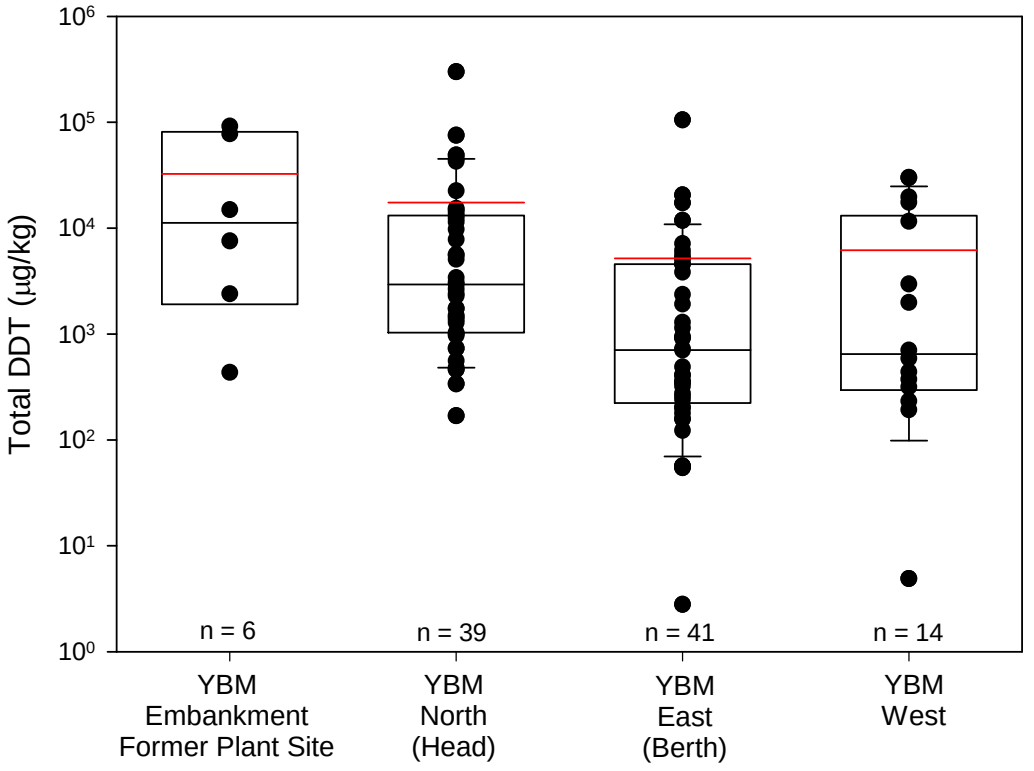



**b. Dieldrin**

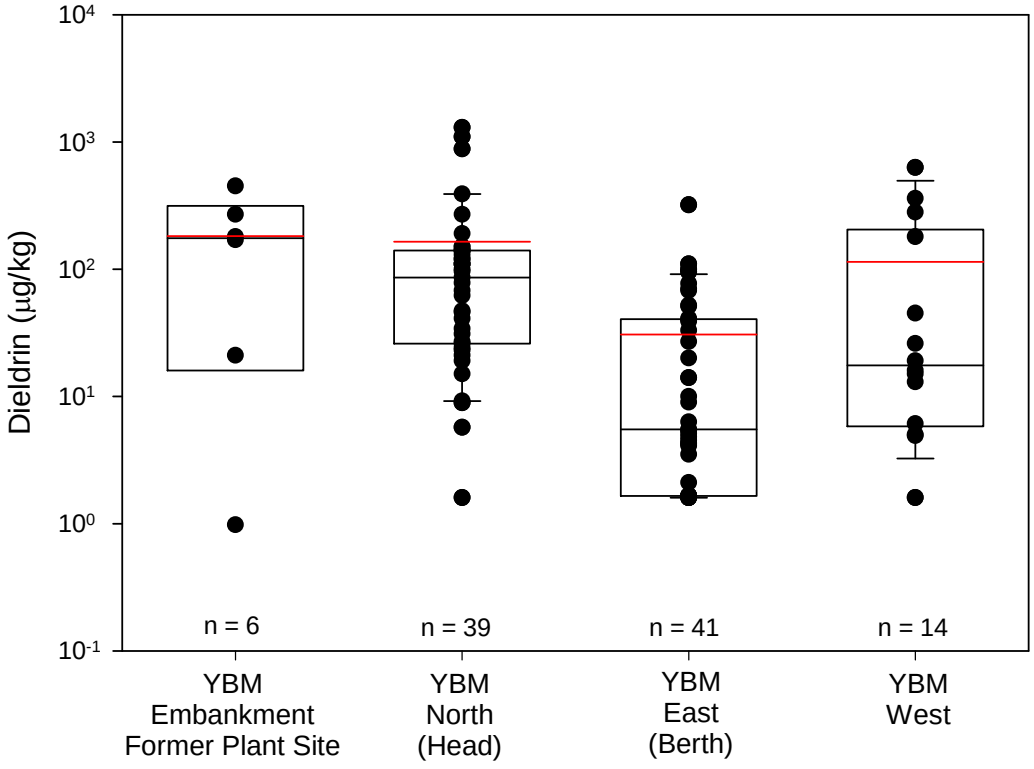
Notes:
The edges of the box are the 25th and 75th percentiles; the black line is the median; the red line is the mean; whiskers are the 10th and 90th percentiles. Total DDT is the sum of the detected 2,4'- and 4,4'- isomers of DDD, DDE, and DDT. For dieldrin, a value of ½ the detection limit is used for non-detects.

**FIGURE3-2**
**Box and Whisker Plots of Total DDT and Dieldrin in Sediment**
*United Heckathorn Superfund Site*
*Richmond, California*

CH2MHILL



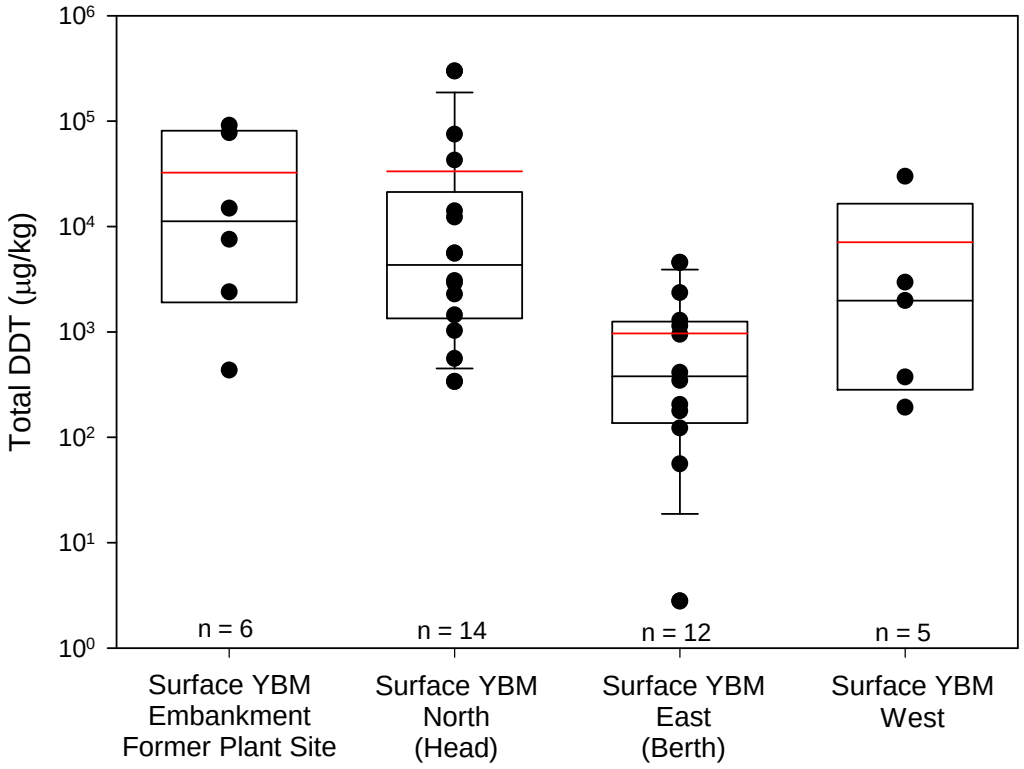

**a. Total DDT**



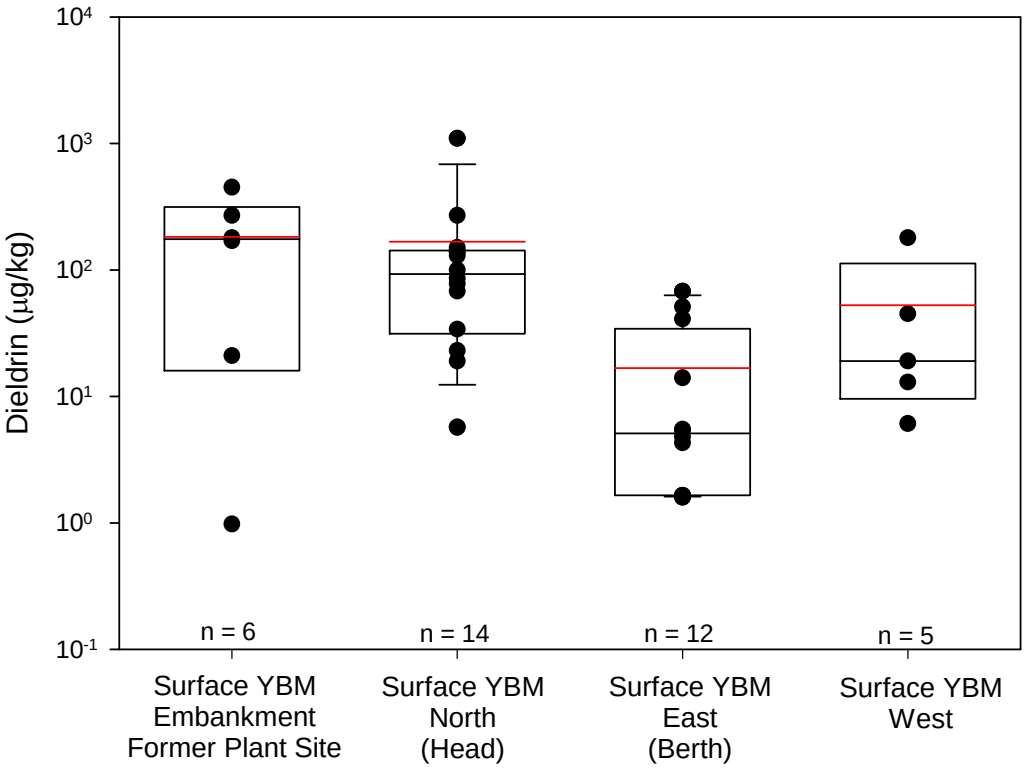

**b. Dieldrin**

Notes:
The edges of the box are the 25th and 75th percentiles; the black line is the median; the red line is the mean; whiskers are the 10th and 90th percentiles. Total DDT is the sum of the detected 2,4'- and 4,4'- isomers of DDD, DDE, and DDT. For dieldrin, a value of ½ the detection limit is used for non-detects.

**FIGURE 3-3**
**Box and Whisker Plots of Total DDT and Dieldrin in Lauritzen Channel Sediment by Subarea**
*United Heckathorn Superfund Site*
*Richmond, California*




**a. Total DDT**

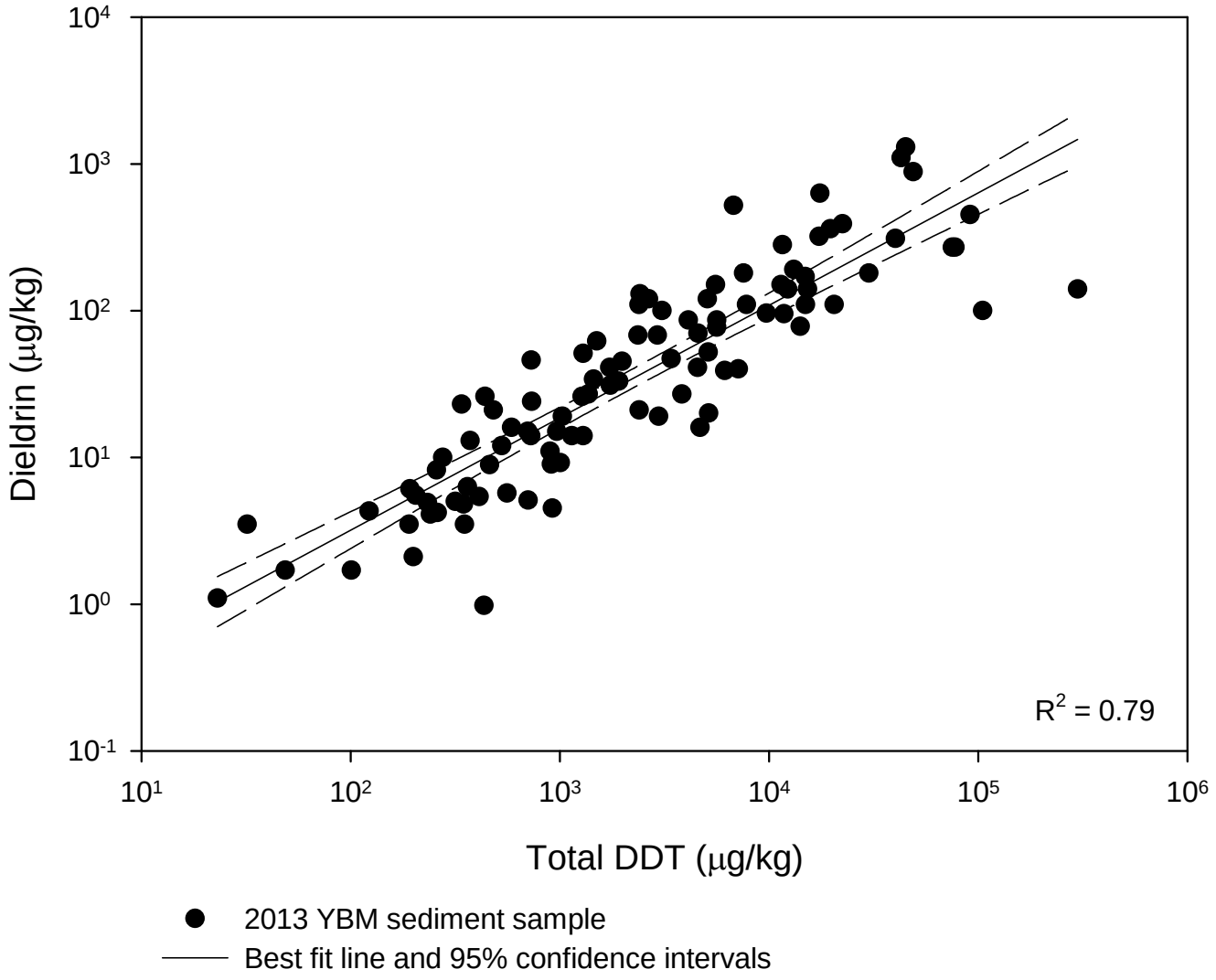



**b. Dieldrin**

Notes:
The edges of the box are the 25th and 75th percentiles; the black line is the median; the red line is the mean; whiskers are the 10th and 90th percentiles. Total DDT is the sum of the detected 2,4'- and 4,4'- isomers of DDD, DDE, and DDT. For dieldrin, a value of ½ the detection limit is used for non-detects.

**FIGURE 3-4**
**Box and Whisker Plots of Total DDT and Dieldrin in Lauritzen Channel Surface Sediment by Subarea**
*United Heckathorn Superfund Site*
*Richmond, California*

CH2MHILL




Notes:
Total DDT is the sum of the detected 2,4'- and 4,4'-isomers of DDD, DDE, and DDT. For dieldrin, a value of ½ the detection limit is used for non-detects.

**FIGURE 3-5**
**Co-occurrence of Total DDT and Dieldrin in YBM**
*United Heckathorn Superfund Site*
*Richmond, California*

Embankment area refers to the partially dredged and undredged areas along eastern side of the Lauritzen Channel within the footprint of the existing and former pier structures.

0 100 200 400 Feet

N

**LEGEND**

- LRTC Stormwater Outfalls
- Municipal Stormwater Outfall
- Other Pipe and Seep Locations
- Former Pier Pilings
- Pier Pilings
- Former Buildings
- Dredged Area
- Partially Dredged Area
- Undredged Area

**Sediment Surface Maximum DDT Results**

- 0 - 10 µg/kg
- 10.1 - 100 µg/kg
- 101 - 300 µg/kg
- 301 - 500 µg/kg
- 501 - 1,000 µg/kg
- 1,001 - 2,000 µg/kg
- 2,001 - 5,000 µg/kg
- 5,001 - 10,000 µg/kg
- 10,001 - 20,000 µg/kg
- >20,000 µg/kg

Imagery: October 26, 2010

**Figure 3-6**
**Total DDT Concentration in Surface Samples (0 to 0.5 feet bss) from 2013 Sediment Locations**
*United Heckathorn Superfund Site*
*Richmond, California*

CH2MHILL

Embankment area refers to the partially dredged and undredged areas along eastern side of the Lauritzen Channel within the footprint of the existing and former pier structures.

0 100 200 400 Feet

N

**LEGEND**

- LRTC Stormwater Outfalls
- Municipal Stormwater Outfall
- Other Pipe and Seep Locations
- Former Pier Pilings
- Pier Pilings
- Former Buildings
- Dredged Area
- Partially Dredged Area
- Undredged Area

**Sediment Core Maximum DDT Results**

- 0 - 10 µg/kg
- 10.1 - 100 µg/kg
- 101 - 300 µg/kg
- 301 - 500 µg/kg
- 501 - 1,000 µg/kg
- 1,001 - 2,000 µg/kg
- 2,001 - 5,000 µg/kg
- 5,001 - 10,000 µg/kg
- 10,001 - 20,000 µg/kg
- >20,000 µg/kg

Imagery: October 26, 2010

**Figure 3-7**
**Maximum DDT Concentrations in All Sample Depths (0 to 6 feet bss) from 2013 Sediment Locations**
*United Heckathorn Superfund Site*
*Richmond, California*

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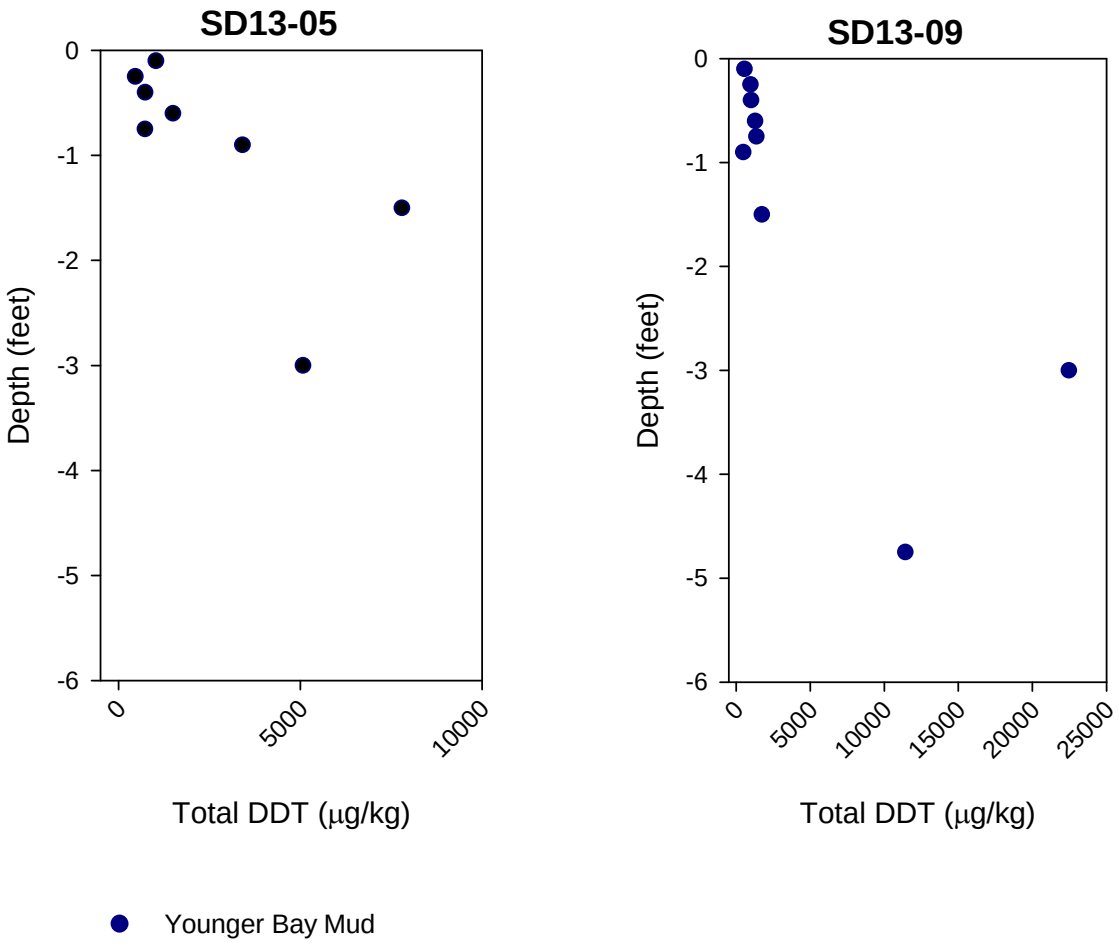


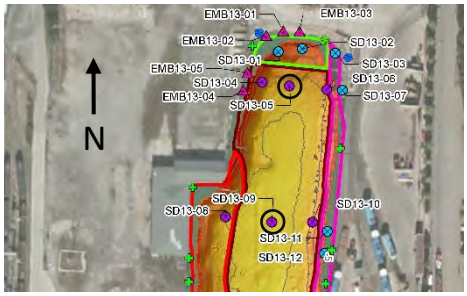


Locations 5 and 9 circled in inset above.

Notes:
Total DDT is the sum of the detected 2,4'- and 4,4'- isomers of DDD, DDE, and DDT.
The depth of each sample is the mid-point of the composite sample interval.
Coring locations are shown in Figure 3-1.

**FIGURE 3-8**
**Vertical Profile of Total DDT in Fine Interval Cores**
*United Heckathorn Superfund Site*
*Richmond, California*

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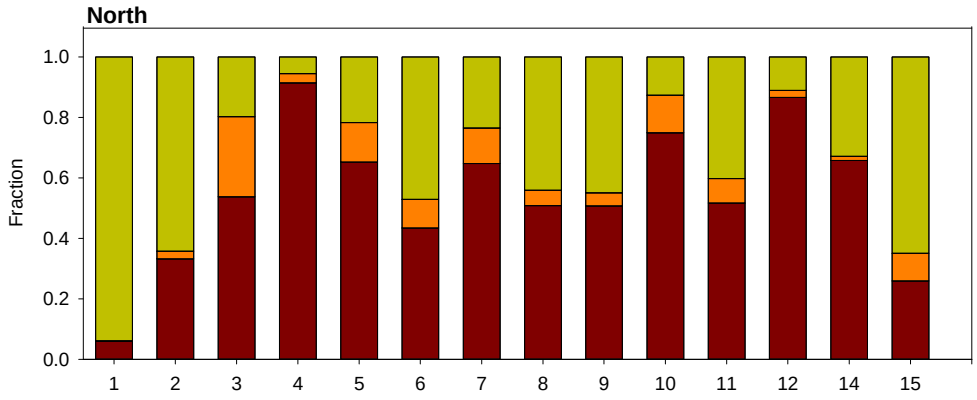


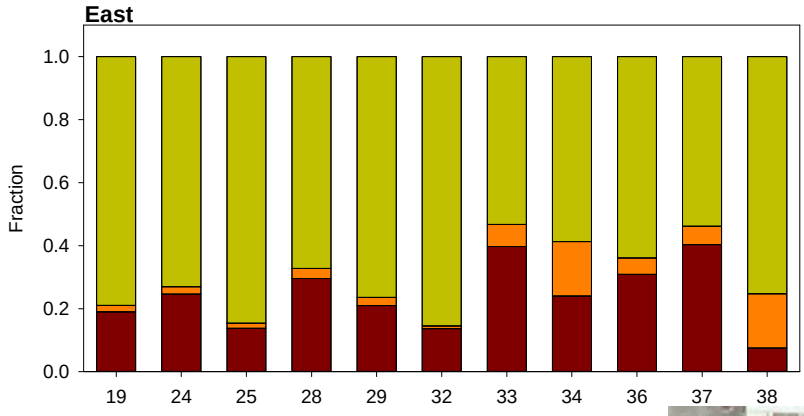


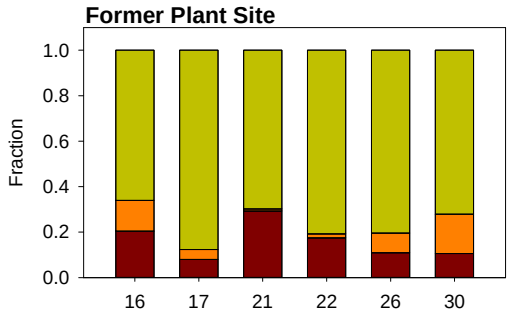


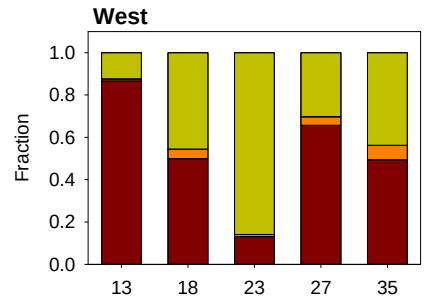


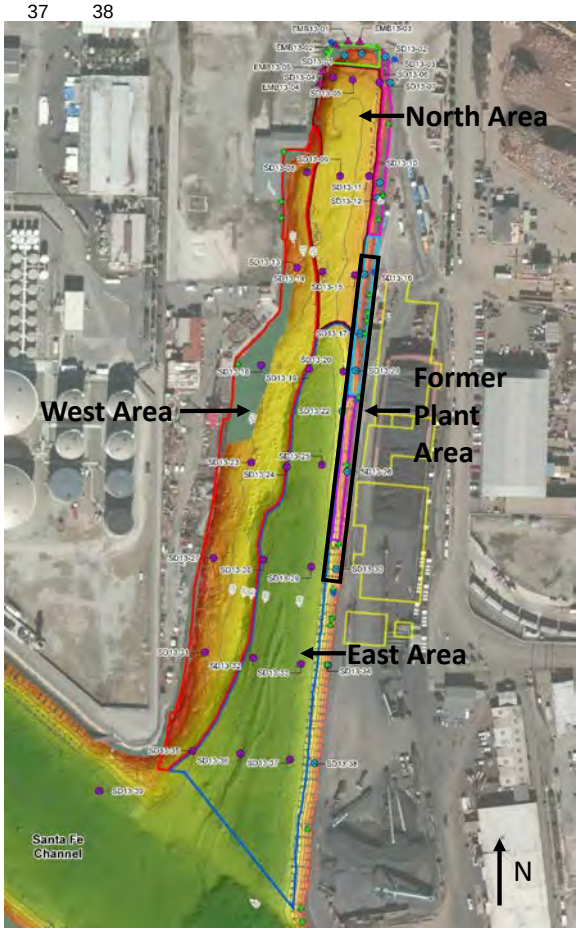


**Legend**

- 4,4'-DDD
- 4,4'-DDE
- 4,4'-DDT

The number under each bar is the location ID SD13-XX.

**FIGURE 3-9**
**Contributions of 4,4'-DDX Isomers in Lauritzen Channel Surface Sediment by Subarea**
*United Heckathorn Superfund Site*
*Richmond, California*

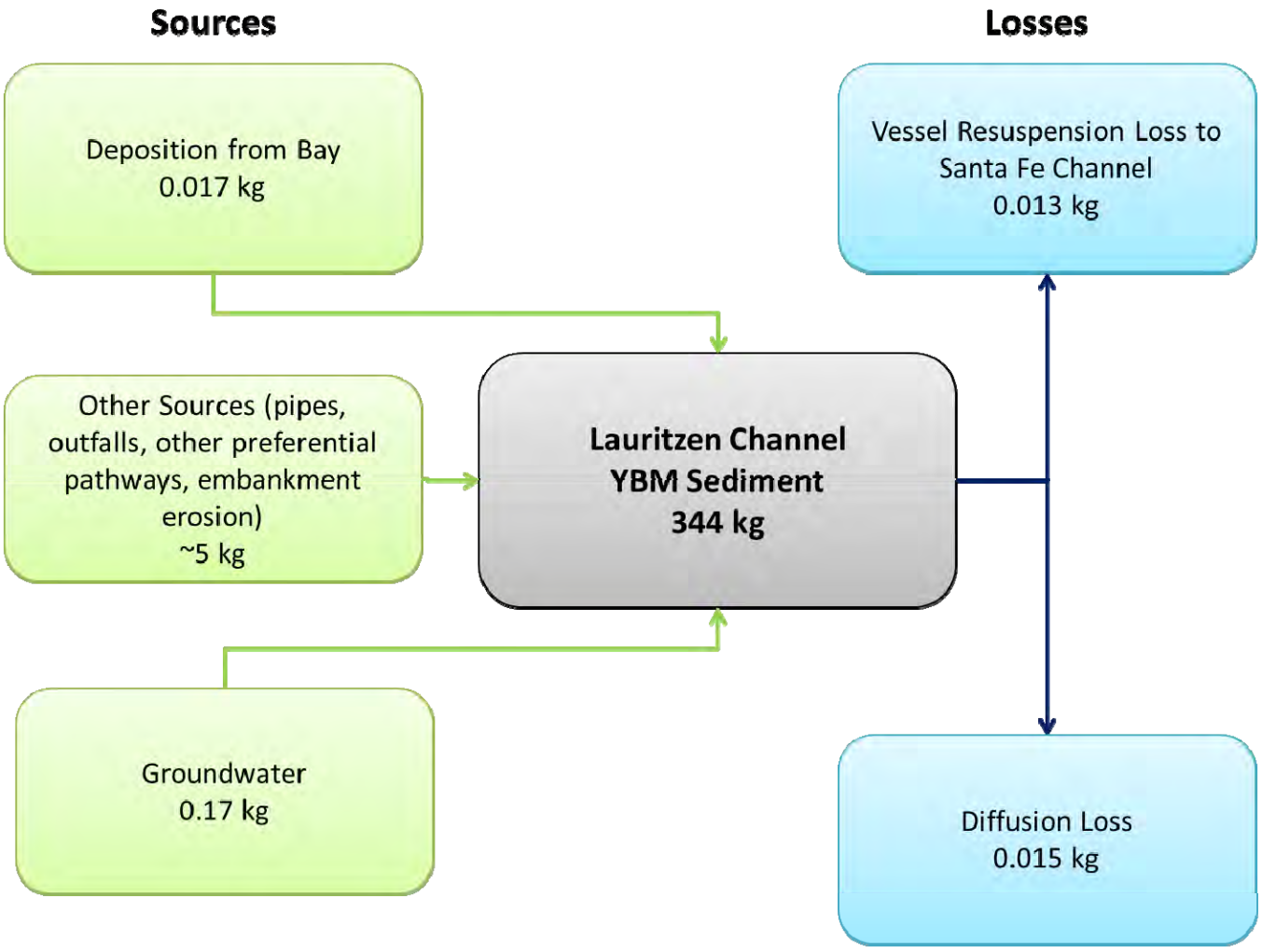


**FIGURE 3-10**
**Conceptual Diagram of Average Yearly Sources and Losses of DDT Mass to the Lauritzen Channel Sediment**
*United Heckathorn Superfund Site, Richmond, California*

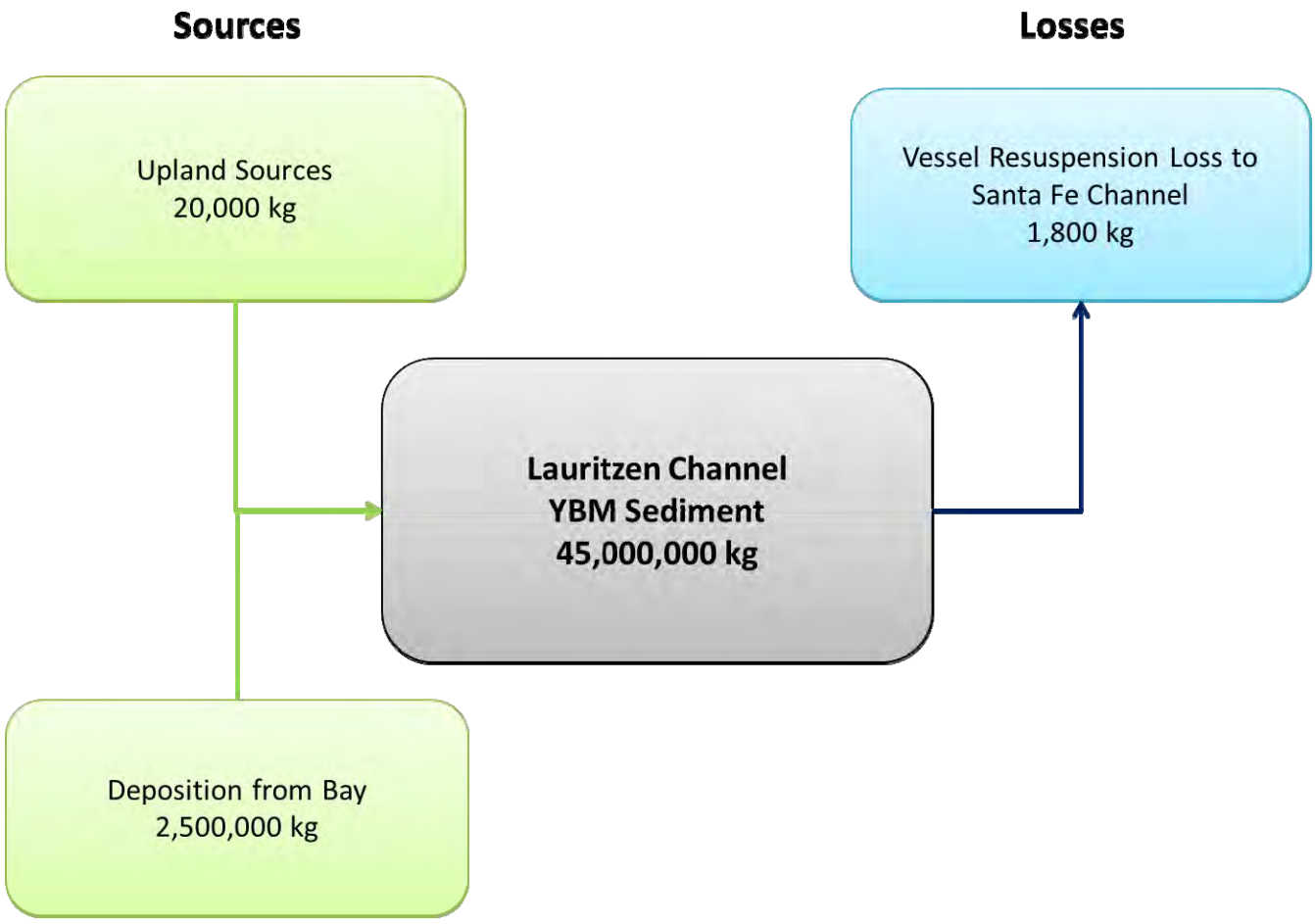


**FIGURE 3-11**
**Conceptual Diagram of the Sources and Losses to the Lauritzen Channel Sediment**
*United Heckathorn Superfund Site, Richmond, California*

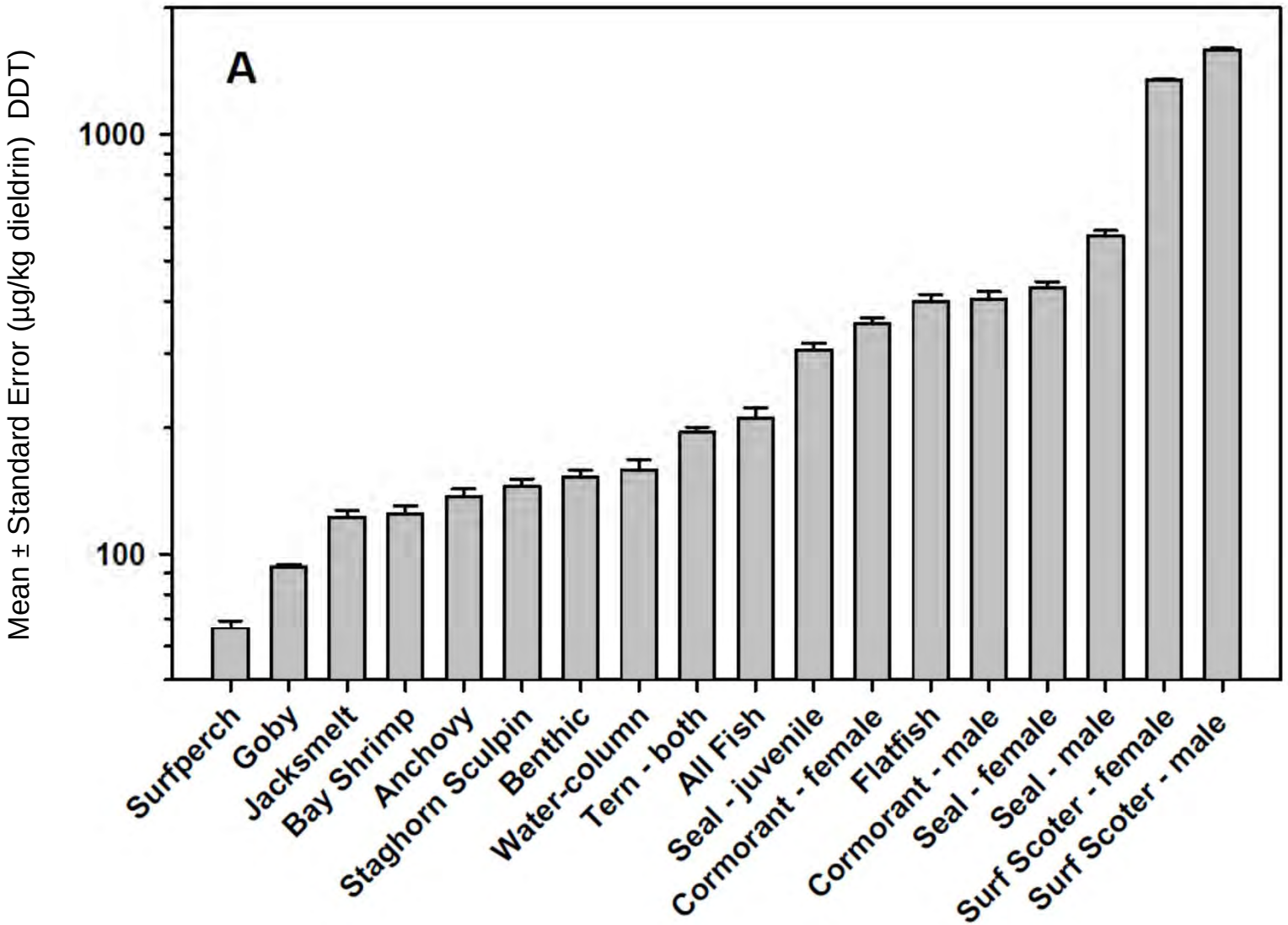


**FIGURE 4-1**
**Ecological Risk-based Concentrations for Dieldrin in Sediment**
*United Heckathorn Superfund Site*
*Richmond, California*

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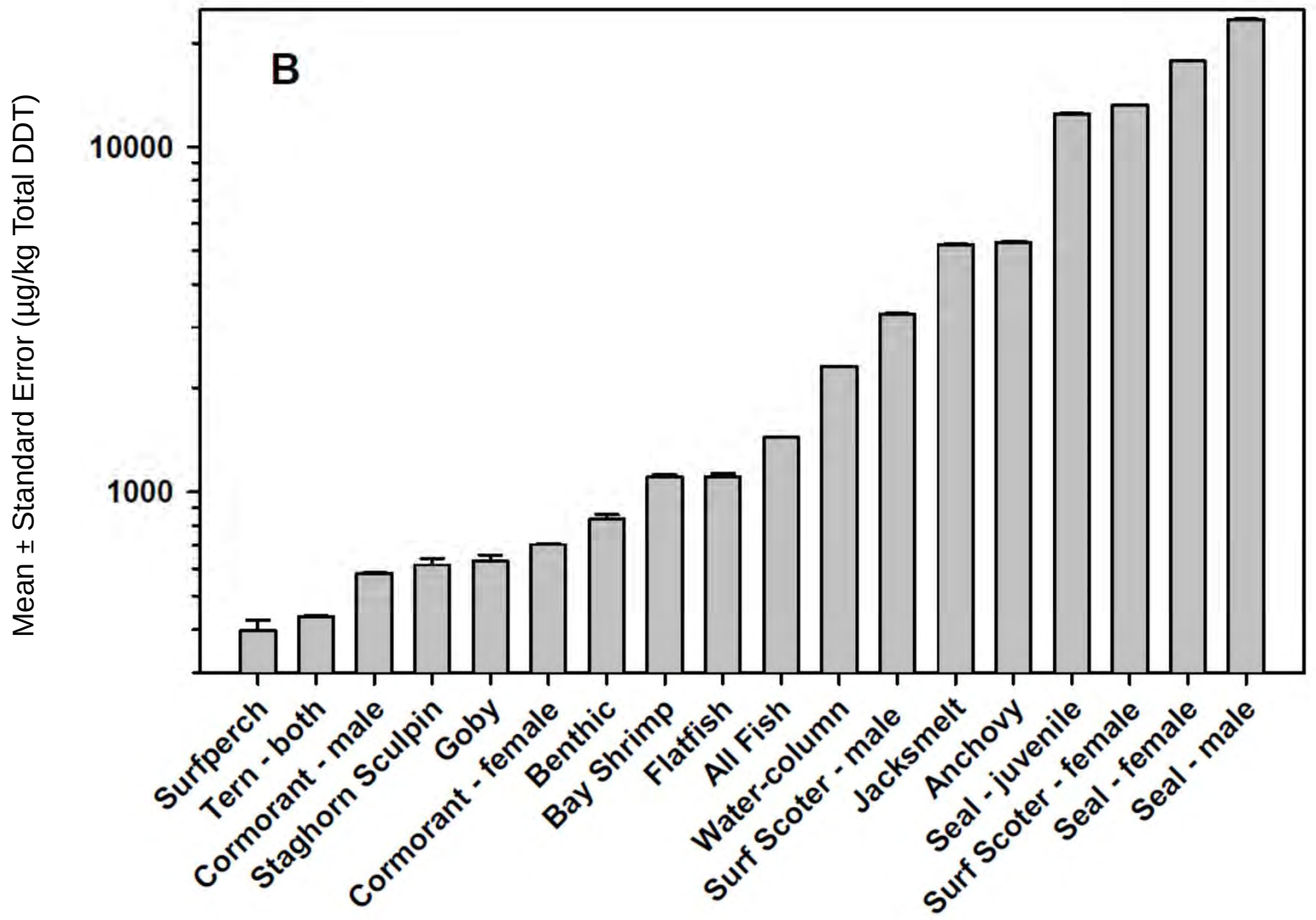


**FIGURE 4-2**
**Ecological Risk-based Concentrations for Total DDT in Sediment**
*United Heckathorn Superfund Site*
*Richmond, California*

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| Endpoint | Total DDT Sediment Concentration (µg/kg) |
|---|---|
| **Human Health** | |
| $1x10^{-6}$ ELCR | 0.74 |
| $1x10^{-5}$ ELCR | 23 |
| $1x10^{-4}$ ELCR | 730 |
| Noncancer Hazard HQ = 1 | 450 |
| Proposed human health $RBC_{sed}$ | 450 |
| **Ecological** | |
| Range of ecological RBCs | 400 – 24,000 |
| Proposed ecological $RBC_{sed}$ | 400 |
| **San Francisco Bay Ambient** | |
| Ambient threshold[1] | 7 |
| RMP Central Bay maximum | 30 |
| **Proposed Remediation Goal** | **400** |

Embankment area refers to the partially dredged and undredged areas along eastern side of the Lauritzen Channel within the footprint of the existing and former pier structures.

0 100 200 400 Feet

N

Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

**LEGEND**

- LRTC Stormwater Outfalls
- Municipal Stormwater Outfall
- Other Pipe and Seep Locations
- Former Pier Pilings
- Pier Pilings
- Former Buildings
- Dredged Area
- Partially Dredged Area
- Undredged Area

**Sediment Core DDT Results**

- < 7 µg/kg
- 8 - 23 µg/kg
- 24 - 200 µg/kg
- 200 - 400 µg/kg
- 400 - 600 µg/kg
- 600 - 1,000 µg/kg
- 1,000 - 5,000 µg/kg
- 5,000 - 10,000 µg/kg
- 10,000 - 20,000 µg/kg
- > 20,000 µg/kg

**Sample Depth**

- 0 - 0.5 feet
- 0.5 - 2 feet
- 2 - 4 feet
- > 4 feet

Imagery: October 26, 2010

**Notes**

1. From Gandesbery and Hetzel (1998) for sediments with greater than 40 percent fines.
2. Core profiles are provided in Appendix F
3. Number associated with each sampling location is the ID SD13-XX

**FIGURE 4-3**
**2013 DDT Results for Younger Bay Mud in the Lauritzen Channel**
***United Heckathorn Superfund Site***
***Richmond, California***

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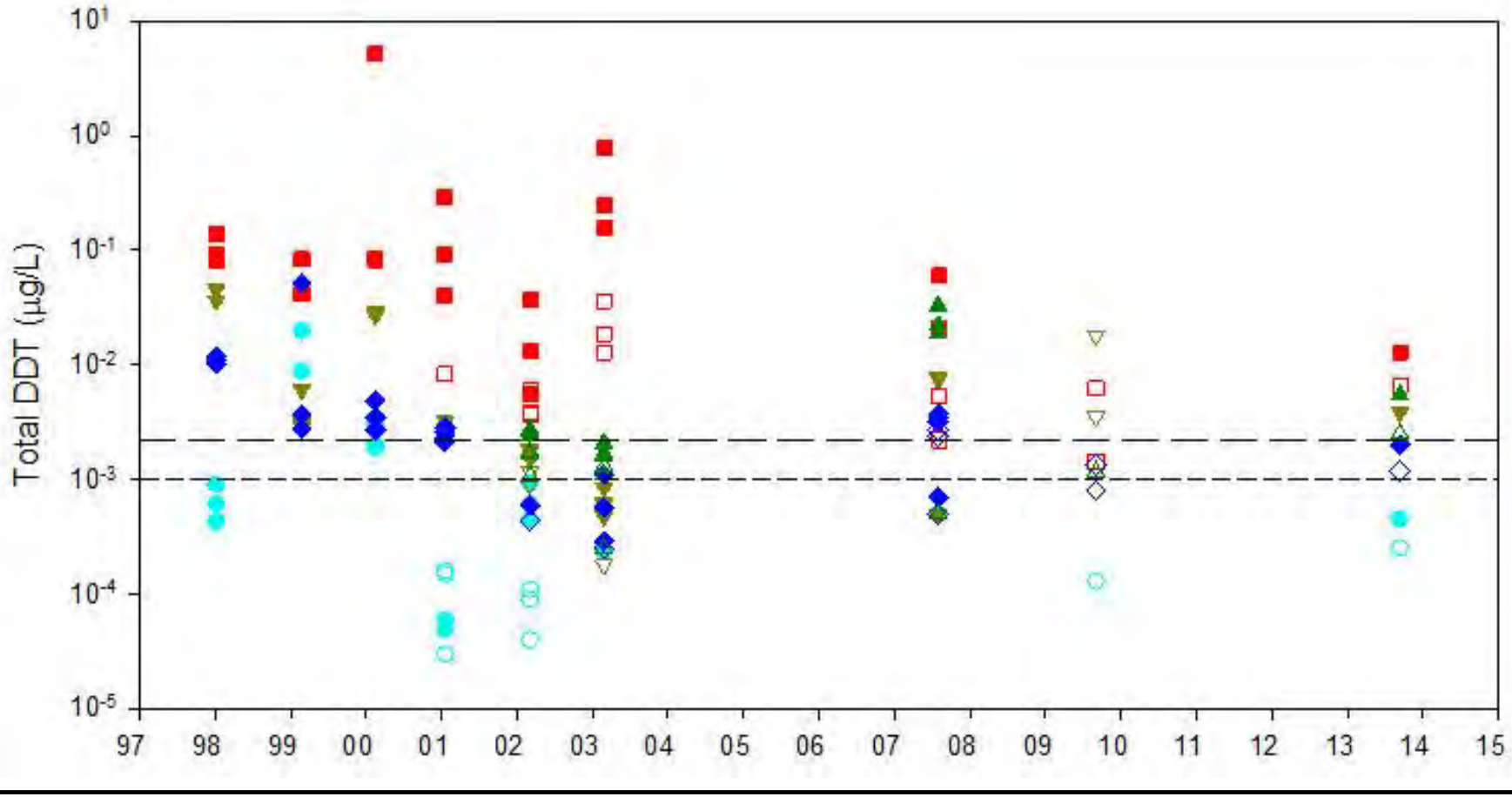


Legend

- 303.1 Richmond Inner Harbor - total
- 303.1 Richmond Inner Harbor - dissolved
- 303.2 Lauritzen Channel mouth - total
- 303.2 Lauritzen Channel mouth - dissolved
- 303.3 Lauritzen Channel mid - total
- 303.3 Lauritzen Channel mid - dissolved
- 303.4 Santa Fe Channel - total
- 303.4 Santa Fe Channel - dissolved
- 303.6 Parr Canal - total
- 303.6 Parr Canal - dissolved
- USEPA AWQC - consumption of organisms
- USEPA AWQC - protection of aquatic life

Notes:
AWQC - ambient water quality criteria; human health criteria corresponds to $10^{-5}$ risk level and aquatic life criteria corresponds to the saltwater chronic value.
Non-detected values reported at 1/2 the detection limit for the 4,4' isomers

**FIGURE 4-4**
**Total DDT Concentrations in Surface Water**
*United Heckathorn Superfund Site*
*Richmond, California*

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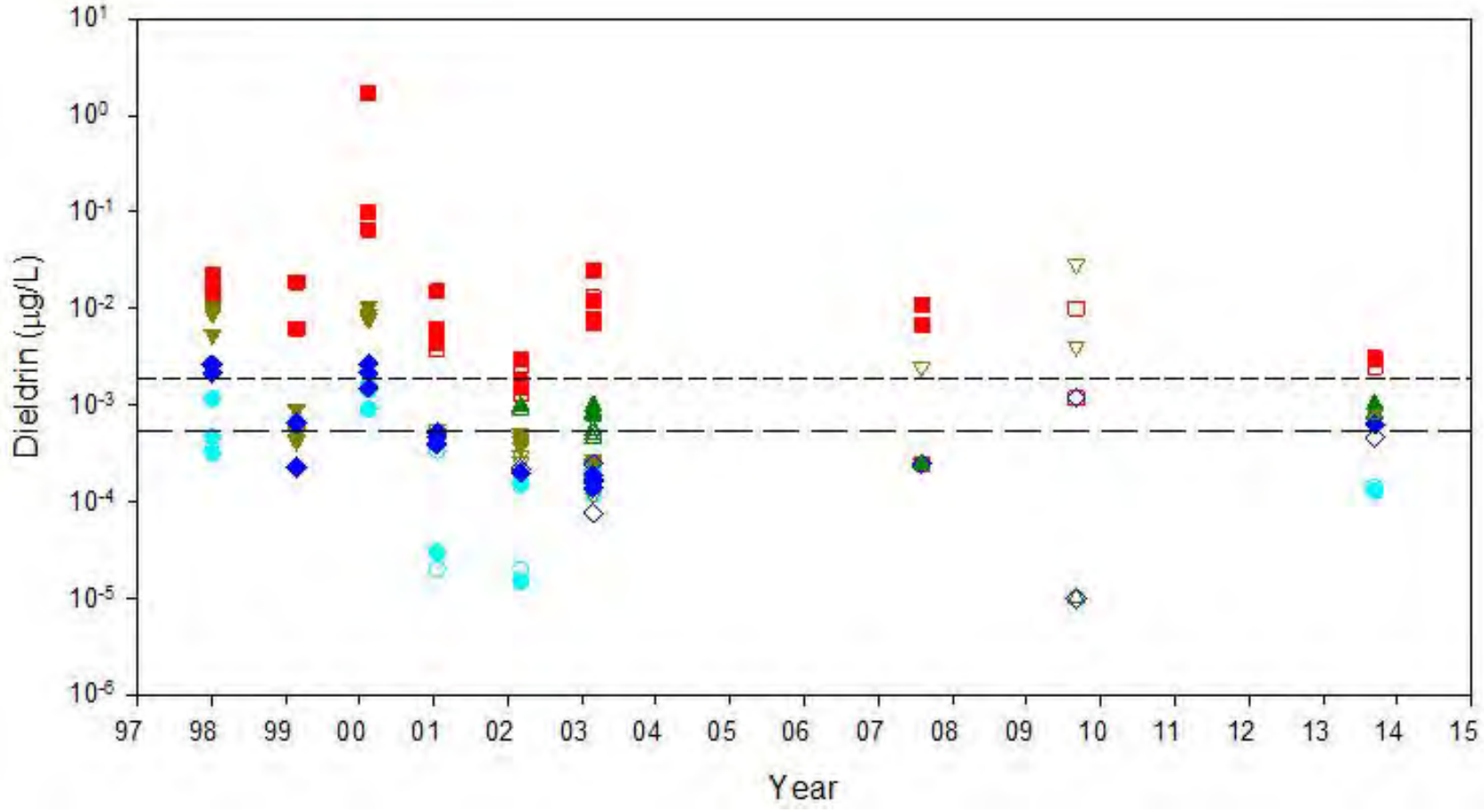


Legend

- 303.1 Richmond Inner Harbor - total
- 303.1 Richmond Inner Harbor - dissolved
- 303.2 Lauritzen Channel mouth - total
- 303.2 Lauritzen Channel mouth - dissolved
- 303.3 Lauritzen Channel mid - total
- 303.3 Lauritzen Channel mid - dissolved
- 303.4 Santa Fe Channel - total
- 303.4 Santa Fe Channel - dissolved
- 303.6 Parr Canal - total
- 303.6 Parr Canal - dissolved
- USEPA AWQC - consumption of organisms
- USEPA AWQC - protection of aquatic life

Notes:
AWQC - ambient water quality criteria; human health criteria corresponds to $10^{-5}$ risk level and aquatic life criteria corresponds to the saltwater chronic value.
Non-detected values reported at 1/2 the detection limit

**FIGURE 4-5**
**Dieldrin Concentrations in Surface Water**
*United Heckathorn Superfund Site*
*Richmond, California*

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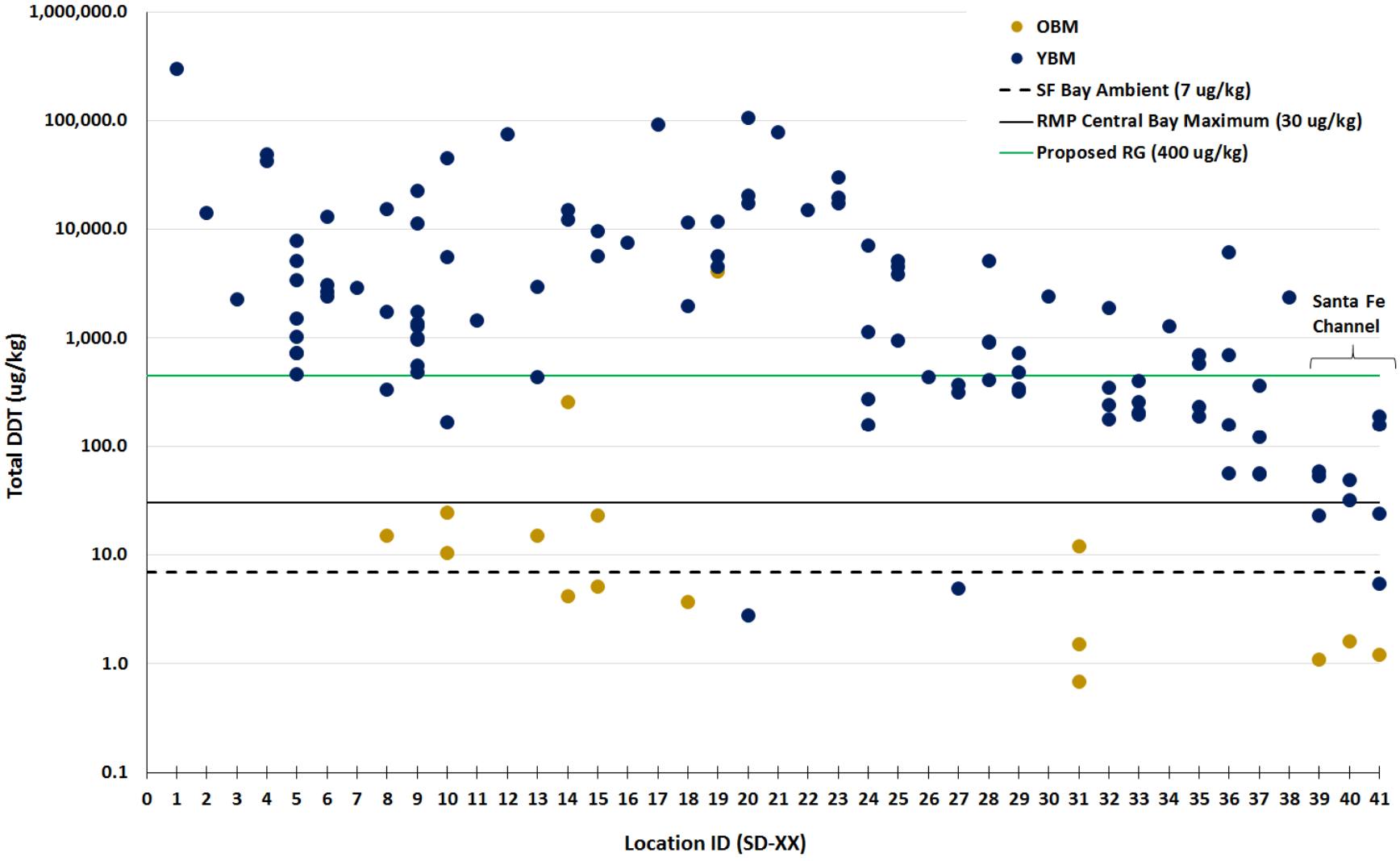


Notes:
Scale on Y-axis is logarithmic.
Locations SD-39, SD-40, and SD-41 are within the Santa Fe Channel.

**FIGURE 4-6**
**Total DDT in Young and Old Bay Mud in Comparison to Proposed Remediation Goal**
*United Heckathorn Superfund Site*
*Richmond, California*

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North End Area

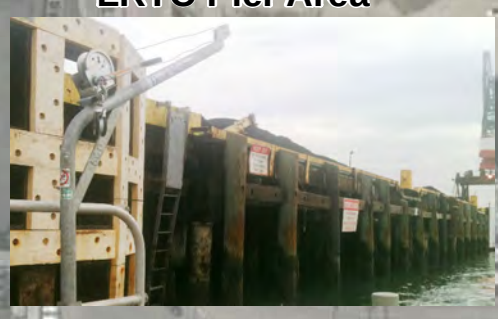
Northern Head

Northern Piles Area

Southern Piles Area

West Side

LRTC Pier Area



East Side

Santa Fe Channel

Lauritzen Channel

**LEGEND**

- Pier Piles (bent number)
- Former Pier Piles (bent number)

**Channel and Shoreline Areas**

- Northern Piles Area
- Southern Piles Area
- LRTC Pier Area
- North End Area
- East Side
- Northern Head
- West Side

**Bathymetry**

-1 ft

-44 ft

**Data Source:**

Sea Engineering Inc. (SEI)
January 29, 2013.

Data were collected by SEI in 2012 using a Reson 7125 multibeam echosounder operating at 400 kHz.

N

0 70 140 280 Feet

**FIGURE 6-1A**
**Channel and Shoreline Areas for Remedial Alternative Development**
*United Heckathorn Superfund Site*
*Richmond, California*

| Summary of Alternatives | |
|---|---|
| | **Alt. 2** |
| ***Dredging (cubic yards)*** | |
| West Side | 17,000 |
| East Side | 41,000 |
| Northern Head | 0 |
| **Total Dredge Volume** | **58,000** |
| ***Capping (square feet)*** | |
| Northern Head | 61,000 |
| Northe End Area | 4,400 |
| Northern Piles Area | 5,600 |
| Southern Piles Area | 10,200 |
| LRTC Pier Area | 5,600 |
| **Total Capping Area** | **86,800** |
| ***Sheet Pile Length (feet)*** | |
| North End Area | 135 |
| Northern Piles Area | 318 |
| Southern Piles Area | 406 |
| LRTC Pier Area | 299 |
| **Total Sheet Pile Length** | **1,158** |

North End Area

**Source Control Measures: Remove accumulated sediment from City of Richmond storm drain system draining to municipal outfall.**

Northern Head

Northern Piles Area

Southern Piles Area

West Side

LRTC Pier Area

East Side

Santa Fe Channel

Lauritzen Channel

**LEGEND**

- Pier Piles (bent number)
- Former Pier Piles (bent number)

**Channel and Shoreline Areas**

- Northern Piles Area
- Southern Piles Area
- LRTC Pier Area
- North End Area
- East Side
- Northern Head
- West Side

Remedial Activity

- Dredging
- Capping
- Source Control Measures - Dredging and capping
- Source Control Measures - Removing and/or sealing non-functional pipes and outfalls along eastern shoreline, removing and/or cutting nonstructural pilings, installing sheet pile, and capping.

0 70 140 280 Feet

N

**FIGURE 6-1B**
**Conceptual Design for Alternative 2**
*United Heckathorn Superfund Site*
*Richmond, California*

| Summary of Alternatives | |
|---|---|
| | **Alt. 3** |
| ***Dredging (cubic yards)*** | |
| West Side | 17,000 |
| East Side | 41,000 |
| Northern Head | 6,000 |
| **Total Dredge Volume** | **64,000** |
| ***Capping (square feet)*** | |
| Northern Head | 17,000 |
| Northe End Area | 4,400 |
| Northern Piles Area | 5,600 |
| Southern Piles Area | 10,200 |
| LRTC Pier Area | 5,600 |
| **Total Capping Area** | **42,800** |

**Source Control Measures: Remove accumulated sediment from City of Richmond storm drain system draining to municipal outfall.**

North End Area

Northern Head

Northern Piles Area

Southern Piles Area

LRTC Pier Area

East Side

West Side

Santa Fe Channel

Lauritzen Channel

**LEGEND**

Pier Piles (bent number)

Former Pier Piles (bent number)

**Channel and Shoreline Areas**

- Northern Piles Area
- Southern Piles Area
- LRTC Pier Area
- North End Area
- East Side
- Northern Head
- West Side

Remedial Activity

- Dredging
- Capping
- Source Control Measures - Dredging and capping
- Source Control Measures - Removing and/or sealing non-functional pipes and outfalls along eastern shoreline, removing and/or cutting nonstructural pilings, installing sheet pile, and capping.

0 70 140 280 Feet

N

**FIGURE 6-1C**
**Conceptual Design for Alternative 3**
***United Heckathorn Superfund Site***
***Richmond, California***

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| Summary of Alternatives | |
|---|---|
| | **Alt. 4** |
| ***Dredging (cubic yards)*** | |
| West Side | 17,000 |
| East Side | 41,000 |
| Northern Head | 8,000 |
| **Total Dredge Volume** | **66,000** |
| ***Capping (square feet)*** | |
| Northern Head | 0 |
| Northe End Area | 4,400 |
| Northern Piles Area | 5,600 |
| Southern Piles Area | 10,200 |
| LRTC Pier Area | 5,600 |
| **Total Capping Area** | **25,800** |

**Source Control Measures: Remove accumulated sediment from City of Richmond storm drain system draining to municipal outfall.**

North End Area

Northern Head

Northern Piles Area

Southern Piles Area

LRTC Pier Area

East Side

West Side

Santa Fe Channel

Lauritzen Channel

**LEGEND**

Pier Piles (bent number)

Former Pier Piles (bent number)

**Channel and Shoreline Areas**

- Northern Piles Area
- Southern Piles Area
- LRTC Pier Area
- North End Area
- East Side
- Northern Head
- West Side

Remedial Activity

- Dredging
- Source Control Measures - Dredging and capping
- Source Control Measures - Removing and/or sealing non-functional pipes and outfalls along eastern shoreline, removing and/or cutting nonstructural pilings, installing sheet pile, and capping.

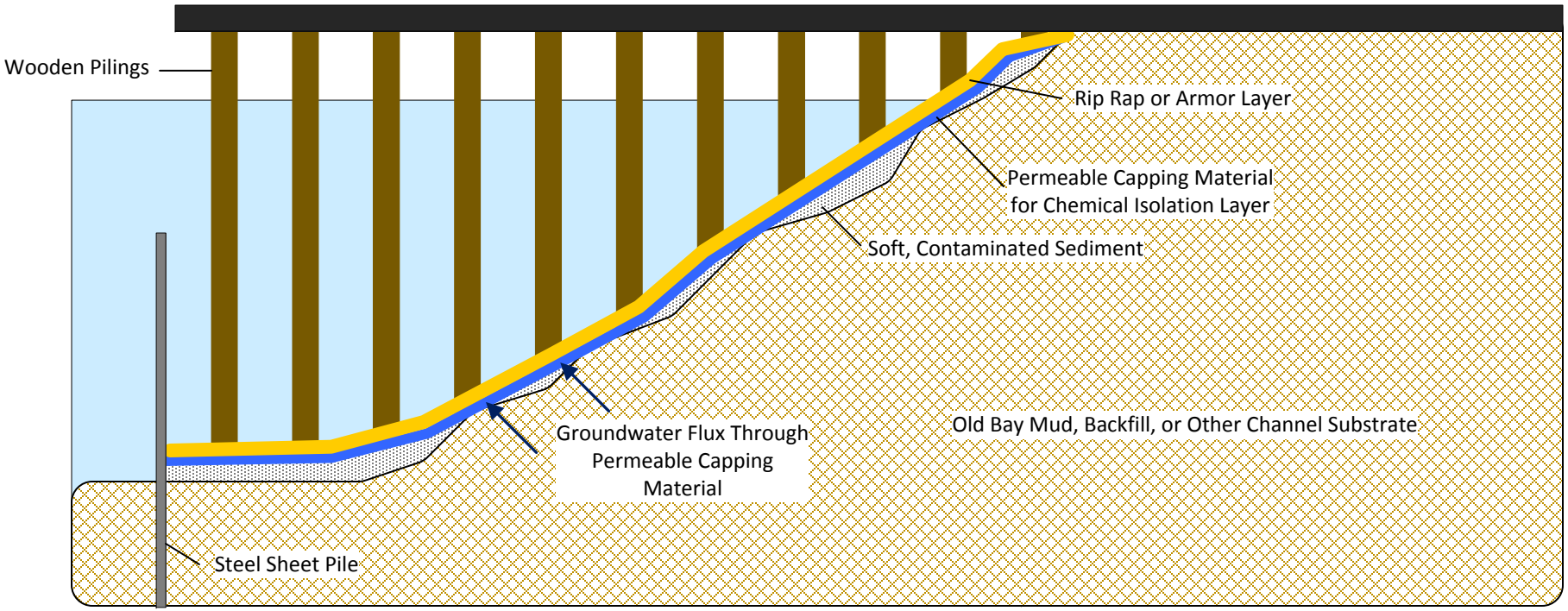
0 70 140 280 Feet

N

**FIGURE 6-1D**
**Conceptual Design for Alternative 4**
***United Heckathorn Superfund Site***
***Richmond, California***

CH2MHILL

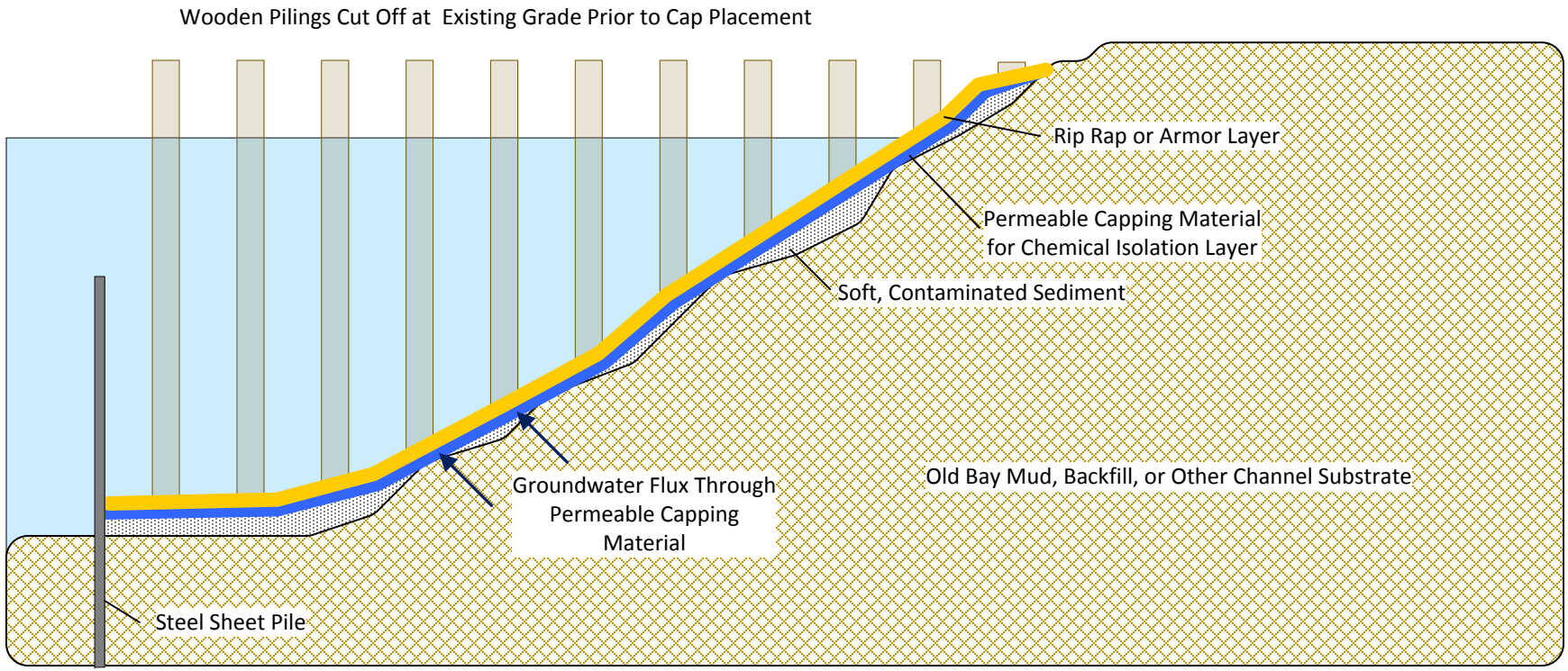
Document Path: \\Zinfandel\proj\USEnvironmentalProte\340138UHFS\GIS\EPA_United_Heckathorn\MapFiles\2014\FFS\Figure_6-1d_Alternative4.mxd




**Note:**
Not to scale. Drawing for conceptual illustration only.
Section adapted from Kohn and Evans (2002).

FIGURE 6-2a
Conceptual Shoreline Cross Section – Active Pier Area
*United Heckathorn Superfund Site*
*Richmond, California*

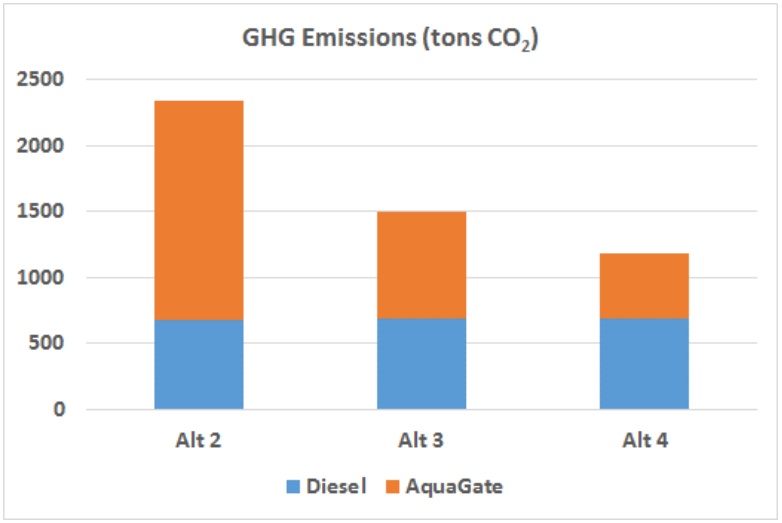
CH2MHILL

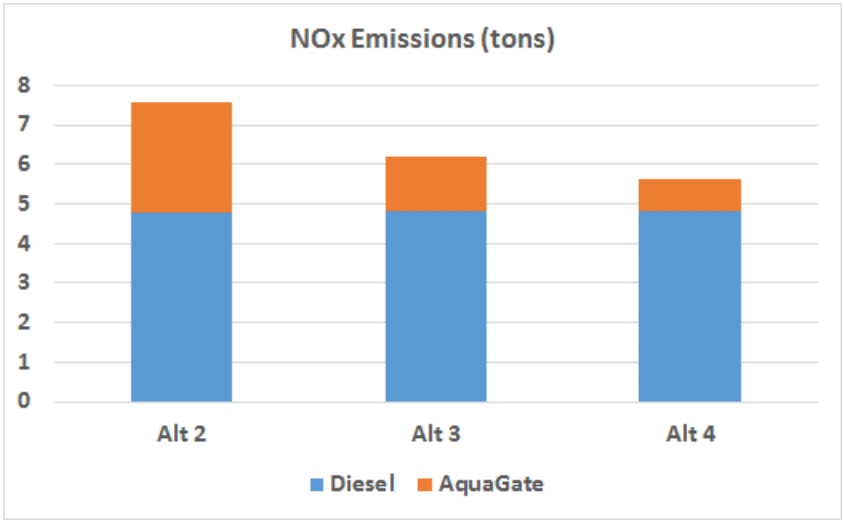


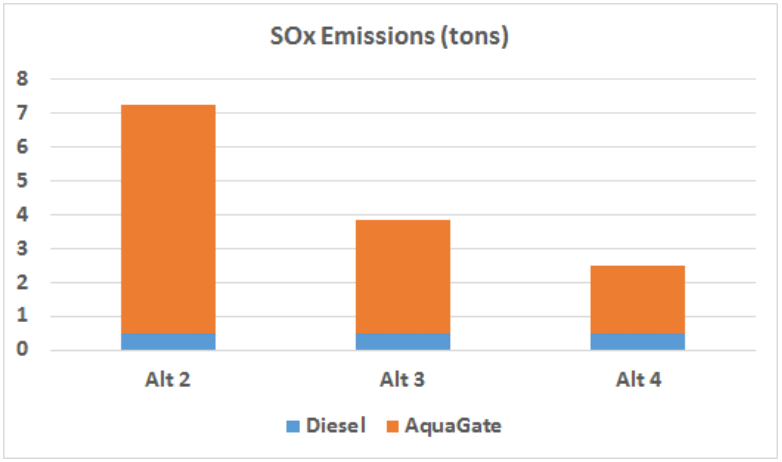

**Note:**
Not to scale. Drawing for conceptual illustration only.
Section adapted from Kohn and Evans (2002).

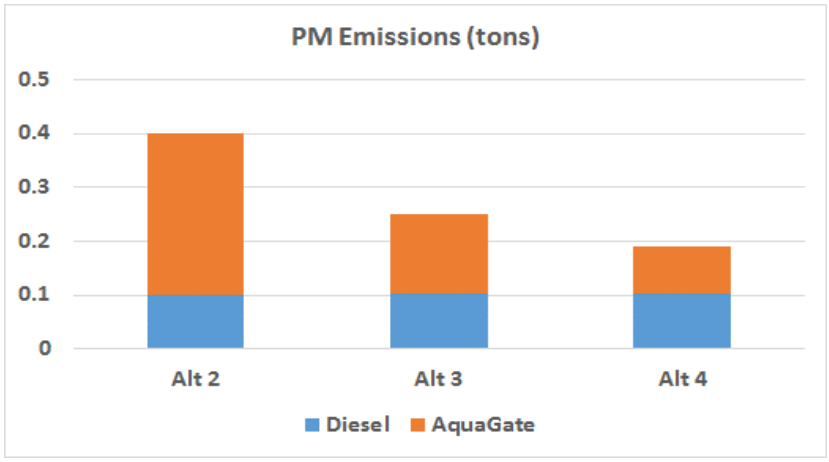
FIGURE 6-2b
Conceptual Shoreline Cross Section – Historical Pier Area
*United Heckathorn Superfund Site*
*Richmond, California*

CH2MHILL



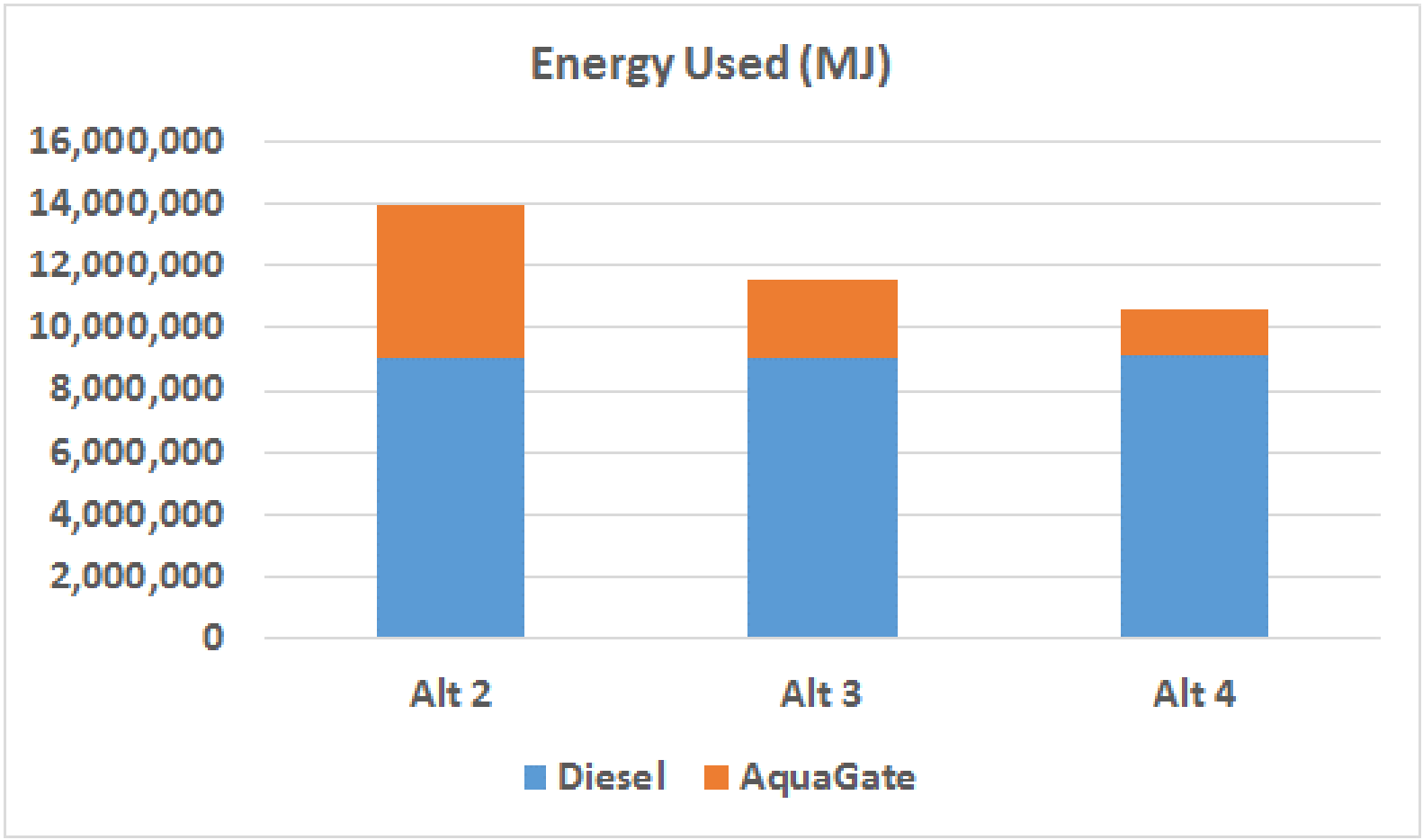




**Notes:**
$CO_2$ – carbon dioxide
GHG – green house gasses
NOx – nitrogen oxides
PM – particulate matter
SOx – sulfur oxides

**FIGURE 6-3**
**Estimated Atmospheric Effects from Alternatives 2, 3, and 4**
*United Heckathorn Superfund Site, Richmond, California*




**Notes:**
MJ - megajoules

**FIGURE 6-4**
**Estimated Energy Consumption for Alternatives 2, 3, and 4**
*United Heckathorn Superfund Site, Richmond, California*

# Appendix A
# Analytical Data

TABLE A-1

**Post-Remedy Surface Water Data**

*United Heckathorn Superfund Site, Richmond, California*

| Location: | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 1/6/1998 | 1/6/1998 | 1/6/1998 | 2/25/1999 | 2/25/1999 | 2/15/2000 | 2/15/2000 | 2/15/2000 | 2/15/2000 | 1/17/2001 | 1/17/2001 | 1/17/2001 | 1/17/2001 | 1/17/2001 | 1/17/2001 | 3/5/2002 |
| Sample Type: | N | N | N | N | N | N | N | N | FD | N | N | N | N | N | N | N |
| Basis: | NA | NA | NA | NA | NA | NA | NA | NA | NA | Filtered | Filtered | Filtered | Total | Total | Total | Filtered |
| **Parameter** | **Units** | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | |
| 2,4'-DDD | µg/L | **0.00028** | **0.00044** | 0.0001 U | **0.00141** | **0.00152** | **0.00038** | **0.00027** | 0.00002 U | **0.00023** | 0.00009 U | 0.00008 U | 0.00008 U | 0.00012 U | 0.00013 U | 0.00013 U | 0.00009 U |
| 2,4'-DDE | µg/L | 0.00002 U | 0.00002 U | 0.00003 U | **0.00007** | 0.00001 U | **0.00037** | **0.00024** | 0.00001 U | **0.00004** | 0.00008 U | 0.00007 U | 0.00007 U | 0.00011 U | 0.00011 U | 0.00012 U | 0.00008 U |
| 2,4'-DDT | µg/L | 0.00005 U | 0.00005 U | **0.00022** | **0.00092** | **0.00022** | **0.0002** | **0.00026** | **0.00029** | **0.00017** | 0.00004 U | 0.00003 U | 0.00003 U | 0.00005 U | 0.00005 U | 0.00006 U | 0.00004 U |
| 4,4'-DDD | µg/L | 0.00005 U | 0.00005 U | **0.00052** | **0.0057** | **0.00206** | **0.00103** | **0.00104** | **0.00077** | **0.00074** | **0.00016** | 0.00004 U | **0.00015** | 0.00007 U | 0.00007 U | 0.00007 U | 0.00005 U |
| 4,4'-DDE | µg/L | **0.00015** | **0.00017** | **0.00017** | **0.00181** | **0.00238** | **0.00036** | **0.00024** | **0.00041** | **0.00025** | 0.00004 U | 0.00004 U | 0.00004 U | 0.00007 U | 0.00007 U | 0.00007 U | **0.00009** |
| 4,4'-DDT | µg/L | 0.00004 U | 0.00004 U | 0.00004 U | **0.00996** | **0.00268** | **0.00064** | **0.00072** | **0.00043** | **0.00055** | 0.00005 U | 0.00005 U | 0.00005 U | 0.00008 U | 0.00008 U | 0.00008 U | 0.00006 U |
| Dieldrin | µg/L | **0.00047** | **0.00116** | **0.00032** | **0.00057** | **0.00067** | **0.00165** | **0.00161** | **0.00145** | **0.00091** | 0.00004 U | 0.00004 U | **0.00034** | 0.00006 U | 0.00006 U | 0.00006 U | **0.00015** |
| Total DDT | µg/L | **0.00043** | **0.00061** | **0.00091** | **0.01987** | **0.00886** | **0.00298** | **0.00277** | **0.0019** | **0.00198** | **0.00016** | 0.00003 U | **0.00015** | 0.00005 U | 0.00005 U | 0.00006 U | **0.00009** |

TABLE A-1
**Post-Remedy Surface Water Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | | 3/5/2002 | 3/5/2002 | 2/25/2003 | 2/25/2003 | 2/25/2003 | 2/25/2003 | 8/1/2007 | 8/1/2007 | 8/1/2007 | 8/1/2007 | 9/1/2009 | 9/1/2009 | 9/10/2013 | 9/10/2013 | 1/7/1998 | 1/7/1998 | 1/7/1998 | 2/25/1999 | 2/25/1999 |
| Sample Type: | | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | FD | N |
| Basis: | | Total | Total | Filtered | Filtered | Total | Total | Total | Filtered | Total | Filtered | Filtered | Filtered | Filtered | Total | NA | NA | NA | NA | NA |
| **Parameter** | **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD | µg/L | **0.00018** | **0.00021** | ND | ND | ND | ND | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.00002 U | **---** | **0.0000484** | **0.0000691** | **0.0066** | **0.00631** | **0.00606** | **0.00048** | **0.00034** |
| 2,4'-DDE | µg/L | 0.00007 U | 0.00006 U | ND | ND | ND | ND | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.00002 U | **---** | 0.0000101 U | 0.0000046 U | 0.00002 U | 0.00002 U | 0.00002 U | 0.00001 U | 0.00001 U |
| 2,4'-DDT | µg/L | 0.00004 U | 0.00003 U | ND | ND | ND | ND | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | **---** | **---** | 0.0000146 U | 0.00000602 U | **0.0039** | **0.00369** | **0.00372** | **0.00021** | **0.00017** |
| 4,4'-DDD | µg/L | **0.00036** | **0.00056** | ND | ND | ND | ND | 0.0005 UJ | 0.0005 U | 0.0005 UJ | 0.0005 U | **---** | **---** | **0.000184** | **0.000275** | **0.0197** | **0.0186** | **0.0148** | **0.00125** | **0.00118** |
| 4,4'-DDE | µg/L | **0.00007** | **0.00016** | ND | ND | ND | ND | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.00002 U | **---** | **0.0000225 J** | **0.0000843** | **0.00225** | **0.00224** | **0.00234** | **0.00041** | **0.00037** |
| 4,4'-DDT | µg/L | 0.00005 U | 0.00005 U | ND | ND | ND | **0.00052** | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.00005 U | **---** | 0.0000163 U | **0.0000226 J** | **0.0126** | **0.0156** | **0.00933** | **0.00052** | **0.00108** |
| Dieldrin | µg/L | **0.00016** | 0.00003 U | **0.00012 J** | ND | ND | **0.00021 J** | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.00002 U | 0.006 U | **0.000141** | **0.000129** | **0.00884** | **0.0103** | **0.0054** | **0.0009** | **0.00043** |
| Total DDT | µg/L | **0.00061** | **0.00093** | ND | ND | ND | **0.00052** | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.00013 U | **0.000025** | **0.0002549** | **0.000451** | **0.04505** | **0.04644** | **0.03625** | **0.00287** | **0.00314** |

TABLE A-1
**Post-Remedy Surface Water Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Date:** | 2/25/1999 | 2/15/2000 | 2/15/2000 | 2/15/2000 | 1/17/2001 | 1/17/2001 | 1/17/2001 | 1/17/2001 | 1/17/2001 | 1/17/2001 | 3/5/2002 | 3/5/2002 | 3/5/2002 | 3/5/2002 | 3/5/2002 | 3/5/2002 | 2/25/2003 | 2/25/2003 | 2/25/2003 |
| **Sample Type:** | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| **Basis:** | NA | NA | NA | NA | Filtered | Filtered | Filtered | Total | Total | Total | Filtered | Filtered | Filtered | Total | Total | Total | Filtered | Filtered | Filtered |
| **Parameter** / **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD µg/L | **0.00062** | **0.00466** | **0.004** | **0.00416** | **0.00046** | **0.00039** | **0.00048** | **0.00042** | **0.00036** | **0.00054** | 0.00009 U | 0.00011 U | 0.00009 U | 0.00007 U | 0.00006 U | 0.0001 U | **0.00018 J** | ND | ND |
| 2,4'-DDE µg/L | **0.00045** | **0.00017** | **0.00015** | **0.00031** | 0.00007 U | 0.00007 U | 0.00008 U | 0.00011 U | 0.00011 U | 0.00011 U | 0.00008 U | 0.0001 U | 0.00008 U | 0.00007 U | **0.00009** | 0.00009 U | ND | ND | ND |
| 2,4'-DDT µg/L | **0.00028** | **0.00092** | **0.0014** | **0.00156** | 0.00004 U | **0.00018** | **0.00022** | 0.00005 U | 0.00005 U | 0.00005 U | 0.00004 U | 0.00005 U | 0.00004 U | **0.00024** | **0.00022** | 0.00004 U | ND | ND | ND |
| 4,4'-DDD µg/L | **0.00175** | **0.0172** | **0.016** | **0.0141** | **0.0012** | **0.00107** | **0.00108** | **0.0011** | **0.00116** | **0.00123** | **0.00074** | **0.00056** | **0.00064** | **0.00078** | **0.00077** | **0.00083** | ND | ND | ND |
| 4,4'-DDE µg/L | **0.00049** | **0.00123** | **0.00149** | **0.00159** | **0.00032** | **0.0003** | **0.00038** | **0.00012** | 0.00006 U | **0.00048** | 0.00005 U | **0.00009** | 0.00005 U | **0.00013** | **0.00021** | **0.00019** | ND | ND | ND |
| 4,4'-DDT µg/L | **0.00249** | **0.00386** | **0.00585** | **0.00517** | **0.00061** | **0.00062** | **0.00041** | **0.00107** | **0.0012** | **0.00096** | **0.00042** | **0.00027** | **0.00027** | **0.00067** | **0.00047** | **0.00049** | ND | **0.00064** | **0.00048 J** |
| Dieldrin µg/L | **0.00052** | **0.0105** | **0.0086** | **0.00779** | **0.0004** | **0.00056** | **0.00042** | **0.00048** | **0.00051** | **0.0004** | **0.00046** | **0.00026** | **0.0003** | **0.00042** | **0.00037** | **0.0005** | **0.00014 J** | ND | **0.00012 J** |
| Total DDT µg/L | **0.00608** | **0.02804** | **0.02889** | **0.02689** | **0.00259** | **0.00256** | **0.00257** | **0.00271** | **0.00272** | **0.00321** | **0.00116** | **0.00092** | **0.00091** | **0.00182** | **0.00176** | **0.00151** | **0.00018** | **0.00064** | **0.00048** |

TABLE A-1
**Post-Remedy Surface Water Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.03 | 303.03 | 303.03 | 303.03 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | | 2/25/2003 | 2/25/2003 | 2/25/2003 | 8/1/2007 | 8/1/2007 | 8/1/2007 | 8/1/2007 | 8/1/2007 | 8/1/2007 | 9/1/2009 | 9/1/2009 | 9/1/2009 | 9/1/2009 | 9/10/2013 | 9/10/2013 | 1/6/1998 | 1/6/1998 | 1/6/1998 | 2/25/1999 |
| Sample Type: | | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| Basis: | | Total | Total | Total | Total | Filtered | Total | Filtered | Total | Filtered | Filtered | Filtered | Filtered | Filtered | Filtered | Total | NA | NA | NA | NA |
| **Parameter** | **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD | µg/L | ND | ND | ND | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | **0.00098** | **0.007518** | --- | --- | **0.000395** | **0.000668** | **0.0167** | **0.0176** | **0.00698** | **0.00582** |
| 2,4'-DDE | µg/L | ND | ND | ND | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | **0.0077 NJ** | 0.00002 U | 0.00002 U | --- | --- | 0.0000106 U | 0.00000372 U | **0.00037** | **0.00039** | **0.00107** | **0.0003** |
| 2,4'-DDT | µg/L | ND | ND | ND | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | --- | --- | --- | --- | **0.0000407 J** | **0.000101** | **0.00779** | **0.0106** | **0.0078** | **0.00486** |
| 4,4'-DDD | µg/L | ND | ND | ND | 0.0005 U | 0.0005 U | **0.0025 NJ** | 0.0005 U | 0.0005 UJ | 0.0005 U | --- | --- | --- | --- | **0.0014** | **0.00217** | **0.0313** | **0.0278** | **0.00228** | **0.0135** |
| 4,4'-DDE | µg/L | ND | ND | ND | 0.0005 U | 0.0005 U | **0.0007** | 0.0005 U | 0.0005 U | 0.0005 U | **0.000334** | **0.000916** | --- | --- | **0.000124** | **0.000603** | **0.00857** | **0.0157** | **0.0435** | **0.00296** |
| 4,4'-DDT | µg/L | **0.00085** | **0.00061** | **0.00049 J** | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | **0.0074 NJ** | 0.0005 U | **0.000695** | **0.002973** | --- | --- | **0.000114** | **0.000328** | **0.027** | **0.0659** | **0.0191** | **0.0138** |
| Dieldrin | µg/L | **0.00016 J** | **0.00024 J** | **0.00027 J** | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | **0.0025** | **0.004087** | **0.028752** | **0.009391** | 0.006 U | **0.00068** | **0.000814** | **0.0147** | **0.0225** | **0.0171** | **0.00628** |
| Total DDT | µg/L | **0.00085** | **0.00061** | **0.00049** | 0.0005 U | 0.0005 U | **0.0032** | 0.0005 U | **0.0074** | **0.0077** | **0.003538** | **0.018035** | **0.004985** | **0.002148** | **0.0020737** | **0.00387** | **0.09173** | **0.13799** | **0.08073** | **0.04124** |

TABLE A-1
**Post-Remedy Surface Water Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 2/25/1999 | 2/15/2000 | 2/15/2000 | 2/15/2000 | 1/17/2001 | 1/17/2001 | 1/17/2001 | 1/17/2001 | 3/5/2002 | 3/5/2002 | 3/5/2002 | 3/5/2002 | 3/5/2002 | 3/5/2002 | 2/25/2003 | 2/25/2003 | 2/25/2003 | 2/25/2003 | 2/25/2003 |
| Sample Type: | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| Basis: | NA | NA | NA | NA | Filtered | Total | Total | Total | Filtered | Filtered | Filtered | Total | Total | Total | Filtered | Filtered | Filtered | Total | Total |
| **Parameter** | **Units** | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD | µg/L | **0.00816** | **0.0155** | **0.223** | **0.0148** | **0.00162** | **0.00686** | **0.00282** | **0.00235** | **0.00081** | **0.00081** | **0.00132** | **0.00085** | **0.00086** | **0.00189** | **0.0092** | **0.0065** | ND | **0.018** | **0.0066** |
| 2,4'-DDE | µg/L | **0.00043** | **0.00034** | **0.013** | **0.0003** | 0.00007 U | **0.0002** | **0.00008** | 0.00009 U | 0.00009 U | 0.00008 U | **0.00012** | 0.00006 U | 0.00006 U | 0.00006 U | ND | ND | **0.00038 J** | **0.00099** | **0.00031 J** |
| 2,4'-DDT | µg/L | **0.00815** | **0.00828** | **0.872** | **0.00449** | **0.00122** | **0.0699** | **0.00884** | **0.00561** | **0.00063** | **0.00051** | **0.00091** | **0.00073** | **0.00094** | **0.0025** | **0.0048** | ND | ND | **0.12** | **0.038** |
| 4,4'-DDD | µg/L | **0.0214** | **0.0411** | **0.68** | **0.0457** | **0.00334** | **0.0125** | **0.00637** | **0.00536** | **0.00112** | **0.00106** | **0.00155** | **0.00123** | **0.0015** | **0.0027** | **0.0081** | **0.0058** | **0.0071** | **0.053** | **0.012** |
| 4,4'-DDE | µg/L | **0.00381** | 0.00001 U | **0.124** | **0.00276** | **0.00058** | **0.00466** | **0.00137** | **0.00115** | 0.00005 U | **0.0002** | **0.00033** | **0.00031** | **0.00053** | **0.00079** | **0.002** | **0.0012** | **0.001** | **0.011** | **0.0032** |
| 4,4'-DDT | µg/L | **0.0414** | **0.0175** | **3.24** | **0.0167** | **0.00149** | **0.2** | **0.0729** | **0.0255** | **0.0011** | **0.00126** | **0.0018** | **0.00237** | **0.00928** | **0.0288** | **0.012** | **0.0052** | **0.0044** | **0.58** | **0.19** |
| Dieldrin | µg/L | **0.0188** | **0.1** | **1.71** | **0.066** | **0.00382** | **0.015** | **0.00609** | **0.00438** | **0.0015** | **0.00134** | **0.0026** | **0.0015** | **0.00172** | **0.00301** | **0.013** | **0.0072** | **0.0076** | **0.025** | **0.0079** |
| Total DDT | µg/L | **0.08335** | **0.08272** | **5.152** | **0.08475** | **0.00825** | **0.29412** | **0.09238** | **0.03997** | **0.00366** | **0.00384** | **0.00603** | **0.00549** | **0.01311** | **0.03668** | **0.0361** | **0.0187** | **0.01288** | **0.78299** | **0.25011** |

TABLE A-1
**Post-Remedy Surface Water Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 2/25/2003 | 8/7/2007 | 8/7/2007 | 8/7/2007 | 8/7/2007 | 9/1/2009 | 9/1/2009 | 9/1/2009 | 9/1/2009 | 9/10/2013 | 9/10/2013 | 1/6/1998 | 1/6/1998 | 1/6/1998 | 2/25/1999 | 2/25/1999 | 2/25/1999 | 2/15/2000 | 2/15/2000 |
| Sample Type: | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| Basis: | Total | Total | Filtered | Total | Filtered | Filtered | Filtered | Filtered | Filtered | Filtered | Total | NA | NA | NA | NA | NA | NA | NA | NA |
| **Parameter** | **Units** | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD | µg/L | **0.011** | **0.0048** | 0.0005 U | **0.0037** | **0.0006** | **0.002341** | **0.000413** | **---** | **---** | **0.00138 J** | **0.00229** | **0.00204** | **0.00226** | **0.00201** | **0.0024** | **0.00038** | **0.00021** | **0.00064** | **0.00058** |
| 2,4'-DDE | µg/L | ND | 0.0005 UJ | 0.0005 U | 0.0005 UJ | 0.0005 UJ | 0.00002 U | 0.00002 U | **---** | **---** | **0.0000298 J** | **0.0000795** | 0.00002 U | 0.00002 U | 0.00002 U | 0.00001 U | **0.00074** | **0.00012** | **0.00007** | 0.00001 U |
| 2,4'-DDT | µg/L | **0.015** | **0.0034 J** | 0.0005 U | 0.0005 UJ | 0.0005 U | **---** | **---** | **---** | **---** | **0.000305 J** | **0.000719** | **0.00015** | 0.00005 U | **0.0001** | **0.00151** | **0.00019** | **0.00016** | **0.00037** | **0.00029** |
| 4,4'-DDD | µg/L | **0.016** | **0.034** | **0.0054** | **0.012** | **0.0016 NJ** | **---** | **---** | **---** | **---** | **0.00359 J** | **0.00583** | **0.00807** | **0.00884** | **0.00962** | **0.015** | **0.00094** | **0.00072** | **0.00199** | **0.00139** |
| 4,4'-DDE | µg/L | **0.0035** | **0.0035** | 0.0005 U | **0.0012 J** | 0.0005 U | **0.000692** | **0.00015** | **---** | **---** | **0.000528 J** | **0.0015** | 0.00003 U | 0.00003 U | 0.00003 U | **0.00169** | **0.00052** | **0.00025** | **0.00046** | **0.00039** |
| 4,4'-DDT | µg/L | **0.11** | **0.014 J** | 0.0005 U | **0.0041 J** | 0.0005 U | **0.000995** | **0.000264** | **---** | **---** | **0.000823 J** | **0.00249** | 0.00004 U | 0.00004 U | 0.00004 U | **0.0307** | 0.00005 U | **0.0022** | **0.00138** | **0.00082** |
| Dieldrin | µg/L | **0.012** | **0.011** | 0.0005 U | **0.0067 NJ** | 0.0005 U | **0.010078** | **0.001171** | **0.05974** | **0.054875** | **0.00251 J** | **0.00306** | **0.00216** | **0.00261** | **0.00265** | **0.00023** | **0.00066** | **0.00023** | **0.00268** | **0.00216** |
| Total DDT | µg/L | **0.1555** | **0.0597** | **0.0054** | **0.021** | **0.0022** | **0.006217** | **0.001434** | **0.045565** | **0.021237** | **0.0066558** | **0.0129085** | **0.01026** | **0.0111** | **0.01173** | **0.0513** | **0.00277** | **0.00366** | **0.00491** | **0.00347** |

TABLE A-1
**Post-Remedy Surface Water Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | | 2/15/2000 | 1/17/2001 | 1/17/2001 | 1/17/2001 | 1/17/2001 | 1/17/2001 | 1/17/2001 | 3/5/2002 | 3/5/2002 | 2/25/2003 | 2/25/2003 | 2/25/2003 | 2/25/2003 | 2/25/2003 | 2/25/2003 | 8/1/2007 | 8/1/2007 | 8/1/2007 | 8/1/2007 |
| Sample Type: | | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | FD |
| Basis: | | NA | Filtered | Filtered | Filtered | Total | Total | Total | Filtered | Total | Filtered | Filtered | Filtered | Total | Total | Total | Total | Filtered | Total | Total |
| **Parameter** | **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD | µg/L | **0.0004** | **0.00051** | **0.00052** | **0.00048** | 0.00009 U | **0.00058** | **0.00075** | 0.00009 U | 0.00007 U | ND | ND | ND | ND | ND | ND | 0.0005 U | 0.0005 U | 0.0005 U | **0.0009** |
| 2,4'-DDE | µg/L | **0.00009** | 0.00007 U | 0.00008 U | 0.00007 U | 0.00008 U | 0.00008 U | 0.00009 U | 0.00008 U | 0.00006 U | ND | ND | ND | ND | ND | ND | 0.0005 U | **0.0027 NJ** | **0.0037 NJ** | 0.0005 U |
| 2,4'-DDT | µg/L | **0.00023** | 0.00007 U | 0.00004 U | **0.00011** | 0.00004 U | **0.00004** | **0.00014** | 0.00004 U | 0.00003 U | ND | ND | ND | ND | ND | ND | 0.0005 U | 0.0005 U | 0.0005 U | **0.0016 NJ** |
| 4,4'-DDD | µg/L | **0.00103** | **0.00137** | **0.00123** | **0.00117** | **0.00179** | **0.00148** | **0.00161** | **0.00035** | **0.00036** | ND | ND | ND | ND | **0.00077** | ND | **0.0032 NJ** | 0.0005 U | 0.0005 UJ | 0.0005 UJ |
| 4,4'-DDE | µg/L | **0.00039** | **0.00018** | **0.00018** | **0.00016** | **0.00006** | **0.00022** | **0.00019** | **0.00009** | **0.00014** | ND | ND | ND | ND | ND | ND | 0.0005 U | 0.0005 U | 0.0005 U | **0.001 NJ** |
| 4,4'-DDT | µg/L | **0.00056** | **0.00023** | **0.00026** | **0.00022** | **0.00029** | **0.00026** | **0.00013** | 0.00006 U | **0.0001** | ND | ND | ND | **0.00057** | **0.00033 J** | **0.00029 J** | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U |
| Dieldrin | µg/L | **0.0015** | **0.00052** | **0.0004** | **0.00048** | **0.00048** | **0.00039** | **0.00051** | **0.00022** | **0.0002** | **0.000076 J** | **0.00016 J** | ND | **0.00019 J** | **0.00014 J** | **0.00017 J** | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U |
| Total DDT | µg/L | **0.0027** | **0.00229** | **0.00219** | **0.00214** | **0.00214** | **0.00258** | **0.00282** | **0.00044** | **0.0006** | ND | ND | ND | **0.00057** | **0.0011** | **0.00029** | **0.0032** | **0.0027** | **0.0037** | **0.0035** |

TABLE A-1
**Post-Remedy Surface Water Data**
*United Heckathorn Superfund Site, Richmond, California*

| | Location: | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date: | 8/1/2007 | 8/1/2007 | 8/1/2007 | 8/1/2007 | 9/1/2009 | 9/1/2009 | 9/1/2009 | 9/1/2009 | 9/10/2013 | 9/10/2013 | 3/5/2002 | 3/5/2002 | 3/5/2002 | 3/5/2002 | 3/5/2002 | 3/5/2002 | 2/25/2003 | 2/25/2003 | 2/25/2003 |
| | Sample Type: | N | FD | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| | Basis: | Filtered | Filtered | Total | Filtered | Filtered | Filtered | Filtered | Filtered | Filtered | Total | Filtered | Filtered | Filtered | Total | Total | Total | Filtered | Filtered | Filtered |
| **Parameter** | **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD | µg/L | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | **0.000563** | **0.000271** | **---** | **---** | **0.000213** | **0.00031** | **0.00027** | **0.00023** | **0.00022** | **0.00029** | **0.00029** | **0.00027** | ND | ND | ND |
| 2,4'-DDE | µg/L | **0.0024 NJ** | 0.0005 U | 0.0005 UJ | 0.0005 U | 0.00002 U | 0.00002 U | **---** | **---** | **0.00000682 J** | **0.0000177 J** | 0.00008 U | 0.00008 U | 0.00008 U | 0.00006 U | 0.00006 U | 0.00006 U | ND | ND | ND |
| 2,4'-DDT | µg/L | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | **---** | **---** | **---** | **---** | 0.00000678 U | **0.000031 J** | 0.00004 U | 0.00004 U | 0.00004 U | **0.00025** | **0.00024** | **0.00022** | ND | ND | ND |
| 4,4'-DDD | µg/L | 0.0005 UJ | 0.0005 UJ | 0.0005 UJ | 0.0005 UJ | **---** | **---** | **---** | **---** | **0.000803** | **0.00117** | 0.00005 U | **0.00071** | **0.0007** | **0.00093** | **0.0009** | **0.0008** | ND | ND | ND |
| 4,4'-DDE | µg/L | 0.0005 U | 0.0005 U | **0.0007** | 0.0005 U | **0.000107** | **0.00008** | **---** | **---** | **0.000123** | **0.000366** | **0.00014** | **0.00021** | **0.00023** | **0.00036** | **0.00032** | **0.00031** | ND | ND | ND |
| 4,4'-DDT | µg/L | 0.0005 U | 0.0005 U | 0.0005 UJ | 0.0005 U | 0.00005 U | 0.00005 U | **---** | **---** | **0.0000494 J** | **0.000106** | **0.00067** | **0.00053** | **0.00057** | **0.00089** | **0.00084** | **0.00081** | ND | **0.0013** | **0.0011** |
| Dieldrin | µg/L | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | **0.001203** | 0.00002 U | 0.006 U | 0.006 U | **0.000463** | **0.000632** | **0.00091** | **0.0009** | **0.0009** | **0.00099** | **0.00098** | **0.00096** | **0.00045 J** | **0.00056** | **0.00051** |
| Total DDT | µg/L | **0.0024** | 0.0005 U | **0.0007** | 0.0005 U | **0.001348** | **0.000797** | **0.00175** | **0.000872** | **0.00119522** | **0.0020007** | **0.00108** | **0.00168** | **0.00172** | **0.00272** | **0.00259** | **0.00241** | ND | **0.0013** | **0.0011** |

TABLE A-1
**Post-Remedy Surface Water Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 | 303.07 | 303.07 | 303.08 | 303.08 | 303.08 | 303.08 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | | 2/25/2003 | 2/25/2003 | 2/25/2003 | 8/1/2007 | 8/1/2007 | 8/1/2007 | 8/1/2007 | 8/1/2007 | 8/1/2007 | 9/1/2009 | 9/1/2009 | 9/10/2013 | 9/10/2013 | 9/1/2009 | 9/1/2009 | 9/1/2009 | 9/1/2009 | 9/1/2009 | 9/1/2009 |
| Sample Type: | | N | N | N | N | N | N | FD | N | FD | N | N | N | N | N | N | N | N | N | N |
| Basis: | | Total | Total | Total | Total | Filtered | Total | Total | Filtered | Filtered | Filtered | Filtered | Filtered | Total | Filtered | Filtered | Filtered | Filtered | Filtered | Filtered |
| **Parameter** | **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD | µg/L | ND | ND | ND | **0.002** | 0.0005 U | **0.0025** | **0.0021 NJ** | 0.0005 U | 0.0005 U | **0.000475** | **---** | **0.000412** | **0.000753** | **0.004133** | **---** | 0.00002 U | 0.00002 U | 0.00002 U | **---** |
| 2,4'-DDE | µg/L | ND | ND | ND | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.00002 U | **---** | **0.0000158 J** | **0.0000423 J** | 0.00002 U | **---** | 0.00002 U | 0.00002 U | 0.00002 U | **---** |
| 2,4'-DDT | µg/L | **0.00038 J** | ND | ND | **0.0037** | 0.0005 U | **0.0036 NJ** | **0.0032 NJ** | 0.0005 U | 0.0005 U | **---** | **---** | **0.0000746 J** | **0.000233** | **---** | **---** | **---** | **---** | **---** | **---** |
| 4,4'-DDD | µg/L | ND | ND | ND | **0.0039 NJ** | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | **---** | **---** | **0.00158** | **0.00281** | **---** | **---** | **---** | **---** | **---** | **---** |
| 4,4'-DDE | µg/L | ND | ND | ND | **0.0022 NJ** | 0.0005 U | 0.0005 U | **0.0015 NJ** | 0.0005 U | 0.0005 U | **0.000103** | **---** | **0.000206** | **0.000663** | **0.000451** | **---** | 0.00002 U | 0.00002 U | 0.00002 U | **---** |
| 4,4'-DDT | µg/L | **0.0017** | **0.0016** | **0.0017** | **0.021 J** | 0.0005 U | **0.016** | **0.012** | 0.0005 U | 0.0005 U | 0.00005 U | **---** | **0.00024** | **0.000946** | **0.000762** | **---** | 0.00005 U | 0.00005 U | 0.00005 U | **---** |
| Dieldrin | µg/L | **0.00086** | **0.001** | **0.00079** | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.00002 U | **0.00669** | **0.00082** | **0.00103** | **0.01658** | **0.026614** | 0.00002 U | 0.00002 U | 0.00002 U | 0.006 U |
| Total DDT | µg/L | **0.00208** | **0.0016** | **0.0017** | **0.0328** | 0.0005 U | **0.0221** | **0.0188** | 0.0005 U | 0.0005 U | **0.001177** | **0.002727** | **0.0025284** | **0.0054473** | **0.011263** | **0.012005** | 0.00013 U | 0.00013 U | 0.00013 U | **0.000045** |

TABLE A-1
**Post-Remedy Surface Water Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | | 303.08 | 303.08 | 303.10 | 303.10 | L01 | L01 | L01 | L01 | L01 | L01 | L02 | L02 | L02 | L02 | L02 | L02 | L03 | L03 | L03 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | | 9/1/2009 | 9/1/2009 | 9/1/2009 | 9/1/2009 | 8/1/2007 | 8/1/2007 | 8/1/2007 | 8/1/2007 | 8/1/2007 | 8/1/2007 | 8/7/2007 | 8/7/2007 | 8/7/2007 | 8/7/2007 | 8/7/2007 | 8/7/2007 | 8/7/2007 | 8/7/2007 | 8/7/2007 |
| Sample Type: | | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | FD | N |
| Basis: | | Filtered | Filtered | Filtered | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total | Total | Filtered |
| **Parameter** | **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD | µg/L | --- | --- | 0.00002 U | --- | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.003 U | 0.0005 U | **0.0033** | 0.0005 U | **0.005 J** | 0.0005 U | **0.0031** | 0.0005 U | **0.014** | **0.03** | 0.0005 U |
| 2,4'-DDE | µg/L | --- | --- | 0.00002 U | --- | **0.004** | 0.0005 U | 0.0005 U | 0.0005 U | **0.011** | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.001 UJ | 0.0025 U | 0.0005 U |
| 2,4'-DDT | µg/L | --- | --- | --- | --- | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.003 U | 0.0005 U | **0.0025 NJ** | 0.0005 U | 0.0005 U | 0.0005 U | **0.005 NJ** | 0.0005 U | 0.001 U | 0.0025 UJ | 0.0005 U |
| 4,4'-DDD | µg/L | --- | --- | --- | --- | **0.0042 NJ** | 0.0005 U | 0.0005 U | **0.0043** | **0.0064 J** | 0.0005 U | **0.0091 J** | 0.0005 U | **0.0098 J** | 0.0005 U | **0.01** | **0.0017 NJ** | **0.054** | **0.14** | 0.0005 U |
| 4,4'-DDE | µg/L | --- | --- | 0.00002 U | --- | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.003 U | 0.0005 U | **0.0016 NJ** | 0.0005 U | **0.0022 NJ** | 0.0005 U | **0.0035 NJ** | 0.0005 U | **0.0029 NJ** | **0.0057** | 0.0005 U |
| 4,4'-DDT | µg/L | --- | --- | 0.00005 U | --- | **0.0039** | 0.0005 U | 0.0005 U | **0.003** | **0.0034** | 0.0005 U | **0.0077 NJ** | 0.0005 U | **0.028 J** | 0.0005 U | **0.015** | **0.0029 NJ** | **0.0023** | **0.0062 J** | 0.0005 U |
| Dieldrin | µg/L | 0.006 U | 0.006 U | 0.00002 U | 0.006 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.003 U | 0.0005 U | **0.0059 NJ** | 0.0005 U | **0.0092 NJ** | 0.0005 U | 0.0005 U | 0.0005 U | **0.0063** | **0.015** | 0.0005 U |
| Total DDT | µg/L | **0.000066** | **0.000073** | 0.00013 U | **0.000027** | **0.0121** | 0.0005 U | 0.0005 U | **0.0073** | **0.0208** | 0.0005 U | **0.0242** | 0.0005 U | **0.045** | 0.0005 U | **0.0366** | **0.0046** | **0.0732** | **0.1819** | 0.0005 U |

TABLE A-1
**Post-Remedy Surface Water Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | | L03 | L03 | L03 | L04 | L04 | L04 | L04 | L05 | L05 | L05 | L05 | L05 | L05 | L06 | L06 | L06 | L06 | L06 | L06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | | 8/7/2007 | 8/7/2007 | 8/7/2007 | 8/7/2007 | 8/7/2007 | 8/7/2007 | 8/7/2007 | 8/7/2007 | 8/7/2007 | 8/7/2007 | 8/7/2007 | 8/7/2007 | 8/7/2007 | 8/1/2007 | 8/1/2007 | 8/1/2007 | 8/1/2007 | 8/1/2007 | 8/1/2007 |
| Sample Type: | | FD | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| Basis: | | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total | Filtered |
| **Parameter** | **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD | µg/L | 0.0005 U | **0.0071** | 0.0005 U | **0.011** | **0.0015** | **0.016 NJ** | 0.0005 U | **0.013** | **0.003** | **0.01 NJ** | 0.0005 U | **0.0046 NJ** | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U |
| 2,4'-DDE | µg/L | 0.0005 U | 0.0005 UJ | 0.0005 U | 0.001 UJ | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U |
| 2,4'-DDT | µg/L | 0.0005 UJ | **0.00059 NJ** | 0.0005 U | 0.001 UJ | 0.0005 U | **0.0026** | 0.0005 U | 0.0005 U | **0.005 NJ** | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U |
| 4,4'-DDD | µg/L | **0.0011** | **0.024** | **0.0022** | **0.047** | **0.0049** | **0.043 J** | 0.0005 U | **0.049 J** | **0.0096 J** | **0.011 J** | 0.0005 U | **0.014 J** | 0.0005 U | **0.0043 NJ** | 0.0005 U | **0.007** | 0.0005 UJ | 0.0005 U | **0.0018 NJ** |
| 4,4'-DDE | µg/L | **0.0005** | **0.00055 J** | 0.0005 U | **0.0049 NJ** | 0.0005 U | **0.0034 NJ** | 0.0005 U | **0.0056 NJ** | **0.0019 NJ** | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | **0.001** | 0.0005 U | 0.0005 U | **0.0016** |
| 4,4'-DDT | µg/L | **0.0013 J** | **0.004 J** | 0.0005 U | **0.0043 J** | 0.0005 U | **0.0085 NJ** | 0.0005 U | **0.01 NJ** | **0.014 NJ** | **0.0042 NJ** | 0.0005 U | **0.0034 J** | 0.0005 U | **0.0036 NJ** | 0.0005 U | **0.016** | 0.0005 U | 0.0005 U | **0.0019** |
| Dieldrin | µg/L | **0.0022** | **0.0084 NJ** | 0.0005 U | **0.011** | 0.0005 U | **0.02 NJ** | 0.0005 U | **0.011 NJ** | 0.0005 U | **0.0069 NJ** | 0.0005 U | **0.0091 NJ** | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U | 0.0005 U |
| Total DDT | µg/L | **0.0029** | **0.03624** | **0.0022** | **0.0672** | **0.0064** | **0.0735** | 0.0005 U | **0.0776** | **0.0335** | **0.0252** | 0.0005 U | **0.022** | 0.0005 U | **0.0079** | 0.0005 U | **0.024** | 0.0005 U | 0.0005 U | **0.0053** |

TABLE A-1
**Post-Remedy Surface Water Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | | Outfall | P4-16 | P4-16 | SEEP | SEEP | SEEP | SEEP | SEEP | SEEP | SEEP | SEEP | W |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | | 3/11/2002 | 7/24/2013 | 7/24/2013 | 2/25/2003 | 2/25/2003 | 2/25/2003 | 2/25/2003 | 2/25/2003 | 2/25/2003 | 2/25/2003 | 2/25/2003 | 7/14/2004 |
| Sample Type: | | N | N | N | FD | N | N | N | FD | N | N | N | N |
| Basis: | | Total | Filtered | Total | Filtered | Filtered | Filtered | Filtered | Total | Total | Total | Total | Dry Fraction |
| **Parameter** | **Units** | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | |
| 2,4'-DDD | µg/L | **1.24** | **0.00212** | **0.00266** | **1** | **1** | **0.85** | **1** | **1.7** | **1.9** | **1.8** | **1.8** | **0.067 J** |
| 2,4'-DDE | µg/L | **0.0124** | **0.000261** | **0.000351 J** | ND | **0.19** | ND | ND | ND | **0.27** | **0.32** | **0.29** | 0.0004 U |
| 2,4'-DDT | µg/L | **0.959** | **0.003** | **0.00414** | ND | ND | ND | ND | **2.8** | **3.1** | **3.2** | **3.2** | 0.0007 U |
| 4,4'-DDD | µg/L | **0.546** | **0.0044** | **0.00586** | **0.83** | **0.64** | **0.48** | **1** | **0.92** | **1.3** | **1.5** | **1.3** | **0.017** |
| 4,4'-DDE | µg/L | **0.238** | **0.00436** | **0.00714** | **0.16** | **0.16** | **0.13** | **0.17** | **0.36** | **0.37** | **0.34** | **0.39** | 0.0004 U |
| 4,4'-DDT | µg/L | **1.46** | **0.00948** | **0.0143** | **0.91** | **0.92** | **0.74** | **0.95** | **2** | **1.9** | **2** | **2** | **0.0014 J** |
| Dieldrin | µg/L | **2.52** | **0.0713 J** | **0.0683 J** | **2.6** | **2.4** | **2.6** | **2.4** | **2.7** | **3.1** | **2.9** | **3** | **0.0065** |
| Total DDT | µg/L | **4.4554** | **0.0236** | **0.0345** | **2.9** | **2.91** | **2.2** | **3.12** | **7.78** | **8.84** | **9.16** | **8.98** | **0.0854** |

Notes:

Detected results are bolded
The total DDTs value is the sum of all six isomers.
-- = not analyzed
FD = field duplicate sample
J = Concentration or reporting limit estimated by laboratory or data validation.
N = primary sample
ND = Not detected
NA = Not available
NJ = Estimated and presumptively identified
U = Not detected at listed reporting limit
µg/L = micrograms per liter

TABLE A-2
**Post-Remedy Mussel Tissue Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.02 | 303.02 | 303.02 | 303.02 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Description:** | Resident | Transplant | Resident | Transplant | Resident | Resident | Resident | Resident | Resident | Transplant | Transplant | Resident | Resident | Transplant | Surface Transplant | Resident | Transplant | Resident | Transplant |
| **Date:** | 1/6/1998 | 1/6/1998 | 2/25/1999 | 2/25/1999 | 2/29/2000 | 1/17/2001 | 3/8/2002 | 3/2/2003 | 6/19/2007 | 10/1/2009 | 10/1/2009 | 11/13/2009 | 11/13/2009 | 3/8/2012 | 10/10/2013 | 1/7/1998 | 1/7/1998 | 2/25/1999 | 2/25/1999 |
| **Sample Type:** | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| **Basis:** | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet |
| **Percent Moisture** | NA | NA | 91.60 | 87.70 | 87.50 | 91.20 | NA | NA | NA | 78.00 | 80.00 | 81.00 | 83.00 | 80.00 | 86.11 | NA | NA | 92.30 | 89.60 |
| **Percent Lipid (wet)** | NA | NA | NA | NA | NA | NA | 0.76 | 1.50 | 0.33 | 1.80 | 1.70 | 1.50 | 1.40 | 1.88 | 1.10 | NA | NA | NA | NA |
| **Parameter** **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD ng/g | **20.4** | **17.2** | **2.45** | **6.26** | **4.92** | **3.35** | **1.41** | ND | **1.5 J** | **4.5 J** | **4.6 J** | **7 J** | **7.4 J** | **5.56** | **4.7** | **203** | **272** | **16.1** | **40.7** |
| 2,4'-DDE ng/g | 0.26 U | 0.26 U | **1.42** | **1.17** | **0.81** | **0.33** | **0.12** | ND | **1.3 NJ** | **3.1 J** | **3.1 J** | **3.6 J** | **3.8 J** | **0.3** | **0.12 J-** | **10.2** | **8** | **1.88** | **2.78** |
| 2,4'-DDT ng/g | **7.46** | **4.52** | **3.37** | **4.17** | **3.99** | **2.23** | 0.24 U | ND | **1.5 NJ** | **2 R** | **2 R** | **2.9 J** | **2.9 J** | **1.53** | **1.17** | **145** | **81** | **32** | **43.1** |
| 4,4'-DDD ng/g | **66.4** | **70.5** | **7.18** | **18.7** | **17.7** | **8.67** | 0.17 U | **11** | **4.4 NJ** | **12 J** | **13 J** | **18 J** | **17 J** | **12.25** | **10.3** | **589** | **825** | **37.7** | **101** |
| 4,4'-DDE ng/g | **19.4** | **11.7** | **8.21** | **8.17** | **13.5** | **6.45** | **4.67** | **17** | **3.4** | **6.7 NJ** | **7.1 NJ** | **15 NJ** | **16 NJ** | **6.74** | **5.16** | **107** | **119** | **31.6** | **32.7** |
| 4,4'-DDT ng/g | **13.6** | **9.04** | **7.08** | **7.07** | **11.1** | **3.83** | **3.13** | ND | **3.4 NJ** | **2.4 J** | **2.6 J** | **6.9 J** | **8.3 J** | **2.84** | **1.43** | **168** | **143** | **56.6** | **61.9** |
| Total DDT ng/g | **127.26** | **112.96** | **29.71** | **45.54** | **52.02** | **24.86** | **9.33** | **28** | **15.5** | **28.7** | **30.4** | **53.4** | **55.4** | **29.22** | **22.88** | **1,222** | **1,448** | **175.88** | **282.18** |
| Dieldrin ng/g | **5.43** | **11.2** | **1.86** | **8.22** | **5.38** | **0.71** | **0.68** | **2.9** | **1.5 NJ** | **4.1 J** | **3.1 J** | **3.3 J** | **3.3 J** | **3.44** | **1.93 J+** | **40.3** | **165** | **6.5** | **26.9** |

TABLE A-2
**Post-Remedy Mussel Tissue Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 | 303.02 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Description:** | Resident | Resident | Resident | Resident | Resident | Resident | Transplant | Transplant | Resident | Resident | Deep Transplant | Deep Transplant | Surface Resident | Surface Resident | Surface Transplant | Surface Transplant | Deep Transplant | Resident | Surface Transplant |
| **Date:** | 2/29/2000 | 1/17/2001 | 1/17/2001 | 3/8/2002 | 3/2/2003 | 6/19/2007 | 10/1/2009 | 10/1/2009 | 11/13/2009 | 11/13/2009 | 3/8/2012 | 3/8/2012 | 3/8/2012 | 3/8/2012 | 3/8/2012 | 3/8/2012 | 10/10/2013 | 10/10/2013 | 10/10/2013 |
| **Sample Type:** | N | N | FD | N | N | N | N | N | N | N | N | FD | N | FD | N | FD | N | N | N |
| **Basis:** | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet |
| **Percent Moisture** | 89.80 | 91.96 | 91.96 | NA | NA | NA | 81.00 | 79.00 | 80.00 | 81.00 | 81.00 | 82.00 | 89.00 | 85.00 | 81.00 | 80.00 | 87.39 | 80.30 | 88.32 |
| **Percent Lipid (wet)** | NA | NA | NA | 0.61 | 1.20 | 0.59 | 1.70 | 1.60 | 2.10 | 1.90 | 1.51 | 1.79 | 0.84 | 1.58 | 1.31 | 1.83 | 1.01 | 2.66 | 0.81 |
| **Parameter** **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD ng/g | 38.6 | 47.8 | 49.1 | 13 | 29 | 48 | 73 J | 63 J | 160 J | 130 J | 22.37 | 18.06 | 34.25 | 41.01 | 25.92 | 19.91 J+ | 21.69 | 157.11 | 37.74 |
| 2,4'-DDE ng/g | 3.15 | 1.92 | 1.6 | 0.66 | ND | 5.9 NJ | 13 J | 9.8 J | 22 J | 19 J | 0.62 | 0.79 | 1.95 | 3.23 | 0.9 | 0.57 | 1.28 | 7 | 1.83 |
| 2,4'-DDT ng/g | 34.5 | 42.9 | 40.7 | 25 | 31 | 30 J | 40 J | 34 J | 100 J | 80 J | 5.83 | 5.83 | 34.09 | 49.1 | 16.17 | 17.2 | 5.02 | 67.42 | 18.68 |
| 4,4'-DDD ng/g | 104 | 119 | 129 | 30.4 | 56 | 97 | 180 J | 150 J | 380 J | 300 J | 31.43 | 38.43 | 76.16 | 83.12 | 26.41 | 31.45 | 75.21 | 385.91 | 104.25 |
| 4,4'-DDE ng/g | 65.4 | 57.4 | 61.6 | 28.8 | 41 | 41 | 84 NJ | 79 NJ | 200 NJ | 160 NJ | 22.4 | 22.37 | 57.08 J- | 105.79 | 18.32 | 17.84 | 30.49 | 207.88 | 54.1 |
| 4,4'-DDT ng/g | 64.8 | 71.3 | 78.8 | 41.5 | 57 | 56 | 100 J | 88 J | 220 J | 170 J | 13.31 | 18.53 J+ | 68.67 J- | 115.36 | 28.7 | 36.44 | 12.89 | 172.64 | 50.9 |
| Total DDT ng/g | 310.45 | 340.32 | 360.8 | 139.36 | 214 | 277.9 | 490 | 423.8 | 1,082 | 859 | 95.96 | 104.01 | 272.2 | 397.61 | 116.42 | 123.41 | 146.58 | 997.96 | 267.5 |
| Dieldrin ng/g | 27.7 | 6.27 | 6.05 | 2.93 | 6.2 J | 26 | 51 J | 39 J | 67 J | 48 J | 8.23 | 6.12 | 6.99 J- | 22.94 | 15.4 | 9.83 J+ | 8.91 | 31.52 | 25.6 |

TABLE A-2
**Post-Remedy Mussel Tissue Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.04 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Description:** | Resident | Transplant | Resident | Transplant | Resident | Resident | Resident | Resident | Resident | Transplant | Transplant | Resident | Resident | Resident | Transplant | Resident | Resident | Surface Transplant | Resident |
| **Date:** | 1/6/1998 | 1/6/1998 | 2/25/1999 | 2/25/1999 | 2/29/2000 | 1/17/2001 | 3/8/2002 | 3/3/2003 | 6/19/2007 | 10/1/2009 | 10/1/2009 | 11/13/2009 | 11/13/2009 | 3/8/2012 | 3/8/2012 | 10/10/2013 | 10/10/2013 | 10/10/2013 | 1/6/1998 |
| **Sample Type:** | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | FD | N | N |
| **Basis:** | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet |
| **Percent Moisture** | NA | NA | 90.80 | 89.10 | 92.00 | 89.11 | NA | NA | NA | 82.00 | 81.00 | 84.00 | 84.00 | 88.00 | 80.00 | 81.65 | 80.71 | 86.49 | NA |
| **Percent Lipid (wet)** | NA | NA | NA | NA | NA | NA | 0.84 | 0.74 | 0.49 | 1.70 | 1.80 | 1.60 | 1.40 | 0.99 | 1.96 | 2.80 | 2.17 | 0.98 | NA |
| **Parameter** **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD ng/g | 820 | 702 | 75.6 | 119 | 60.5 | 144 | 43.5 | 61 | 230 | 340 J | 290 J | 380 J | 410 J | 441.59 | 106.92 | 441.47 | 509.19 | 171.99 | 47.1 |
| 2,4'-DDE ng/g | 29 | 19 | 4.65 | 7.8 | 4.51 | 4.71 | 3.22 | ND | 18 J | 25 J | 22 J | 33 J | 36 J | 16.99 | 5.13 | 24.59 | 23.03 | 7.59 | 3.03 |
| 2,4'-DDT ng/g | 549 | 220 | 113 | 167 | 83.5 | 169 | 48.9 | 76 | 160 J | 270 J | 230 J | 460 J | 540 J | 581.96 | 97.15 | 353.13 | 306.97 | 114.76 | 15 |
| 4,4'-DDD ng/g | 1,860 | 1,980 | 143 | 311 | 157 | 357 | 86.8 | 110 | 470 | 700 J | 590 J | 780 J | 820 J | 816.7 | 193.5 | 1,411 | 1,324 | 477.92 | 136 |
| 4,4'-DDE ng/g | 434 | 207 | 71.5 | 87.5 | 74.5 | 160 | 45.9 | 64 | 170 | 240 NJ | 200 NJ | 420 NJ | 440 NJ | 548.53 | 85.25 | 607.28 | 531.15 | 191.12 | 29.9 |
| 4,4'-DDT ng/g | 811 | 373 | 198 | 289 | 142 | 301 | 82.1 | 120 | 220 | 490 J | 410 J | 930 J | 1,100 J | 939.27 | 186.21 | 588.31 | 543.6 | 226.47 | 24.7 |
| Total DDT ng/g | 4,503 | 3,501 | 605.75 | 981.3 | 522.01 | 1,136 | 310.42 | 431 | 1,268 | 2,065 | 1,742 | 3,003 | 3,346 | 3,345 | 674.16 | 3,426 | 3,238 | 1,190 | 255.73 |
| Dieldrin ng/g | 184 | 279 | 28.4 | 106 | 42.7 | 32.1 | 17 | 18 | 81 | 230 J | 190 J | 110 J | 90 J | 59.16 | 64.8 | 116.46 | 122.57 | 90.56 | 8.18 |

TABLE A-2
**Post-Remedy Mussel Tissue Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.06 | 303.06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Description:** | Transplant | Resident | Transplant | Resident | Resident | Resident | Resident | Resident | Resident | Resident | Transplant | Deep Transplant | Resident | Surface Transplant | Deep Transplant | Resident | Surface Transplant | Resident | Transplant |
| **Date:** | 1/6/1998 | 2/25/1999 | 2/25/1999 | 2/29/2000 | 1/17/2001 | 3/8/2002 | 3/3/2003 | 6/19/2007 | 10/1/2009 | 10/1/2009 | 10/1/2009 | 3/8/2012 | 3/8/2012 | 3/8/2012 | 10/10/2013 | 10/10/2013 | 10/10/2013 | 3/8/2002 | 10/1/2009 |
| **Sample Type:** | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| **Basis:** | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet |
| **Percent Moisture** | NA | 90.60 | 90.10 | 89.60 | 89.75 | NA | NA | NA | 83.00 | 82.00 | 80.00 | 82.00 | 89.00 | 82.00 | 86.55 | 82.31 | 87.66 | NA | 79.00 |
| **Percent Lipid (wet)** | NA | NA | NA | NA | NA | 0.54 | 0.56 | 0.19 | 1.80 | 2.00 | 1.70 | 1.81 | 0.83 | 1.68 | 0.93 | 2.41 | 1.10 | 0.68 | 1.90 |
| **Parameter** **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD ng/g | 138 | 6.58 | 10.3 | 7 | 20.2 | 2.2 | 6.8 | 17 | 31 J | 35 J | 25 J | 12.01 | 7.02 | 9.37 | 14.62 | 36.84 | 15.41 | 3.48 | 41 J |
| 2,4'-DDE ng/g | 4.46 | 0.55 | 0.8 | 0.84 | 0.26 U | 0.21 | ND | 1.6 J | 14 J | 15 J | 11 J | 0.83 | 0.51 | 0.57 | 1.04 | 2.17 | 0.96 | 0.13 | 12 J |
| 2,4'-DDT ng/g | 26.2 | 10.5 | 7.64 | 7.11 | 12.4 | 2.79 | ND | 10 J | 8.5 J | 9.8 J | 5.6 J | 3.54 | 3.97 | 3.14 | 3.61 | 11.37 | 4.44 | 3.82 | 13 J |
| 4,4'-DDD ng/g | 349 | 18.9 | 32.1 | 23.2 | 58.6 | 6.31 | ND | 36 | 110 J | 120 J | 77 J | 33.32 | 18.54 | 25.95 | 61.32 | 174.32 | 65.26 | 12.1 | 140 J |
| 4,4'-DDE ng/g | 54.2 | 17.5 | 12.8 | 18 | 30.3 | 6.27 | 9.4 | 14 | 66 NJ | 76 NJ | 43 NJ | 18.26 | 18.13 | 13.93 | 28.13 | 82.1 | 30.34 | 10.8 | 46 NJ |
| 4,4'-DDT ng/g | 41.3 | 21.6 | 16.1 | 19 | 27.9 | 5.79 | 8.6 | 15 | 20 J | 23 J | 14 J | 7.47 | 7.86 | 6.31 | 9.96 | 29.98 | 12.66 | 9.47 | 56 J |
| Total DDT ng/g | 613.16 | 75.63 | 79.74 | 75.15 | 149.4 | 23.57 | 24.8 | 93.6 | 249.5 | 278.8 | 175.6 | 75.43 | 56.03 | 59.27 | 118.68 | 336.78 | 129.07 | 39.8 | 308 |
| Dieldrin ng/g | 83.1 | 2.77 | 9.73 | 6.38 | 3.32 | 0.62 | 1.3 | 7.3 | 18 J | 20 J | 17 J | 4.91 | 1.09 | 5.41 | 10.12 | 15.85 | 13.4 | 1.16 | 21 J |

TABLE A-2
**Post-Remedy Mussel Tissue Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 | 303.07 | 303.07 | 303.07 | 303.07 | 303.07 | 303.07 | 303.07 | 303.08 | 303.08 | 303.09 | 303.09 | 303.10 | 303.10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Description:** | | Transplant | Resident | Resident | Resident | Surface Transplant | Resident | Resident | Transplant | Transplant | Resident | Resident | Resident | Transplant | Transplant | Transplant | Transplant | Transplant | Transplant | Transplant |
| **Date:** | | 10/1/2009 | 11/13/2009 | 11/13/2009 | 3/12/2012 | 10/10/2013 | 11/1/2013 | 6/19/2007 | 10/1/2009 | 10/1/2009 | 11/13/2009 | 11/13/2009 | 3/8/2012 | 3/8/2012 | 10/1/2009 | 10/1/2009 | 10/1/2009 | 10/1/2009 | 10/1/2009 | 10/1/2009 |
| **Sample Type:** | | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| **Basis:** | | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet |
| **Percent Moisture** | | 82.00 | 80.00 | 80.00 | 90.00 | 87.79 | 87.16 | NA | 80.00 | 83.00 | 86.00 | 86.00 | 89.00 | 82.00 | 79.00 | 77.00 | 79.00 | 79.00 | 80.00 | 79.00 |
| **Percent Lipid (wet)** | | 1.60 | 2.50 | 2.30 | 0.61 | 0.91 | 1.69 | 0.29 | 2.10 | 1.40 | 1.30 | 1.10 | 0.93 | 1.50 | 1.60 | 1.90 | 1.60 | 1.80 | 1.50 | 2.00 |
| **Parameter** | **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD | ng/g | 37 J | 170 J | 190 J | 10.79 | 15.24 | 26.62 | 6.7 | 230 J | 170 J | 320 J | 330 J | 115.03 | 105.36 | 2.6 J | 3 J | 2 J | 3.4 J | 1.8 J | 1.7 J |
| 2,4'-DDE | ng/g | 10 J | 29 J | 33 J | 0.87 | 1.1 | 2.4 | 1.8 NJ | 21 J | 15 J | 36 J | 34 J | 4.22 | 4.68 | 1.9 J | 2.5 J | 1.9 J | 2.9 J | 2.4 J | 2 J |
| 2,4'-DDT | ng/g | 11 J | 300 J | 410 J | 8.15 | 6.08 | 7.83 J- | 4.8 J | 61 J | 54 J | 190 J | 180 J | 79.26 | 61.11 | 1.9 R | 1.9 R | 1.9 R | 3.8 J | 2 R | 2 R |
| 4,4'-DDD | ng/g | 120 J | 360 J | 390 J | 31.88 | 66.97 | 110.4 | 15 | 630 J | 440 J | 900 J | 930 J | 249.96 | 269.35 | 6.8 J | 8.3 J | 5.5 J | 10 J | 5 J | 4.7 J |
| 4,4'-DDE | ng/g | 45 NJ | 270 NJ | 340 NJ | 23.66 | 20.27 | 62.24 | 8.8 | 130 NJ | 110 NJ | 330 NJ | 300 NJ | 130.65 | 69.66 | 4.3 NJ | 5.3 NJ | 3.4 NJ | 5.5 NJ | 4 NJ | 4.1 NJ |
| 4,4'-DDT | ng/g | 34 J | 620 J | 790 J | 16.34 | 15.28 | 21.61 | 9 | 150 J | 140 J | 430 J | 420 J | 150.65 | 126.59 | 1.8 J | 1.7 J | 2.3 J | 25 J | 1.6 J | 1.2 J |
| Total DDT | ng/g | 257 | 1,749 | 2,153 | 91.69 | 124.94 | 231.1 | 46.1 | 1,222 | 929 | 2,206 | 2,194 | 729.77 | 636.75 | 17.4 | 20.8 | 15.1 | 50.6 | 14.8 | 13.7 |
| Dieldrin | ng/g | 17 J | 36 J | 38 J | 3.35 | 11.69 | 6.39 | 4.5 | 190 J | 120 J | 130 J | 110 J | 22.15 | 72.02 | 2.4 J | 2.6 J | 1.3 J | 1.8 J | 1.3 J | 1.4 J |

TABLE A-2
**Post-Remedy Mussel Tissue Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | | 8" Pipe | B1400 | B1400 | B1400 | Background | Background | Background | L01 | L01 | L01 | L01 | L02 | L02 | L02 | L02 | L03 | L04 | Manson Ladder | SEEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Description:** | | SMPL | Resident | Resident | Transplant | | | Resident | Resident | Deep Transplant | Resident | Surface Transplant | Resident | Deep Transplant | Resident | Surface Transplant | Resident | Resident | | |
| **Date:** | | 3/2/2003 | 3/8/2012 | 3/8/2012 | 3/8/2012 | 9/3/1997 | 2/25/1999 | 3/12/2012 | 6/19/2007 | 3/8/2012 | 3/8/2012 | 3/8/2012 | 6/19/2007 | 3/8/2012 | 3/8/2012 | 3/8/2012 | 6/19/2007 | 6/19/2007 | 3/2/2003 | 3/3/2003 |
| **Sample Type:** | | N | N | FD | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| **Basis:** | | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet |
| **Percent Moisture** | | NA | 85.00 | 85.00 | 82.00 | NA | 83.80 | 80.00 | NA | 81.00 | 87.00 | 83.00 | NA | 81.00 | 85.00 | 79.00 | NA | NA | NA | NA |
| **Percent Lipid (wet)** | | 1.00 | 2.16 | 1.20 | 1.41 | NA | NA | 2.12 | 0.37 | 1.41 | 1.28 | 1.14 | 0.17 | 1.54 | 1.15 | 1.63 | 0.35 | 0.24 | 0.81 | 1.60 |
| **Parameter** | **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD | ng/g | **150** | **552.02** | **476.77** | **115.22** | 0.25 U | 0.35 U | **1.54 J+** | **79** | **27.27** | **109.66** | **49.62** | **48** | **54.44** | **184.09** | **133.86** | **180** | **120** | **68** | **32,000** |
| 2,4'-DDE | ng/g | ND | **30.5** | **33.01** | **7.54** | 0.26 U | **5.68** | 0.03 U | **7.4 J** | **1** | **8.12** | **2.4** | **3.3 J** | **1.51** | **17.26** | **10.53** | **16 J** | **11 J** | ND | **1,700** |
| 2,4'-DDT | ng/g | **99** | **339.59** | **257.59** | **64.41** | 0.18 U | 0.49 U | **0.15** | **74 J** | **7.78** | **121.79** | **38.09** | **51 J** | **24.03** | **244.84** | **171.88** | **58 NJ** | **55 J** | **59** | **35,000** |
| 4,4'-DDD | ng/g | **390** | **1,370** | **1,127** | **282.08** | **0.38** | **0.68** | **0.34 J+** | **170** | **71.57** | **193.92** | **76.95** | **94** | **115.9** | **295.94** | **201.62** | **460** | **300** | **130** | **21,000** |
| 4,4'-DDE | ng/g | **110** | **570.1** | **592.8** | **107.28** | **0.67** | **2.37** | **1.11** | **79** | **26.96** | **252.64** | **59.37** | **45** | **40.91** | **304.94** | **151.19** | **100** | **81** | **68** | **15,000** |
| 4,4'-DDT | ng/g | **180** | **731.96** | **511.35** | **157.94** | 0.15 U | 0.34 U | **0.05** | **130** | **27.33 J+** | **309.2** | **110.48** | **82** | **56.51** | **538.41** | **423.46** | **80** | **90** | **92** | **31,000** |
| Total DDT | ng/g | **929** | **3,595** | **2,999** | **734.47** | **1.05** | **8.73** | **3.19** | **539.4** | **161.91** | **995.33** | **336.91** | **323.3** | **293.3** | **1,585** | **1,093** | **894** | **657** | **417** | **135,700** |
| Dieldrin | ng/g | **49** | **82.94** | **59.9** | **69.33** | **0.66** | **1.34** | **0.93** | **39** | **9.71** | **27.86** | **33.76** | **24** | **19.66** | **23.48** | **87.36** | **59** | **46** | **20** | **4,000** |

TABLE A-2
**Post-Remedy Mussel Tissue Data**
*United Heckathorn Superfund Site, Richmond, California*

| | |
|---|---|
| **Location:** | **Transect +2_0** |
| **Sample Description:** | **SMPL** |
| **Date:** | **3/3/2003** |
| **Sample Type:** | **N** |
| **Basis:** | **Wet** |
| **Percent Moisture** | **NA** |
| **Percent Lipid (wet)** | **0.79** |

| Parameter | Units | |
|---|---|---|
| **Pesticides** | | |
| 2,4'-DDD | ng/g | **78** |
| 2,4'-DDE | ng/g | ND |
| 2,4'-DDT | ng/g | **120** |
| 4,4'-DDD | ng/g | **130** |
| 4,4'-DDE | ng/g | **86** |
| 4,4'-DDT | ng/g | **200** |
| Total DDT | ng/g | **614** |
| Dieldrin | ng/g | **26** |

Notes:

Detected results are bolded
The total DDTs value is the sum of all six isomers.
FD = field duplicate sample
J = Concentration or reporting limit estimated by laboratory or data validation.
J- = Concentration or reporting limit estimated by laboratory or data validation, biased low
J+ = Concentration or reporting limit estimated by laboratory or data validation, biased high
N = primary sample
ND = Not detected
NA = Not available
ng/g = nanograms per gram
NJ = Estimated and presumptively identified
R = Rejected by laboratory or data validation
U = Not detected at listed reporting limit

TABLE A-3
**Post-Remedy Fish Tissue Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Description:** | Shiner Surfperch | Bay Shrimp | Bay Shrimp | Anchovy | Anchovy | Anchovy | Anchovy | Shiner Surfperch | Shiner Surfperch | Shiner Surfperch | Shiner Surfperch | Shiner Surfperch | Shiner Surfperch | Shiner Surfperch | Shiner Surfperch | Shiner Surfperch | Starry Flounder | Starry Flounder | Halibut | Halibut |
| **Date:** | 5/14/2008 | 5/14/2008 | 5/14/2008 | 5/14/2008 | 5/14/2008 | 5/14/2008 | 5/14/2008 | 5/14/2008 | 5/14/2008 | 5/14/2008 | 5/14/2008 | 5/14/2008 | 5/14/2008 | 5/14/2008 | 5/14/2008 | 5/14/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 |
| **Sample Type:** | N | N | N | N | N | N | N | N | FD | N | N | N | N | N | N | N | N | FD | N | FD |
| **Basis:** | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet |
| **Percent Moisture** | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Percent Lipid (wet)** | 5.00 | 1.70 | 1.60 | 1.80 | 1.60 | 1.40 | 1.30 | 1.40 | 1.40 | 5.30 | 4.80 | 2.90 | 5.00 | 4.50 | 3.30 | 4.00 | 4.70 | 1.90 | 2.00 | |
| **Parameter** | **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD | ng/g | **2.4** | 0.8 U | 0.8 U | **1.2** | **1.2** | **2.4** | **1.3** | **3.6** | **3.9** | **3.8** | **10** | **2.8** | **3** | **4.8** | **4.4** | **1.9** | **2.1** | **1.6** | **2.3** |
| 2,4'-DDE | ng/g | **3 NJ** | 0.8 U | 0.8 U | **2.4** | **2.7** | **2.2** | **2.3 NJ** | 0.8 U | 0.8 U | 0.8 U | 0.8 U | 0.8 U | **3.4 NJ** | **3.9 NJ** | **4.3 NJ** | 0.8 U | 0.8 UJ | **6.1 NJ** | **6.4** |
| 2,4'-DDT | ng/g | **0.93** | 0.8 U | 0.8 U | 0.8 U | 0.8 U | 0.8 U | **1.1 NJ** | **1.5** | **1.7** | **1.5** | **6.9** | **1.4** | **0.99 NJ** | **6.3** | **1.6** | **1.8** | **2** | **0.95 NJ** | **1.2** |
| 4,4'-DDD | ng/g | **11** | **1.5** | **1.5** | **11** | **16** | **14** | **11** | **21** | **21 J** | **19** | **33** | **14 J** | **13** | **19** | **20** | **12** | **14** | **15** | **20** |
| 4,4'-DDE | ng/g | **30** | **6.1** | **7.2** | **14** | **21** | **12** | **13** | **40** | **39 J** | **33** | **34 J** | **39 J** | **38** | **58 J** | **33** | **14** | **16** | **73** | **68** |
| 4,4'-DDT | ng/g | **3.1 NJ** | **0.81 NJ** | **0.8 NJ** | **4 NJ** | **7.1 NJ** | **7.1 NJ** | **4.4 NJ** | **4.5** | **4.6 NJ** | **6.2 NJ** | **8.8 NJ** | **4.5 NJ** | **4.1 NJ** | **19 NJ** | **5.1 NJ** | **4.4** | **5 NJ** | **8.2 NJ** | **8.7** |
| Total DDT | ng/g | **50.43** | **8.41** | **9.5** | **32.6** | **48** | **37.7** | **33.1** | **70.6** | **70.2** | **63.5** | **92.7** | **61.7** | **62.49** | **111** | **68.4** | **34.1** | **39.1** | **104.85** | **106.6** |
| Dieldrin | ng/g | **2.1** | 0.8 U | 0.8 U | **2.3** | **2.7** | **2.2** | **2.3** | **3.2** | **3.3 J** | **5.5 J** | **7.9 J** | **3.6** | **3.9** | **3.9** | **3.3** | **3.1** | **3.5** | **1.4** | **1.6** |

TABLE A-3
**Post-Remedy Fish Tissue Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.01 | 303.03 | 303.03 | 303.03 | 303.03 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Description:** | Halibut | Starry Flounder | Sculpin | Sculpin | Sanddab | Starry Flounder | Halibut | Halibut | Halibut | Starry Flounder | Starry Flounder | Halibut | Halibut | Halibut | Starry Flounder | Shiner Surfperch | Shiner Surfperch | Shiner Surfperch | Starry Flounder |
| **Date:** | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 |
| **Sample Type:** | N | N | N | N | N | N | N | FD | N | N | N | N | FD | N | N | N | FD | N | N |
| **Basis:** | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet |
| **Percent Moisture** | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Percent Lipid (wet)** | 3.20 | 2.80 | 1.40 | 1.60 | 2.80 | 1.50 | 0.40 | 0.30 | 0.60 | 0.70 | 2.66 | 1.02 | NA | 1.84 | 1.79 | 3.10 | 3.30 | 4.70 | 1.30 |
| **Parameter** / **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD / ng/g | **3.2** | **1.5** | 0.8 UJ | 0.81 UJ | **1.2 J** | 0.8 UJ | 0.8 U | 0.8 U | 0.8 U | 0.8 U | **1.09** | **0.9** | **1.19** | **1.74** | **0.97** | **100** | **90** | **190** | **330** |
| 2,4'-DDE / ng/g | **6.2** | **2.4** | 0.8 UJ | 0.81 UJ | 0.8 UJ | 0.8 UJ | **1 NJ** | **1.1** | **1.5** | 0.8 U | 0.4 U | **3.12** | **3.3** | **3.75** | **1.44** | **8.6 J** | **11** | **15 J** | **23 J** |
| 2,4'-DDT / ng/g | **1.5 NJ** | **1.1 NJ** | 0.8 UJ | 0.81 UJ | 0.8 UJ | **0.87 J** | 0.8 U | 0.8 U | 0.8 U | 0.8 U | **1.3** | **0.63** | **0.73** | **0.93** | **0.76** | **140** | **120** | **190** | **180** |
| 4,4'-DDD / ng/g | **30** | **10** | **2.9 J** | **4 J** | **5.9 J** | **4.4 J** | **1.9** | **3** | **5.5** | **2.1** | **7.91** | **7.34** | **10.06** | **17.21** | **6.22** | **150** | **130** | **560** | **1,400** |
| 4,4'-DDE / ng/g | **68 J** | **24** | **4.9 J** | **6 J** | **4.9 J** | **5.4 J** | **7.8** | **8.9** | **12** | **4.5** | **9.38** | **34.87** | **33.44** | **38.77** | **14.66** | **93** | **80** | **760** | **400** |
| 4,4'-DDT / ng/g | **7.7 NJ** | **4 NJ** | **1.1 NJ** | **1.4 NJ** | **2 NJ** | **1.7 NJ** | **1.1 NJ** | **1.4** | **2.1 NJ** | **0.85 NJ** | **2.95** | **4.05** | **4.43** | **4.78** | **2.49** | **110** | **95** | **310** | **410** |
| Total DDT / ng/g | **116.6** | **43** | **8.9** | **11.4** | **14** | **12.37** | **11.8** | **14.4** | **21.1** | **7.45** | **22.42** | **50.43** | **52.68** | **66.76** | **25.97** | **601.6** | **526** | **2,025** | **2,743** |
| Dieldrin / ng/g | **2.5** | **2.4** | 0.8 UJ | **1.1 J** | **2.1 J** | **1.3 J** | 0.8 U | 0.8 U | 0.8 U | 0.8 U | **2.13** | **0.82** | **0.9** | **1.4** | **1.44** | **280** | **240** | **130** | **180** |

TABLE A-3
**Post-Remedy Fish Tissue Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Description:** | Sculpin | Sculpin | Sculpin | Sculpin | Anchovy | Anchovy | Anchovy | Goby | Shiner Surfperch | Shiner Surfperch | Shiner Surfperch | Starry Flounder | Sculpin | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt |
| **Date:** | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 |
| **Sample Type:** | N | N | FD | N | N | N | N | N | N | N | N | N | N | N | N | N | FD | N | N |
| **Basis:** | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet |
| **Percent Moisture** | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Percent Lipid (wet)** | 1.90 | 1.50 | 1.30 | 1.40 | 1.70 | 1.80 | 1.50 | 1.50 | 4.80 | 4.30 | 4.10 | 1.60 | 1.40 | 1.00 | 4.80 | 4.20 | 3.50 | 3.40 | 1.70 |
| **Parameter** / **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD ng/g | 89 | 130 | 110 | 98 | 46 | 63 | 46 | 360 | 1,500 | 1,000 | 710 | 490 | 58 | 1.2 NJ | 56 | 40 | 43 | 34 | 4.5 |
| 2,4'-DDE ng/g | 7.2 J | 12 | 13 J | 6.5 J | 4.8 J | 5.1 J | 3.7 J | 20 J | 68 NJ | 110 NJ | 43 J | 51 J | 5.5 J | 1.3 J | 9.8 J | 13 | 11 J | 11 J | 4.3 J |
| 2,4'-DDT ng/g | 39 | 66 | 54 | 28 | 21 | 35 | 29 | 23 | 88 | 390 | 98 | 100 | 25 | 0.86 | 23 | 29 | 31 | 29 | 3 |
| 4,4'-DDD ng/g | 680 | 920 | 880 | 540 | 370 | 420 | 270 | 4,800 | 7,500 | 6,100 | 5,800 | 4,300 | 460 | 11 J | 670 | 570 | 660 | 950 | 84 |
| 4,4'-DDE ng/g | 94 | 270 | 250 | 110 | 97 | 90 | 71 | 410 | 850 J | 2,200 | 750 | 1,400 | 66 | 28 | 170 | 220 | 230 | 280 | 84 |
| 4,4'-DDT ng/g | 170 | 250 | 250 | 110 | 150 | 120 | 77 | 250 | 210 | 1,200 | 280 | 380 | 130 | 6.4 | 140 | 220 | 220 | 310 | 35 |
| Total DDT ng/g | 1,079 | 1,648 | 1,557 | 892.5 | 688.8 | 733.1 | 496.7 | 5,863 | 10,216 | 11,000 | 7,681 | 6,721 | 744.5 | 48.76 | 1,069 | 1,092 | 1,195 | 1,614 | 214.8 |
| Dieldrin ng/g | 130 | 110 | 98 | 110 | 66 | 69 | 55 | 320 | 550 | 260 | 330 | 300 | 72 | 14 | 390 | 330 | 340 | 340 | 30 |

TABLE A-3
**Post-Remedy Fish Tissue Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.03 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample Description: | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Starry Flounder | Sculpin | Sanddab | Sanddab | Sanddab | Bay Shrimp | Bay Shrimp | Bay Shrimp |
| Date: | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 |
| Sample Type: | N | N | N | N | N | FD | N | N | N | N | N | N | N | N | N | N | N | N | N |
| Basis: | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet |
| Percent Moisture | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Percent Lipid (wet) | 0.50 | 0.20 | 0.80 | 0.90 | 4.30 | 0.50 | 0.76 | 2.82 | 2.74 | 2.25 | 2.78 | 1.60 | 1.40 | 2.50 | 1.80 | 2.40 | 1.60 | 1.50 | 1.40 |
| **Parameter** **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD ng/g | **0.84 NJ** | **12** | **7.2** | **8.9** | **1.9** | **2.1** | **1.03** | **37.06** | **25.93** | **22.42** | **3.42** | **6** | **1.7 J** | **4.8 J** | **3.7 J** | **7 J** | **0.82 J** | **1.5 NJ** | **1.2** |
| 2,4'-DDE ng/g | 0.8 U | **2.3 J** | **2.4 J** | **2.9 J** | **2** | **2.2 J** | **0.88** | **6.57** | **8.45** | **7.26** | **3.34** | 0.8 U | 0.8 UJ | 0.8 UJ | 0.8 UJ | 0.8 UJ | 0.8 UJ | 0.8 U | 0.8 U |
| 2,4'-DDT ng/g | 0.8 U | **5.2** | **5.4** | **8.1** | **1.2** | **1.5** | **0.64** | **15.34** | **18.88** | **19.36** | **2.25** | **4.1 J** | **2.3** | **2.4 J** | **2.5 J** | **4.5 J** | 0.8 UJ | 0.8 U | 0.8 U |
| 4,4'-DDD ng/g | **7** | **140** | **120** | **220** | **35** | **39** | **9.11** | **441.83** | **376.98** | **613.13** | **63.58** | **31 J** | **31 J** | **26 J** | **26 J** | **48** | **4.9 J** | **7.4 J** | **4.9 J** |
| 4,4'-DDE ng/g | **17** | **39** | **44** | **74** | **37** | **41** | **22.81** | **113.6** | **144.51** | **184.94** | **64.41** | **39** | **49** | **26 J** | **26 J** | **50** | **19 J** | **33 J** | **35 J** |
| 4,4'-DDT ng/g | **3.5 NJ** | **34** | **43** | **84** | **14** | **15** | **5.03** | **94.37** | **144.08** | **205.71** | **26.25** | **14 J** | **16 J** | **6.7 J** | **7.7 J** | **15 J** | **2.4 J** | **4.1** | **2.8** |
| Total DDT ng/g | **28.34** | **232.5** | **222** | **397.9** | **91.1** | **100.8** | **39.12** | **708.76** | **718.83** | **1,053** | **163.25** | **94.1** | **100** | **65.9** | **65.9** | **124.5** | **27.12** | **46** | **43.9** |
| Dieldrin ng/g | **10** | **90** | **70** | **96** | **13** | **14** | **12.11** | **260.85** | **218.48** | **227.4** | **22.92** | **8.5** | **5.9** | **4.9 J** | **4.7 J** | **8.9** | **1.1 J** | **1.5** | **1.4** |

TABLE A-3
**Post-Remedy Fish Tissue Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Description:** | Bay Shrimp | Bay Shrimp | Goby | Starry Flounder | Starry Flounder | Starry Flounder | Starry Flounder | Starry Flounder | Starry Flounder | Starry Flounder | Shiner Surfperch | Shiner Surfperch | Shiner Surfperch | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt |
| **Date:** | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 |
| **Sample Type:** | N | N | N | N | N | N | N | N | N | FD | N | N | N | N | N | N | N | N | N |
| **Basis:** | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet |
| **Percent Moisture** | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Percent Lipid (wet)** | 1.50 | 1.50 | 1.40 | 1.70 | 2.00 | 1.70 | 2.00 | 1.90 | 1.80 | 1.80 | 4.30 | 2.50 | 4.90 | 3.40 | 3.90 | 6.00 | 1.30 | 1.80 | 4.10 |
| **Parameter** **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD ng/g | **1.6** | **1.3** | **3.7** | **8** | **16** | **9.9** | **4.6 J** | **6.7 J** | **5.7** | **5.7** | **11 J** | 3 UJ | **12** | **8.5** | **8.7** | **8.4** | **2.2** | **7.2** | **1.8** |
| 2,4'-DDE ng/g | 0.8 U | 0.8 U | 0.8 U | 0.8 U | **8.1 J** | **7.3 J** | 0.8 UJ | 0.81 UJ | 0.8 U | 0.8 U | 0.8 UJ | 0.8 UJ | 0.8 UJ | **7.8 J** | **3.3 J** | **9.2 J** | **4.7 J** | **2.7** | **1.6** |
| 2,4'-DDT ng/g | **1.6** | **1.5** | **2.2** | **6.1** | **15** | **8.1** | **2.8 J** | **4.3 J** | **5.2** | **5.1** | **10 J** | 0.8 UJ | **6.4** | **3** | **4.2** | **3.8** | **1.1 NJ** | **6.9** | 0.79 U |
| 4,4'-DDD ng/g | **6.2 J** | **5.1 J** | **39 J** | **46** | **80 J** | **59 J** | **29 J** | **47 J** | **38** | **49 J** | **49** | **11 J** | **88** | **78** | **42** | **120** | **43** | **34 J** | **9 J** |
| 4,4'-DDE ng/g | **32** | **35** | **32** | **52 J** | **58 J** | **56 J** | **29 J** | **52 J** | **39** | **53 J** | **57** | **13 J** | **140** | **52** | **37** | **79** | **89** | **30** | **35** |
| 4,4'-DDT ng/g | **3.5 NJ** | **3.8 NJ** | **12 NJ** | **24 NJ** | **33 J** | **22 J** | **9.1 NJ** | **13 NJ** | **18** | **17** | **16 J** | **2.1 NJ** | **26 NJ** | **18 NJ** | **13** | **25** | **20 NJ** | **16** | **3.1 NJ** |
| Total DDT ng/g | **44.9** | **46.7** | **88.9** | **136.1** | **210.1** | **162.3** | **74.5** | **123** | **105.9** | **129.8** | **143** | **26.1** | **272.4** | **167.3** | **108.2** | **245.4** | **160** | **96.8** | **50.5** |
| Dieldrin ng/g | **1.7** | **1.5 NJ** | **6.5** | **9 J** | **18** | **12** | **5.4 J** | **9.7** | **6.2** | **6.2** | **13 J** | **5 J** | **16** | **45** | **19** | **66** | **22** | **24** | **7** |

TABLE A-3
**Post-Remedy Fish Tissue Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.04 | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Description:** | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Sculpin | Sculpin | Sculpin | Sculpin | Sculpin | Sculpin |
| **Date:** | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 6/12/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 |
| **Sample Type:** | N | N | N | N | N | FD | N | N | N | N | N | N | N | N | N | N | N | N | N |
| **Basis:** | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet |
| **Percent Moisture** | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Percent Lipid (wet)** | 1.10 | 1.00 | 1.00 | 0.60 | 0.30 | 0.60 | 1.30 | 2.33 | 2.67 | 3.88 | 0.97 | 1.18 | 2.83 | 1.20 | 1.10 | 1.10 | 1.50 | 1.10 | 0.90 |
| **Parameter** **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD ng/g | 3 | 2.5 | 1.5 | 0.87 | 0.8 U | 0.8 U | 0.79 U | 5.94 | 6.06 | 5.47 | 1.58 | 4.4 | 1.16 | 8.1 | 13 | 4.8 | 14 | 6.2 | 7.5 |
| 2,4'-DDE ng/g | 2.9 J | 0.8 U | 2 J | 2.1 J | 1.4 | 1.4 | 0.79 U | 5.52 | 2.07 | 6.15 | 3.48 | 2.16 | 1.05 | 210 J | 15 J | 6.4 J | 30 J | 19 J | 7.7 |
| 2,4'-DDT ng/g | 1.1 | 1.2 | 0.8 U | 0.8 U | 0.8 U | 0.8 U | 0.79 U | 2.12 | 2.92 | 2.36 | 0.77 | 4.22 | 0.4 U | 21 | 9.4 | 8.9 | 22 | 14 | 14 |
| 4,4'-DDD ng/g | 25 | 12 | 20 | 17 | 12 J | 11 | 3.3 J | 53.35 | 29.23 | 77.6 | 30.85 | 24.93 | 6.41 | 120 | 200 | 82 | 260 | 97 | 93 |
| 4,4'-DDE ng/g | 18 | 9.9 | 14 | 38 | 11 | 10 | 10 | 36.18 | 25.46 | 51.44 | 65.16 | 22.17 | 23.66 | 200 NJ | 200 | 120 | 350 | 150 | 130 |
| 4,4'-DDT ng/g | 6.1 NJ | 3.9 | 4.6 NJ | 7.9 NJ | 2.6 NJ | 2.4 | 1.1 NJ | 12.46 | 9.13 | 16.35 | 14.34 | 10.48 | 2.19 | 120 NJ | 60 | 65 | 140 | 80 | 90 |
| Total DDT ng/g | 56.1 | 29.5 | 42.1 | 65.87 | 27 | 24.8 | 14.4 | 115.57 | 74.7 | 159.2 | 116 | 68.03 | 34.12 | 679.1 | 497.4 | 287.1 | 816 | 366.2 | 345.1 |
| Dieldrin ng/g | 15 | 5.8 | 12 | 8.3 | 9.4 | 8.9 | 2.4 | 31.05 | 13.38 | 43.1 | 15.6 | 17.98 | 4.91 | 9.8 NJ | 15 | 6.5 | 17 | 7.6 | 7.7 |

TABLE A-3
**Post-Remedy Fish Tissue Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 | 303.06 | 303.07 | 303.07 | 303.07 | 303.07 | 303.07 | 303.07 | 303.07 | 303.07 | UH-F-01 | UH-F-02 | UH-F-03 | UH-F-04 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Description:** | Sculpin | Walleyed Perch | Walleyed Perch | Walleyed Perch | Walleyed Perch | Walleyed Perch | Sculpin | Anchovy | Anchovy | Anchovy | Flounder/go by | Sculpin | Bay Shrimp | Bay Shrimp | Bay shrimp | Barred Surfperch | Barred Surfperch | Barred Surfperch | Barred Surfperch |
| **Date:** | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 5/15/2008 | 11/22/2013 | 11/22/2013 | 11/21/2013 | 11/21/2013 |
| **Sample Type:** | FD | N | N | FD | N | N | N | N | N | N | N | N | N | N | FD | N | N | N | N |
| **Basis:** | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet |
| **Percent Moisture** | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 71.63 | 71.68 | 75.47 | 73.58 |
| **Percent Lipid (wet)** | 1.20 | 3.70 | 3.90 | 4.20 | 4.50 | 3.40 | 1.60 | 2.60 | 6.50 | 6.50 | 2.10 | 1.90 | 1.40 | 1.50 | 1.40 | 3.04 | 1.67 | 2.73 | 3.23 |
| **Parameter** / **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD ng/g | 9.5 | 17 | 12 | 12 | 5.8 | 11 | 30 | 2.4 NJ | 2.2 | 3.6 | 2.8 | 4.4 | 0.87 | 1.1 | 1.3 | 1.89 | 1.35 | 12.51 | 14.56 |
| 2,4'-DDE ng/g | 8.7 | 12 | 7.5 | 8.4 | 4.6 | 8 | 52 NJ | 4.1 J | 0.8 U | 4.5 J | 0.8 U | 0.8 U | 0.8 U | 0.8 U | 0.8 U | 0.09 J | 0.07 J | 0.64 | 0.71 |
| 2,4'-DDT ng/g | 17 | 14 | 3.5 | 4.1 | 1.7 | 4.9 | 19 | 0.8 U | 0.8 U | 1.2 NJ | 2.3 | 1.8 | 0.8 U | 0.8 U | 0.8 U | 0.59 J- | 0.47 J- | 3.31 J- | 3.87 J- |
| 4,4'-DDD ng/g | 110 | 95 | 52 | 58 | 28 | 63 | 540 | 9.6 | 7.9 | 12 | 21 J | 32 | 3.6 | 4.8 | 4.1 J | 10.17 | 10.28 | 101.96 | 172.87 |
| 4,4'-DDE ng/g | 150 | 110 | 67 | 78 | 41 | 75 | 530 | 17 | 21 | 21 | 19 J | 37 J | 19 | 28 | 30 NJ | 15.07 | 17.82 | 124.85 | 206.34 |
| 4,4'-DDT ng/g | 110 | 52 J | 16 | 20 NJ | 7.6 NJ | 23 NJ | 120 NJ | 2.9 NJ | 2.3 NJ | 2.7 NJ | 8.4 J | 8.8 NJ | 1.7 J | 2.1 | 2.1 J | 1.76 | 1.99 | 27.83 | 29.17 |
| Total DDT ng/g | 405.2 | 300 | 158 | 180.5 | 88.7 | 184.9 | 1,291 | 36 | 33.4 | 45 | 53.5 | 84 | 25.17 | 36 | 37.5 | 29.57 | 31.98 | 271.1 | 427.52 |
| Dieldrin ng/g | 9.3 | 19 | 15 | 16 | 9.1 | 14 | 32 | 3.1 | 3.2 | 5.7 | 3.4 NJ | 6.6 J | 0.81 | 0.85 | 0.91 | 1.09 | 1.23 | 14.74 | 13.46 |

TABLE A-3
**Post-Remedy Fish Tissue Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | UH-F-05 | UH-F-06 | UH-F-07 | UH-F-08 | UH-F-09 | UH-F-10 | UH-F-11 | UH-F-12 | UH-F-13 | UH-F-14 | UH-F-15 | UH-F-16 | UH-F-17 | UH-F-18 | UH-F-19 | UH-F-20 | UH-F-21 | UH-F-22 | UH-F-23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample Description: | Barred Surfperch | Barred Surfperch | Jacksmelt | White Surfperch | Barred Surfperch | Barred Surfperch | White Surfperch | Barred Surfperch | Barred Surfperch | Barred Surfperch | Jacksmelt | Jacksmelt | White Surfperch | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | White Surfperch | Shiner Surfperch |
| Date: | 11/22/2013 | 11/21/2013 | 11/20/2013 | 11/21/2013 | 11/21/2013 | 11/21/2013 | 11/21/2013 | 11/21/2013 | 11/21/2013 | 11/22/2013 | 11/20/2013 | 11/20/2013 | 11/21/2013 | 11/20/2013 | 11/20/2013 | 11/20/2013 | 11/20/2013 | 11/21/2013 | 11/21/2013 |
| Sample Type: | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| Basis: | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet |
| Percent Moisture | 77.78 | 72.79 | 71.43 | 76.32 | 81.20 | 71.43 | 77.97 | 78.00 | 75.68 | 74.13 | 75.00 | 73.28 | 75.16 | 75.86 | 77.12 | 72.28 | 71.03 | 74.31 | 72.22 |
| Percent Lipid (wet) | 0.32 | 3.72 | 5.35 | 5.09 | 0.22 | 4.63 | 1.51 | 0.33 | 0.78 | 2.08 | 1.64 | 1.73 | 4.42 | 1.16 | 1.49 | 3.56 | 2.03 | 2.47 | 7.22 |
| **Parameter** / **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD | ng/g | 1.51 | 17.69 | 1.53 | 9.54 | 3.75 | 15.88 | 0.93 | 2.61 | 8.75 | 2.3 | 32.53 | 2.73 | 6.81 | 2.14 | 0.29 | 1.19 | 0.4 | 13.48 | 51.23 |
| 2,4'-DDE | ng/g | 0.12 J | 0.84 | 0.13 | 0.66 | 0.16 | 0.98 | 0.26 | 0.07 J | 0.33 | 0.08 J | 2.8 | 0.47 | 0.56 | 0.32 | 0.05 J | 0.12 J | 0.07 J | 0.89 | 4.98 |
| 2,4'-DDT | ng/g | 0.62 J- | 5.02 J- | 0.35 J- | 3.22 J- | 0.76 J- | 2.76 J- | 0.61 J- | 0.78 J- | 2.6 J- | 0.67 J- | 16.35 J- | 1.39 J- | 2.65 J- | 1.01 J- | 0.11 J- | 0.3 J- | 0.13 J- | 3.88 J- | 11.74 J- |
| 4,4'-DDD | ng/g | 19.14 J+ | 230.18 | 9.86 | 149.77 | 34.14 | 140.58 | 5.67 | 34.28 | 85.49 | 13.58 | 355.95 | 48.03 | 108.29 J+ | 72.36 | 1.33 | 6.32 | 1.91 | 135.41 | 215.75 |
| 4,4'-DDE | ng/g | 26.02 | 240.89 | 13.79 | 170.16 | 57.67 | 158.52 | 11.05 | 63.56 | 100.18 | 21.77 | 140.73 | 56.09 | 149.06 J+ | 30.2 | 2.55 | 6.6 | 4.02 | 123.2 J+ | 241.42 |
| 4,4'-DDT | ng/g | 2.86 | 39.09 | 1.29 | 20.78 | 5.77 | 21.66 | 0.5 | 9.96 | 20.38 | 1.77 | 88.87 | 8.69 | 15.67 | 6.54 | 0.12 J | 1.04 | 0.29 | 37.47 | 41.39 |
| Total DDT | ng/g | 50.27 | 533.71 | 26.95 | 354.13 | 102.25 | 340.38 | 19.02 | 111.26 | 217.73 | 40.17 | 637.23 | 117.4 | 283.04 | 112.57 | 4.45 | 15.57 | 6.82 | 314.33 | 566.51 |
| Dieldrin | ng/g | 0.93 | 14.13 | 1.85 | 11.64 | 3.36 | 18.23 | 0.62 | 1.56 | 6.9 | 2.03 | 34.9 | 5.26 | 9.34 | 1.94 | 0.39 | 1.3 | 0.61 | 10.41 | 23.06 |

TABLE A-3
**Post-Remedy Fish Tissue Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | UH-F-24 | UH-F-25 | UH-F-26 | UH-F-27 | UH-F-28 | UH-F-29 | UH-F-30 | UH-F-31 | UH-F-32 | UH-F-33 | UH-F-34 | UH-F-35 | UH-F-36 | UH-F-37 | UH-F-38 | UH-F-39 | UH-F-40 | UH-F-41 | UH-F-42 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample Description: | Shiner Surfperch | Shiner Surfperch | Shiner Surfperch | Shiner Surfperch | Shiner Surfperch | Shiner Surfperch | Shiner Surfperch | Jacksmelt | Jacksmelt | Jacksmelt | White Surfperch | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Jacksmelt | Barred Surfperch | Barred Surfperch |
| Date: | 11/21/2013 | 11/21/2013 | 11/21/2013 | 11/21/2013 | 11/21/2013 | 11/21/2013 | 11/21/2013 | 11/20/2013 | 11/20/2013 | 11/20/2013 | 11/20/2013 | 11/20/2013 | 11/20/2013 | 11/20/2013 | 11/20/2013 | 11/20/2013 | 11/20/2013 | 11/21/2013 | 11/21/2013 |
| Sample Type: | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| Basis: | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet | Wet |
| Percent Moisture | 70.75 | 72.38 | 70.63 | 69.81 | 67.77 | 71.68 | 67.92 | 71.30 | 70.87 | 70.47 | 80.30 | 74.53 | 66.97 | 72.48 | 68.81 | 72.37 | 70.37 | 81.55 | 81.25 |
| Percent Lipid (wet) | 10.18 | 8.48 | 12.05 | 9.24 | 9.43 | 6.61 | 9.46 | 4.43 | 11.48 | 8.26 | 1.75 | 6.65 | 11.77 | 7.60 | 9.38 | 8.57 | 7.42 | 0.20 | 0.28 |
| **Parameter** **Units** | | | | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | | | |
| 2,4'-DDD ng/g | 51.39 | 33.63 | 70.08 | 49.43 | 43.51 | 39.18 | 48.67 | 3.27 | 1.47 | 12.86 | 14.75 | 12.93 | 7.55 | 7.44 | 12.87 | 9.45 | 13.58 | 3.24 | 4.65 |
| 2,4'-DDE ng/g | 3.71 | 2.46 | 4.87 | 2.53 | 1.96 | 2.23 | 4.68 | 0.4 | 0.19 | 0.95 | 0.91 | 1.66 | 0.65 | 0.83 | 1.75 | 0.78 | 1.82 | 0.09 J | 0.18 |
| 2,4'-DDT ng/g | 11.12 J- | 10.9 J- | 16.91 J- | 11.04 J- | 8.74 J- | 10.69 J- | 10.37 J- | 0.8 J- | 0.5 J- | 4.69 J- | 4.62 J- | 6.44 J- | 1.51 J- | 1.72 J- | 6.11 J- | 1.9 J- | 4.24 J- | 0.68 J- | 0.8 J- |
| 4,4'-DDD ng/g | 255.19 | 182.07 | 335.98 | 302.2 | 230.32 J+ | 200.8 | 236.98 | 28.33 | 12.37 | 104.48 | 218.51 J+ | 176.74 J+ | 44.03 | 50.89 | 294.25 | 78.39 | 226.89 | 27.35 | 40.3 |
| 4,4'-DDE ng/g | 249.16 | 193.73 | 308.2 | 292.82 | 247.43 J+ | 219.38 | 255.5 | 36.76 | 20.43 | 112.55 | 276.95 | 189.14 | 48.49 | 56.14 | 345.47 | 92.57 | 219.94 | 61.11 | 52.85 |
| 4,4'-DDT ng/g | 35.92 | 38.39 | 53.32 | 38.01 | 28.71 | 40.11 | 32.95 | 3.82 | 4.04 | 28.17 | 49.63 | 42.35 | 5.26 | 7.83 | 55.77 | 9.41 | 34.93 | 6.8 | 6.37 |
| Total DDT ng/g | 606.49 | 461.18 | 789.36 | 696.03 | 560.67 | 512.39 | 589.15 | 73.38 | 39 | 263.7 | 565.37 | 429.26 | 107.49 | 124.85 | 716.22 | 192.5 | 501.4 | 99.27 | 105.15 |
| Dieldrin ng/g | 26.3 | 20.76 | 36.61 | 24 | 24.6 | 19.35 | 23.41 | 6.03 | 1.75 | 16.99 | 13.04 | 20.93 | 8.98 | 8.91 | 15.67 | 14.36 | 25.1 | 3.22 | 3.56 |

TABLE A-3
**Post-Remedy Fish Tissue Data**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | | UH-F-43 | UH-F-44 | UH-F-45 |
|---|---|---|---|---|
| Sample Description: | | Barred Surfperch | Barred Surfperch | Barred Surfperch |
| Date: | | 11/21/2013 | 11/21/2013 | 11/21/2013 |
| Sample Type: | | N | N | N |
| Basis: | | Wet | Wet | Wet |
| Percent Moisture | | 78.18 | 77.21 | 76.69 |
| Percent Lipid (wet) | | 0.35 | 2.70 | 2.94 |
| **Parameter** | **Units** | | | |
| **Pesticides** | | | | |
| 2,4'-DDD | ng/g | **2.1** | **14.84** | **20.26** |
| 2,4'-DDE | ng/g | **0.13** | **0.92** | **1.26** |
| 2,4'-DDT | ng/g | **0.66 J-** | **3.91 J-** | **4.49 J-** |
| 4,4'-DDD | ng/g | **16.81** | **178.57** | **156.44** |
| 4,4'-DDE | ng/g | **21.57** | **206.01** | **176.27** |
| 4,4'-DDT | ng/g | **4.42** | **31.08** | **36.51** |
| Total DDT | ng/g | **45.69** | **435.33** | **395.23** |
| Dieldrin | ng/g | **2.09** | **10.34** | **13.59** |

Notes:

Detected results are bolded
The total DDTs value is the sum of all six isomers.
FD = field duplicate sample
J = Concentration or reporting limit estimated by laboratory or data validation
J- = Concentration or reporting limit estimated by laboratory or data validation, biased low
J+ = Concentration or reporting limit estimated by laboratory or data validation, biased high
N = primary sample
NA = Not available
ng/g = nanograms per gram
NJ = Estimated and presumptively identified

# Appendix B
# Source Identification Study

*Final*

# Source Identification Study Report United Heckathorn Superfund Site

Prepared for

United States Environmental Protection Agency, Region 9

March 2014

CH2MHILL®

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# Acronyms and Abbreviations

| | |
|---|---|
| µg/kg | micrograms per kilogram |
| µg/L | micrograms per liter |
| ATSDR | Agency for Toxic Substances and Disease Registry |
| CSM | conceptual site model |
| CWM | Chemical Waste Management Inc. |
| DDD | dichlorodiphenyldichloroethane |
| DDE | dichlorodiphenyldichloroethene |
| DDT | dichlorodiphenyltrichloroethane |
| DTSC | Department of Toxic Substances Control |
| ERA | ecological risk assessment |
| ETS | Environmental Technical Services |
| $ft^2$/day | square feet per day |
| FFS | focused feasibility study |
| g | gram |
| GIS | global information system |
| HLA | Harding Lawson Associates |
| K | hydraulic conductivity |
| KLI | Kinnetic Laboratories, Inc. |
| $K_{oc}$ | sediment-water partition coefficient |
| $K_{ow}$ | octanol-water partition coefficients |
| LRTC | Levin Richmond Terminal Corporation |
| mg/kg | milligrams per kilogram |
| MLLW | mean lower low water |
| MSL | mean sea level |
| NAVD88 | North American Vertical Datum of 1988 |
| OBM | Older Bay Mud |
| PVC | polyvinyl chloride |
| RMP | Regional Monitoring Program |
| RI | remedial investigation |
| ROD | Record of Decision |
| SAP | sampling and analysis plan |
| SFEI | San Francisco Estuary Institute |
| SF USACE | United States Army Corps of Engineers San Francisco District |
| SVOC | semivolatile organic compound |
| USACE | United States Army Corps of Engineers |
| USEPA | United States Environmental Protection Agency |
| VOC | volatile organic compound |
| YBM | Younger Bay Mud |

SECTION 1

# Introduction

This report presents the results of the source identification study that was performed for the United Heckathorn Superfund Site in Richmond, California, to identify and quantify if possible any ongoing source(s) of contamination to the Lauritzen Channel as part of a Focused Feasibility Study (FFS). The study focused on identifying the source(s) of the DDT[1] and Dieldrin that have been consistently measured in sediment, surface water, and biota in the Lauritzen Channel since the remedy was completed in 1997. The potential ongoing sources of contamination that were evaluated include the following:

1. Embankments (e.g., point source discharges from pipes, outfalls, and seeps and/or erosion of DDT-contaminated embankment soils)
2. Groundwater discharge from the upland portion of the site into the Lauritzen Channel
3. DDT-contaminated wood pilings
4. Stormwater outfalls
5. Sources outside of the Lauritzen Channel
6. Dredging residuals

Each potential source was evaluated using historical information, data from previous source investigations and other post-remediation studies, and new data that were collected in 2012 and 2013. The previous investigations will be summarized in more detail in the forthcoming FFS. The 2012-2013 data were collected as outlined the *Focused Feasibility Study Data Gaps Sampling and Analysis Plan Addendum #2 – Source Identification Study, United Heckathorn Superfund Site* (SAP Addendum) (CH2M HILL, 2013a). The results of the source identification study will be evaluated in conjunction with the results of the Tier 1 and Tier 2 sediment transport studies, the DDT fate and transport study, long-term monitoring data, and data from previous investigations to refine the conceptual site model (CSM) for the United Heckathorn site and identify any necessary source control measures for consideration in the FFS.

## 1.1 Site History

The United Heckathorn Superfund Site is located in Richmond Harbor on the east side of San Francisco Bay in Richmond, California (Figure 1-1). The site includes the former United Heckathorn facility where organochlorine pesticides were processed, packaged, and shipped and the adjacent waterways affected by releases from the former facility. A Record of Decision (ROD) that presented the selected remedial action for the site was issued in 1994 (United States Environmental Protection Agency [USEPA], 1994). Remediation activities for the upland portion of the site consisted of excavation and offsite disposal of contaminated soil (from 1982 to 1993), and placement of concrete and geotextile/gravel caps (from 1998 to 1999) over approximately 4.5 acres of Levin Richmond Terminal Corporation's (LRTC) upland soils to prevent erosion and collect surface runoff (USEPA, 2001). Remediation activities for the waterways were performed in 1996 and 1997 and consisted of (1) dredging and offsite disposal of sediment from the Lauritzen Channel and Parr Canal and (2) placement of clean sand in the channels to promote the recovery of the benthic community. However, post-dredging monitoring of surface water and sediment has indicated that the remediation levels specified in the ROD have not been maintained (USEPA, 2011).

[1] DDT is defined as the sum of 2,4'- and 4,4'-dichlorodiphenyltrichloroethane (DDT); 2,4'- and 4,4'-dichlorodiphenyldichloroethane (DDD); and 2,4'- and 4,4'-dichlorodiphenyldichloroethene (DDE)

## 1.2 Report Organization

This report is organized into the following sections:

**Section 1, Introduction.** Provides background information and an overview of the study objectives.

**Section 2, Field Investigations.** Summarizes the scope of the field activities performed for the source identification study, including descriptions of the sample collection and analytical methods.

**Sections 3 through 8** present an evaluation of each potential source, including the objectives and approach, background, and lines of evidence and findings, as follows:

3. **Embankments**
4. **Groundwater Discharge**
5. **Wood Pilings**
6. **Stormwater Outfalls**
7. **Source Material Outside of the Lauritzen Channel**
8. **Dredging Residuals**

**Section 9, Conclusions.** Identifies the sources that were determined most likely to be responsible for the majority of the DDT mass currently found in Lauritzen Channel sediments, and the ongoing sources that could potentially recontaminate the channel in the future if not controlled.

**Section 10, References.** Provides references cited in this report.

**Appendix A** provides supporting detail for the groundwater discharge evaluation.

SECTION 2

# Field Investigations

This section provides an overview of the field work performed for the source identification study in accordance with the SAP Addendum (CH2M HILL, 2013a). Additional details related to the field investigations are provided in the field summary reports (CH2M HILL, 2013b; 2013c; 2013d; and 2013e). The results of these field investigations are incorporated into the evaluation of each potential source in Sections 3 through 8.

## 2.1 Site Survey

A site survey was performed on November 29 and December 10, 2012, to document present-day site conditions on a comprehensive map of shoreline and embankment features. This survey was also used to verify the locations of selected major features to assure accuracy within the global information system (GIS) database. The eastern side of the Lauritzen Channel was inspected by boat and on foot to locate potential point sources of contamination, including outfall pipes, breaks in the sheet pile walls, and other features that potentially could act as preferential pathways for contaminant transport into the channel.

## 2.2 Sediment Sampling

Surface sediment grab and sediment core samples were collected in March and April 2013 to assess the present-day nature and extent of contamination and determine the thickness of the DDT-contaminated sediment layer in the Lauritzen Channel. Sediment sample locations are shown in Figure 2-1.[2]

Grab samples were collected near the head of the channel and along the eastern embankment to evaluate potential ongoing sources from the embankment (i.e., embankment soil erosion and/or discharges from pipes or seeps). Eleven of the fourteen grab samples were unbiased and were collected near the head of the channel and along the eastern embankment (between pilings and under the Levin pier). The other three grab samples were biased and were collected at locations previously identified as potential ongoing sources: one outfall (SD13-12 at T -27.5, one former seep (SD13-17 at T -8.5), and a hot spot under the Levin pier identified in the Phase I source investigation (SD13-22 at T+2.5) (Kohn and Evans, 2002).

Five grab samples also were collected along the northwest shoreline of the Lauritzen Channel in September 2013 to investigate potential shoreline sources to channel sediments in this area. Samples from locations EMB13-01 through EMB13-04 were collected near the tide line, and the sample from EMB13-05 was an upland embankment soil sample.

Vibracore samples were collected from the Lauritzen Channel and Santa Fe Channel to delineate the extent and volume of the contaminated Younger Bay Mud (YBM). A total of 24 sediment cores were collected from a sampling grid in the Lauritzen Channel and 3 cores were collected in the Santa Fe Channel. The target coring depth was 8 feet below the sediment surface, which was estimated to be sufficient to reach the contact between the YBM and the underlying Older Bay Mud (OBM). Field measurements associated with the sediment core collection, including water depth, sediment surface elevation, and thickness of the YBM layer, are provided in Table 2-1. The nature and extent of contamination based on the 2013 sample results will be discussed in the forthcoming FFS.

[2] A transect numbering system was established along the eastern shoreline by LRTC based on “bent” numbers assigned to the rows of pilings supporting the Levin pier. Each row of pilings is assigned a whole number, starting with +1 at the north end of the pier. The bent numbers range from +1 to +73 from north to south along the Levin pier, and from +1 to -45 from south to north, north of the Levin pier. Abandoned rows of pilings abut the shoreline north of the Levin pier, where the pier deck has been removed. Locations between pilings are preceded by the letter “T” for transect.

## 2.3 Groundwater Sampling and Hydraulic Characterization

Groundwater sampling and hydraulic testing were conducted in March 2013 to evaluate the potential for DDT transport into the Lauritzen Channel by groundwater discharge from the upland part of the site. Groundwater samples were collected from ten temporary soil borings and two monitoring well locations as shown in Figure 2-2. The borings and monitoring wells were located to provide systematic spatial coverage along the shoreline adjacent to the former plant site and to target areas where the highest DDT and Dieldrin concentrations had been measured historically in embankment soils. The borings were drilled to a depth of at least 10 feet below the water table and 10-foot screens were installed to allow sufficient borehole length to obtain the required volume of water for sampling.

Two sets of paired, flush-mounted monitoring wells were installed for hydraulic testing, as shown in Figure 2-2. The wells were constructed using 2-inch-diameter, Schedule 40 polyvinyl chloride (PVC) casing and screen. All wells had a 10-foot screen interval. Groundwater samples were collected from two of the wells (MW13-01 and MW13-03).

All groundwater samples were analyzed for total and dissolved DDT and Dieldrin, total and dissolved semivolatile organic compounds (SVOCs), and volatile organic compounds (VOCs). Field parameters are provided in Table 2-2.

Slug tests were performed on each of the four monitoring wells on March 26, 2013, to estimate hydraulic conductivity of subsurface soils and groundwater flow velocities. Two “slug in” and two “slug out” tests were performed on each well. The replicate tests from each well provided substantially similar results; therefore, only one slug in and one slug out test was evaluated for each well. In addition, a tidal fluctuation study was performed to estimate mean water levels and propagation of tidal influence through the aquifer. This study was conducted using the two sets of monitoring wells from 4:00 PM on March 26 to 4:00 PM on March 29, 2013. A stilling well was installed in the Lauritzen Channel to minimize the effect of wave action on the data logging transducer placed in the channel. Data logging pressure transducers with vented cables were placed in each monitoring well and the stilling well. The pressure transducers were synchronized and the tidal study was run for 72 hours.

## 2.4 Stormwater Sampling from Municipal Outfalls

Two storm drain systems discharge to the Lauritzen Channel. The City of Richmond municipal stormwater system provides drainage for the area surrounding the site and discharges to a 48-inch-diameter outfall at the head of the Lauritzen Channel. A separate stormwater management system was constructed on the LRTC property in conjunction with the construction of the upland cap. Municipal and LRTC stormwater outfall locations are shown in Figure 2-1. These systems are described further in Section 6.

The SAP Addendum includes the collection and analysis of stormwater samples from the City of Richmond municipal outfalls that discharge to the heads of the Lauritzen Channel and Parr Canal. These stormwater samples were proposed to be collected after the removal of residual sediment from the municipal storm drain system, because these sediments are known to be contaminated with DDT. To date, the municipal storm drains have not been cleaned out; therefore, the stormwater sampling will not be conducted and the cleaning of the storm drain system will be included in the evaluation of remedial alternatives in the FFS. Stormwater samples were not collected from the LRTC storm drain system because it is routinely monitored as part of a Stormwater Pollution Prevention Plan and Stormwater Monitoring Plan (Environmental Technical Services [ETS], 2013a).

## 2.5 Sampling from Other Pipes and Seeps

As shown in Figure 2-1, a number of other pipes and seeps are present along the shoreline of the Lauritzen Channel. The SAP Addendum included the collection of water samples from any pipe or seep that was found to be discharging to the Lauritzen Channel and was determined to not be tidal drainage based on salinity or conductivity measurements. None of the other pipes or seeps were found to be discharging during the site survey in November–December 2012, or during the subsequent site visits at low tide during the winter months in early 2013 (except one location where the water from a dripping pipe was assumed to be tidal drainage because of its

intertidal location). None of the site visits coincided with wet weather conditions. If possible, the other pipes and seeps will be revisited under future wet weather conditions, such as when the municipal storm drains are sampled, and a sample will be collected from any feature that is found to be flowing continuously.[3]

An active seep was identified under the Levin pier at bent +37 in April 2013. A sample was collected from this seep during low tide on July 24, 2013. The sample was analyzed for total and dissolved DDT and Dieldrin and total suspended solids; results are provided in Section 3.

[3] The "continuous flow" criterion was incorporated into the SAP to exclude sampling features that were dripping. Sampling discontinuous low-rate flows was determined to be impractical because of the large sample volume required for analysis. In many cases, pipes that are submerged at high tide drip at low tide as seawater drains from the pipe.

SECTION 3

# Embankments

The embankments along the shoreline of the Lauritzen Channel have been identified as a potential ongoing source of DDT contamination to channel sediments. The following contaminant transport pathways were evaluated:

- Discharges from features along the embankment that could act as preferential pathways for the transport of DDT from the former plant site to the Lauritzen Channel, including seeps and outfalls that are not related to the municipal or LRTC stormwater systems
- Erosion of contaminated embankment soils above the tide line into the Lauritzen Channel (erosion and transport of undredged sediments below the tide line are addressed in Section 8)

## 3.1 Objectives and Approach

The objectives of the source identification study relative to the embankments were as follows:

- Identify and document pipes, outfalls, or point sources along the embankment that may act as conduits or preferential pathways for the transport of DDT from the former plant site to the Lauritzen Channel.
- Estimate the magnitude of ongoing contributions from other pipe outfalls or features acting as preferential pathways if possible.
- Determine whether contaminated soils in the embankment above the tide line are eroding into the Lauritzen Channel.
- Estimate the magnitude of ongoing contributions from embankment soil erosion if possible.

The first two objectives were investigated by documenting shoreline features (including pipes, outfalls, and seeps) and collecting water and sediment grab samples from or near features that were identified as potential ongoing sources of contamination. The sampling results were evaluated in conjunction with previous data collected in the Phase I source investigation (Kohn and Evans, 2002). The observed pipes, outfalls, and seeps are illustrated in Figure 3-1. This figure also illustrates what types of materials comprise the shoreline along the embankment, including the shotcrete that was applied between bent -4 and bent +9 during July 2013.

Embankment soil erosion was evaluated by reviewing historical data and information related to embankment soils, visually inspecting the embankments for signs of soil erosion, and reviewing sediment grab sample data collected along the base of the embankment.

## 3.2 Background

The Phase 1 and Phase 2 source investigations (Kohn and Evans, 2002 and 2004) evaluated pipes, outfalls, and embankment soils and sediments along the eastern bank of the Lauritzen Channel.

### 3.2.1 Pipes, Outfalls and Seeps

During the Phase 1 source investigation (Kohn and Evans, 2002), sediment and water samples were collected from selected outfalls and passive samplers were deployed to determine whether water flowing from pipe outfalls carried significant quantities of pesticides. The Phase 1 investigation concluded that most of the identified outfalls were not likely to be significant sources of the DDT to the Lauritzen Channel. Two outfalls were identified for further investigation:

- Concrete outfall at T-8.5 – a concrete outfall on the eastern bank of the channel was found to be discharging a small volume of water during the Phase 1 sampling event. The water contained part-per-million levels of total DDT and Dieldrin. This feature is referred to as P1-4 on Figure 3-1.

- 8-inch outfall at T-27.5 – this outfall was recommended for further investigation because the data collected during the Phase 1 investigation were inconclusive and the outfall could not be ruled out as a potential source. No further investigation of this feature was performed in the Phase 2 source investigation. This feature is referred to as P1-1 on Figure 3-1.

During the Phase 2 source investigation field sampling, water was observed discharging from the broken concrete outfall on the embankment below the high tide line at T-8.5. This feature was referred to as the "seep."[4] The highest concentrations of total DDT were measured in water, sediment, and mussels sampled from the seep pipe. High total DDT in water samples collected approximately 1 year apart suggested that the seep was an ongoing source of DDT contamination to the channel. The seep was sealed with grout by USEPA on July 18, 2003.

### 3.2.2 Embankment Soil Erosion

The remedial investigation (RI) for the upland portion of the United Heckathorn site (Levine-Fricke, 1990) delineated the length of embankment along the eastern side of the Lauritzen Channel that was contaminated by chlorinated pesticides. Embankment soils with DDT concentrations greater than 1 milligram per kilogram (mg/kg) were determined to extend from the northern end of the channel southward for a distance of approximately 1,200 feet. The highest concentrations (up to 27 percent DDT) were detected over a localized area of the embankment adjacent to the former facility. DDT concentrations in embankment soils tended to decrease with depth and distance away from the former facility.

Between 1990 and 1993, contaminated soil and visible pesticide residue were removed from the upland part of the site and embankment in a series of interim removal actions (Levine Fricke, 1991a; 1991b; and 1993; Weston, 1993). The embankment excavation areas were located adjacent to the former plant site and former train scale area, as shown in Figure 3-1. The visible pesticide residue extended from approximately bent +3 to bent -3, at the north end of the Levin pier. The cleanup goal for the interim removal actions was 100 mg/kg total DDT. The removal actions did not include the removal of sediments below about 0 feet mean lower low water (MLLW); pre-construction sampling results indicated that the subtidal sediments adjacent to the visible pesticide residue had total DDT concentrations exceeding 100 mg/kg in a relatively localized area (i.e., a hot spot). The western extent of this hot spot was not delineated because of the presence of a ferry at the Levin pier.

Most of the soil excavated under the removal actions was transported to an offsite landfill for disposal; however, some of the soil was temporarily stored in stockpiles at the north end of the Lauritzen Channel and in the former train scale area (Figure 3-1). A portion of these soils were removed and disposed in a hazardous waste landfill in 1992 and the remaining soils were disposed in a hazardous waste landfill in April 1993 (Levine Fricke, 1993).

The Phase 1 and Phase 2 source investigations included collection and analysis of embankment soil and sediment samples (Kohn and Evans, 2002 and 2004). The sediment sampling results are shown in Figures 3-2a and 3-2b. The embankment sediment samples collected near the north end of the Levin pier indicated the presence of a DDT hot spot. The location of this hot spot corresponds to the hot spot that was identified in preconstruction sampling performed for the interim removal actions and appears to be embankment sediment below 0 feet MLLW that was not removed in either the upland or marine remedies.

Additional embankment soil samples were collected in the Phase 2 source investigation to characterize the depth of contamination in the embankment. The results varied by sampling location, with the highest concentrations at the surface at some locations and in the subsurface at others. Under the north end of Levin pier, embankment soils were substantially more contaminated at depth than at the surface. The Phase 2 investigation concluded that the hot spot under the north end of the Levin pier and the seep at T-8.5 were the sources that were most likely contributing to high DDT concentrations detected in mussels collected from nearby pilings.

[4] The Phase 2 source investigation report mistakenly refers to this feature as being located at T(-12.5).

# 3.3 Lines of Evidence and Findings

A comprehensive site features map was compiled based on previous reports and field observations documented during the 2012 site survey. This map is provided in Figure 3-1. The eastern shoreline of the Lauritzen Channel is constructed of sheet pile (steel plates supported by railroad ties), concrete, rip rap, and/or shotcrete. Evidence of soil erosion was observed during the site surveys performed in 2012. Erosion under the sheet pile wall, observed as approximately 1- to 2-foot voids, was noted at the north end of the eastern bank of the channel. These features were noted between bent -37 and the head of the channel. Sink holes and exposed cap material were also observed on the Levin property in the vicinity of bent -24 and T-8.5 (embankment soils were not exposed in these locations). Additional information including photo documentation of the features described above is provided in the site survey field summary report (CH2M HILL, 2013b).

## 3.3.1 Pipes, Outfalls, and Seeps

Table 3-1 summarizes the embankment features identified during all phases of the investigation, including associated analytical data. The table includes the City of Richmond municipal outfalls at the heads of the Lauritzen Channel and Parr Canal, the five stormwater outfalls associated with LRTC's upland cap stormwater management system, and other pipes and outfalls on the west, north, and eastern shores of the Lauritzen Channel. All pipe and outfall locations are shown on Figure 3-1. New features that were identified in 2012 include four pipes along the western side of the channel (P4-4 through P4-7) and eight new pipes (P4-8 through P4-15) along the eastern side of the channel underneath the Levin pier. In addition, two electrical conduits were observed on the eastern side of the channel beneath the Levin pier. As noted in Section 2.5, none of the features were observed to be flowing continuously during the site surveys or any of the subsequent site visits in early 2013.

The SAP Addendum (CH2M HILL, 2013a) specified the collection of water samples from any feature found to be flowing continuously, particularly the following two locations:

- P1-1, the 8-inch pipe at T-27.5 that was previously sampled
- P1-4, the area around the former seep pipe at T-8.5 that was sealed by USEPA in 2003

The former seep at P1-4 was not observed during the field surveys and therefore was not sampled. The 8-inch pipe at P1-1 was located and observed to be dripping.[5] This pipe was not sampled because it was not flowing continuously. However, two sediment grab samples were collected adjacent to these features. The sediment sample locations are shown in Figure 2-1 and grab sample results are provided in Table 3-2. The grab sample collected near P1-1 (SD13-12) had a total DDT concentration of 75 mg/kg, which is substantially higher than the concentrations measured at the adjacent grab samples collected along the shoreline. The high concentration at SD13-12 could be attributable to discharges from outfall P1-1, and/or to historical soil contamination in the vicinity of the former train scale area that was not removed in the interim removal actions. The total DDT concentration measured in the grab sample collected near the former seep pipe (SD13-17) was 92 mg/kg, indicating that high DDT concentrations persist in this area even though the seep has been sealed. The high DDT concentrations could also be attributed to historical soil contamination that was not removed in the interim removal actions.

The seep that was observed at bent +37 under the Levin pier in April 2013 was sampled in July 2013. The analytical results are provided in Table 3-3. The total DDT concentrations in filtered and whole water samples were 0.024 and 0.034 micrograms per liter (µg/L), respectively, indicating that the majority of the total DDT contamination is in the dissolved phase. The dissolved and whole water Dieldrin concentrations were nearly the same (0.071 and 0.068 µg/L, respectively). The flow from the seep was estimated to be about 10 to 15 liters per minute at the time of sample collection. If the flow rate from this seep is constant, then the annual load of total DDT and Dieldrin to the Lauritzen Channel from this seep would be less than 1 gram (g).

Based on the 2012 site survey and the 2013 sampling results, the pipes, outfalls, and seeps do not appear to be ongoing sources of DDT contamination to the Lauritzen Channel under dry weather conditions. The pipes and

[5] The 8-inch pipe at P1-1 is located in the intertidal zone, so the dripping observed at low tide was assumed to be tidal drainage.

outfalls that were identified do not convey dry weather flow, and the one continuously-flowing seep contained only low levels of pesticides. The pipes and outfalls have not been inspected or sampled during wet weather conditions. If possible, the outfalls will be inspected again during wet weather conditions and any features that are found to be flowing continuously under wet weather conditions will be sampled.

### 3.3.2 Embankment Soil

No soil samples were collected from the embankment along the eastern side of the Lauritzen Channel in 2013. However, sediment grab samples below the tide line were collected adjacent to the embankment. Twelve of these samples were collected from unbiased locations on a systematic grid, and three were collected from biased locations as shown in Figure 2-1. Sample results are provided in Table 3-2.

The 2013 sediment grab sample results are consistent with the historical data for embankment soils. Total DDT concentrations between 15 and 92 mg/kg were found in samples adjacent to the former train scale area and the former plant site (including the hot spot under the north end of the Levin pier), where the interim soil removal actions were performed. As noted in Section 3.2.2, the cleanup level for the interim removal actions was 100 mg/kg, and sediments below about 0 feet MLLW were not included. Therefore, these shoreline sediments were not removed as part of the upland removal actions. They were also apparently not dredged during the Lauritzen Channel remedy in 1996-1997. The completion report indicates that dredging was to be completed to within 10 feet of the shoreline, plus or minus 2 feet of the toe of the slope (Chemical Waste Management Inc. [CWM], 1997). The 2013 shoreline grab samples were collected at the top of the slope. Therefore, these highly contaminated shoreline sediments adjacent to the former plant site and former train scale area most likely represent historical contamination that was never removed.

The 2012 site survey identified evidence of embankment soil erosion at the base of the sheetpile wall from bent 37 to the head of the channel. The total DDT concentrations in the sediment grab sample from this area (SD13-07) was 2.9 mg/kg, which is lower than the concentrations near the former plant site and former train scale area, but well above the sediment remediation goal of 590 µg/kg.

The highest total DDT concentration in a sediment grab sample was found at SD13-01 in the northwest corner of the Lauritzen Channel. The total DDT concentration was 299 mg/kg, and contained over 90 percent 4,4'-DDT, indicating that the DDT mixture is less degraded compared to samples from adjacent locations. Total DDT concentrations in adjacent surface sediment samples were an order of magnitude lower and contained a larger proportion of 4,4'-DDD (i.e., were more degraded).

Five additional embankment soil and sediment samples were collected along the northwestern edge of the channel to investigate the potential source of contamination to SD13-01. The sample locations are shown in Figure 2-1 and the results are reported in Table 3-2. The highest total DDT concentration (14 mg/kg; 78 percent 4,4'-DDT) was found at EMB13-01, which is located between the former soil stockpile location (Figure 3-1) and SD13-01. The other embankment soil and sediment samples contained between 0.5 and 11 mg/kg total DDT (with 18 to 49 percent 4,4'-DDT), indicating widespread contamination along the shoreline.

The former soil stockpile at the northwest corner of the site was placed partially on an asphalt concrete pad, on top of a visquine liner (Levine Fricke, 1993). The stockpile was removed in April 1993. A composite confirmation soil sample collected from the area beneath the liner contained 23,480 mg/kg total DDT (72 percent 4,4'-DDT). Additional cleanup was performed in the area beneath the former stockpile, including pressure washing (the wash water was contained by a sorbent dike around the perimeter). A second confirmation sample collected after the additional cleanup was completed contained 226 mg/kg total DDT (71 percent 4,4'-DDT). These results indicate that the soil in the stockpile was not effectively contained, and runoff from the stockpile to the northwest corner of the channel may have occurred. The sediments along the northern edge of the Lauritzen Channel were not completely dredged in 1997, and the localized hot spot at SD13-01 is most likely undredged residual contamination.

The 2013 sediment grab sample data in conjunction with historical embankment soil and sediment data indicate that erosion of contaminated embankment soils on the northern and eastern sides of the channel is an ongoing source of contamination to the Lauritzen Channel. However, the magnitude of the source is difficult to quantify because most of the embankment is lined with sheetpile, rip rap, and/or concrete, with only localized areas of exposed soil subject to erosion.

SECTION 4

# Groundwater Discharge

## 4.1 Objectives and Approach

Groundwater data were collected at the United Heckathorn Site in the mid-1980s as part of the upland investigation (Harding Lawson Associates [HLA], 1986). However, because site conditions have changed since that time, total DDT mass flux into the Lauritzen Channel from the eastern shoreline was evaluated as part of the source identification study.

The approach used for the 2013 groundwater characterization was as follows:

- Characterize contaminant concentrations in groundwater along the eastern shoreline of the Lauritzen Channel.
- Estimate the hydraulic conductivity of shallow water-bearing soils.
- Characterize hydraulic gradients and tidal influence in the shallow water-bearing soils.
- Calculate the volumetric discharge rate from the eastern shoreline into the Lauritzen Channel.
- Calculate the flux of dissolved DDT into the Lauritzen Channel from the eastern shoreline.

The results of this evaluation are presented in Section 4.3.

## 4.2 Background

During the upland investigation in the mid-1980s, groundwater elevations varied from 0 to 4.7 feet mean sea level (MSL) across the site and the groundwater flow was reported to be very complex, with an overall westward flow direction toward the Lauritzen Channel. The saturated thickness of the artificial fill unit was less than 18 inches and in some cases no groundwater was found in the fill. Table 4-1 lists the estimated groundwater discharge rates into Lauritzen Canal from the historical investigation (HLA, 1986; Levine Fricke, 1990) and Figure 2-2 depicts the locations of the monitoring wells listed in Table 4-1.

Groundwater samples collected from the upland part of the site between 1983 and 1986 had total DDT concentrations ranging from below the detection limit to 178 µg/L (HLA, 1986). The solvents chlorobenzene and trans-1,2-dichloroethene were sporadically detected at low part per billion levels. The 1990 RI Report for the upland area concluded that chemicals in groundwater were not a significant concern compared to the contamination documented in upland soils and the embankment sediments (Levine Fricke, 1990).

## 4.3 Lines of Evidence and Findings

The following sections summarize the groundwater chemistry data, slug testing findings, and tidal evaluation study results and evaluate potential groundwater discharge and associated total DDT transport into the Lauritzen Channel from the eastern upland area.

### 4.3.1 Groundwater Analytical Results

Filtered and unfiltered groundwater samples were analyzed for total and dissolved organochlorine pesticides and SVOCs, as well as total VOCs. The analytical data are provided in Table 4-2 and a statistical summary of the results is presented in Table 4-3. DDT was detected in the filtered and unfiltered samples from all 12 sampling locations. The total DDT in the filtered samples ranged from 0.03 to 14.6 µg/L, with an average concentration of 1.62 µg/L. Total DDT in the unfiltered samples ranged from 0.27 to 69.6 µg/L, with an average concentration of 12.8 µg/L. The maximum total DDT concentrations in the filtered and unfiltered samples were detected at location GW13-11, which is within the footprint of the former main building (Figure 2-2). The highest total DDT

concentrations are on the same order of magnitude as the solubility limits for the DDT and DDD isomers, which range from 25 to 100 µg/L (Agency for Toxic Substances and Disease Registry [ATSDR], 2002).

Three SVOC compounds were detected in groundwater: bis(2-ethylhexyl-phthalate), Caprolactam, and diethyl phthalate. The two phthalate compounds were detected in two filtered and in two unfiltered samples. Caprolactam was detected in nine of the twelve filtered samples and was not detected in the unfiltered samples. Caprolactam concentrations ranged from 6.7 to 83 µg/L.

VOCs were sporadically detected and the compounds with the highest observed concentrations included 1,3-dichlorobenzene (41 µg/L), cis-1,2,-dichloroethene (7,500 µg/L), trans-1,2-dichloroethene (29 µg/L), tetrachloroethene (84 µg/L), trichloroethene (1,300 µg/L), and vinyl chloride (370 µg/L). These compounds were detected in as many as four wells and the maximum concentrations were observed at GW13-08, which is located in the northern portion of the site, near the former train scale area (Figure 2-2).

### 4.3.2 Slug Testing Results

Slug testing was conducted at each of the four newly-constructed monitoring wells to estimate the hydraulic conductivity (K) of the water-bearing shallow soils. The groundwater sampling field summary report (CH2M HILL, 2013e) contains the soil boring logs and well completion diagrams for these four new monitoring wells. The new monitoring wells include MW13-01 and MW13-02 near the north end of the Former Main Building and MW13-03 and MW13-04 near the south end of Former Building #3 (Figure 2-2). Two slug-in and two slug-out tests were conducted at each monitoring well.

The slug-in test was accomplished by rapidly lowering a 1.5-inch-diameter, 5-foot-long displacement device into each well until the top of the device was below the static water level and recording the response of groundwater levels in the well. The test was allowed to run until the water level reached static (pre-test) levels. After completing the slug-in test, a slug-out test was conducted by rapidly removing the slug device and recording water levels until the water levels again returned to static levels. Although water level changes due to tidal influence occurred in all wells, the water level fluctuations during the test (typically several minutes) were not significant enough to impact the slug test analysis.

The time-series water-level data that resulted from slug testing were input to AQTESOLV for Windows[6] Version 4.x to estimate the K needed to fit these time-series water levels. The Bouwer and Rice (1976) method was used in AQTESOLV to estimate the K values. Table 4-4 presents the estimated K values for the four wells tested in 2013, as well as those published in HLA (1986). The geometric mean of the K values listed in Table 4-4 is $2.96\times10^{-4}$ centimeters per second (0.84 feet per day).

The K values estimated for the new monitoring wells are associated with an upper portion of the Bay Mud that underlies the fill because little to no water was encountered in the fill material during the drilling of the four new monitoring wells. The K values estimated by HLA (1986) are representative of an upper portion of the Bay Mud and overlying saturated fill and this is likely why the HLA (1986) K values are higher than those estimated using the 2013 slug testing data.

### 4.3.3 Tidal Study Results

A study of tidal fluctuation in the Lauritzen Channel and four new monitoring wells was conducted in March 2013 to estimate mean water levels and propagation of tidal influence through the shallow water-bearing soils. A data logging pressure transducer with vented cables was instrumented within each of the four available monitoring wells and within a stilling well. The stilling well was temporarily secured to a piling in the Lauritzen Channel to minimize the influence of wave actions on the water level inside the stilling well. Data logging pressure transducers were vented to compensate for barometric pressure changes during the tidal study.

The tidal study was conducted over a 72-hour period. Data were downloaded from the transducers and processed to remove anomalous readings associated with placement and removal of the transducers and to reference the

6 http://www.aqtesolv.com/ (Accessed August 5, 2013)

water levels to a common vertical datum (i.e., North American Vertical Datum of 1988 [NAVD88]). Appendix A lists the processed water levels for the first 71 hours of the test; these water levels were further processed using the filtering method described by Serfes (1991) to compute mean groundwater levels. Table 4-5 lists summary statistics associated with the 2013 tidal study data.

### 4.3.4 Groundwater Discharge Evaluation

The objective of the groundwater discharge evaluation was to estimate the total DDT mass flux from the shallow water-bearing soils of the upland area immediately east of the Lauritzen Channel to assess whether groundwater discharge may be contributing to the high concentrations of DDT detected in the Lauritzen Channel sediments. Data and information sources that were used to achieve the evaluation objective are as follows:

- Estimates of the K values resulting from slug testing conducted by CH2M HILL in March 2013 and those resulting from prior aquifer tests conducted by HLA (Table 4-4) – the geometric mean of these K estimates was used in conjunction with the hydraulic gradients estimated using the 2013 tidal study data and an assumed saturated thickness of shallow water bearing soils to compute volumetric groundwater discharge rates into Lauritzen Channel from the upland area east of the channel.
- Soil boring logs associated with MW13-01, MW13-02, MW13-03, and MW13-04 (Appendix A) – these logs were reviewed and used in conjunction with the K estimates and assumed saturated thickness of shallow water bearing sediments to inform the groundwater discharge estimates.
- Tidal study data (Table 4-5) – groundwater level data from the tidal study monitoring wells provided the basis for estimating ranges of horizontal hydraulic gradients in the upland area immediately east of the Lauritzen Channel. The horizontal hydraulic gradients were used in conjunction with the geometric mean of the K estimates and assumed saturated thickness to compute groundwater discharge rates via Darcy's Law over an assumed width of the groundwater flow field.
- March 2013 unfiltered total DDT concentration data (Table 4-2) – these data were used in conjunction with the volumetric groundwater discharge rates to compute the potential annual mass flux of total DDT into Lauritzen Channel from the upland area east of the channel. Annual mass flux estimates were computed using unfiltered total DDT concentrations to account for the potential presence of contaminated colloids in the groundwater.

The annual mass flux of total DDT to Lauritzen Channel from the eastern upland area was computed using two methods, as follows:

- Method 1. This method uses a single hydraulic gradient value (i.e., $4.80\times10^{-3}$ foot per foot) computed with the mean groundwater levels at MW13-03 and MW13-04 (see Table 4-5 for mean water levels) from the 2013 tidal study and the separation distance of 105.4 feet between these monitoring wells. These particular monitoring wells were selected because the mean groundwater levels at MW13-01 and MW13-02 indicated net landward groundwater flow rather than net groundwater flow toward Lauritzen Channel. The annual total DDT mass flux estimates were computed using the following equations:

$$Q = 0.019661 \cdot Tiw$$

$$AMF = 0.52596 \cdot QC$$

  where

  T = transmissivity [square feet per day or ft²/day]; a value of 27 ft²/day was used.

  i = hydraulic gradient [foot per foot]; a value of $4.80\times10^{-3}$ foot per foot was used.

  w = cross-sectional width perpendicular to groundwater flow [feet]; a value of 1,500 feet was used.

  Q = annual volumetric groundwater discharge to Lauritzen Channel [liters per minute]; this value was rounded to the nearest whole number.

  C = unfiltered total DDT concentration in groundwater [µg/L]; a value of 69.6 µg/L was used.

  AMF = annual mass flux of total DDT from the eastern upland aquifer to Lauritzen Channel [grams per year]

- Method 2. This method uses time-varying hydraulic gradients between MW13-03 and MW13-04 computed at 5-minute intervals over the 2013 tidal study. Time-varying landward hydraulic gradient values were replaced with a value of zero, given that DDT would not discharge to the channel during periods of landward gradients. The mass flux of total DDT was computed for each 5-minute interval during the 2013 tidal study, summed over the 3-day tidal study, and then multiplied by a factor of 365.25 ÷ 3. This method essentially integrates the mass flux of total DDT for periods of groundwater discharge to Lauritzen Channel during the 3-day 2013 tidal study and then, assuming this mass flux is representative for periods during the rest of the year, sums the mass that would occur over one calendar year.

Table 4-6 summarizes the parameters used and results of the groundwater discharge and total DDT mass flux evaluation. The results indicate that the annual total DDT flux using Method 1 is 146 g, whereas this flux using Method 2 is 167 g. There was no need to adjust these estimates for total DDT that would enter the Lauritzen Channel with groundwater that upwells into the bottom of the channel because sampling has confirmed that the Older Bay Mud beneath the channel is not contaminated; therefore, groundwater upwelling through the Older Bay Mud beneath the channel is not a DDT transport pathway.

Discharge of groundwater to Lauritzen Channel with the unfiltered maximum total DDT concentrations measured in the 2013 groundwater samples could lead to contamination of sediments to levels above the remediation goal of 590 µg/kg.[7] The potential effects of groundwater discharge on surface water quality in Lauritzen Channel will be further evaluated in the DDT fate and transport study.

The groundwater discharge and total DDT mass flux evaluation presented in Table 4-6 is based on the following assumptions:

- Groundwater level conditions during the March 2013 tidal study are representative of the longer-term range of groundwater levels that have occurred and will occur within the upland area east of Lauritzen Channel.
- Errors introduced by not accounting for potential preferential contaminant transport pathways, such as those created by backfill around subsurface pipes, are negligible.
- Errors introduced by not accounting for groundwater density variations across the upland area east of Lauritzen Channel are negligible.

[7] Assuming equilibrium partitioning from groundwater to sediment containing 2 percent total organic carbon and a Log $K_{oc}$ of 5.18 (partition coefficient for 4,4'DDT and 4,4'-DDD; ASTDR, 2002).

SECTION 5

# Wood Pilings

## 5.1 Objectives and Approach

One of the objectives of the source identification study was to determine whether the abandoned wood pilings along the northeastern shoreline of the Lauritzen Channel act as an ongoing source of DDT to the Lauritzen Channel sediments and surface water. The analysis previously completed for the Sediment Recontamination Study (Kohn and Gilmore, 2001) was used for this assessment.

## 5.2 Background

Wood chip samples were collected from six creosote-treated wood pilings evenly spaced along the eastern side of the Lauritzen Channel during a sediment recontamination study conducted in 1999 (Kohn and Gilmore, 2001). The wood samples were collected during a low tide as close as possible to the 0 foot MLLW elevation on the pilings. Scrapings of selected pilings were collected to a depth of approximately 3 millimeters. All six samples were screened for DDT using EnviroGard commercial test kits, and five samples were submitted for confirmation analyses for DDT and Dieldrin. The sampling locations are illustrated in Figure 5-1 and the confirmation analysis results from the wood chip analyses are provided in Table 5-1. Samples CR-35 and CR-33 exhibited similar total DDT concentrations from the test kit results (82 and 94 µg/kg, respectively), and sample CR-35 was not submitted for further confirmatory analysis.

## 5.3 Findings and Lines of Evidence

The analytical results for the wood chips are provided in Table 5-1. The total DDT concentrations ranged from 1,700 to 200,000 µg/kg, with DDD comprising 88 to 100 percent of the total. Four of the six samples contained greater than 50,000 µg/kg DDT. Dieldrin was detected in four of the five samples and the detected concentrations ranged from 3,000 to 14,000 µg/kg.

Kohn and Gilmore (2001) presented an analysis of this potential source and found that although very high DDT and Dieldrin concentrations are associated with the creosote-treated pilings sampled, the pilings are unlikely to be a significant source of DDT to surface water or sediment. DDT isomers have both very high octanol-water partition coefficients ($K_{ow}$) and sediment-water partition coefficients ($K_{oc}$), indicating that these pesticides are much more likely to bind with an organic solvent, such as the creosote constituents, or the organic carbon present in sediment, wood, or petroleum. The log $K_{ow}$ and log $K_{oc}$ values utilized for the 2001 evaluation for DDT were 6.19 and 5.39, respectively, indicating that, at equilibrium, the concentration associated with organic solvents or organic carbon is expected to be approximately a million times greater than the concentration in water. More recently published log $K_{ow}$ and log $K_{oc}$ values for the six DDT isomers range from 5.87 to 6.91 and from 4.70 to 5.35, respectively (ATSDR, 2002). Using the more recent log $K_{ow}$ and log $K_{oc}$ would not change the conclusions of the 2001 evaluation.

Kohn and Gilmore (2001) also noted that the pilings could contribute to sediment contamination through mechanical weathering, which includes a range of ablative effects from anthropogenic activity, resulting in particle deposition to the sediment. If the pilings are not removed or cut off, the DDT-contaminated wood particles will continue to accumulate in sediments, increasing sediment DDT concentrations and potentially being incorporated into the food web.

SECTION 6

# Stormwater Outfalls

## 6.1 Objectives and Approach

One of the objectives of the source identification study was to determine whether discharges from the City of Richmond municipal storm drain system or LRTC upland cap stormwater management system are ongoing sources of contamination to the Lauritzen Channel and if so, to estimate the magnitude of ongoing contributions from stormwater outfalls. The storm drain systems were evaluated as follows:

- Stormwater discharges from the municipal storm drain at the head of the Lauritzen Channel were to be sampled as part of this source identification study after the residual sediments in the storm drain system had been removed. However, these sediments have not yet been removed, so the potential for the municipal storm drain system to act as an ongoing DDT transport pathway in the future cannot be evaluated. If the residual sediments are removed prior to completion of the FFS, then stormwater sampling may be performed to verify whether or not discharges from the municipal storm drain system are an ongoing source of contamination to the Lauritzen Channel. Otherwise, development of the remedial alternatives should address this potential ongoing source.
- Monitoring data collected for the LRTC stormwater management system for the upland part of the site were reviewed and evaluated to determine whether the system is functioning as intended.

## 6.2 Background

The storm drain systems at and around the site are shown in Figure 6-1. There are two components to the storm drain system described below: the City of Richmond municipal storm drain system and the storm water management system within the LRTC property.

### 6.2.1 City of Richmond Municipal Storm Drains

The City of Richmond municipal stormwater system provides drainage for the area surrounding the United Heckathorn site. There are no municipal drains on the LRTC property; the municipal drain inlets are located on the public roads adjacent to the property (ETS, 2013a; 2013b). These inlets are shown on Figure 6-1. Stormwater from areas to the north, east, and west of the site is carried into the municipal stormwater sewer and enters the Lauritzen Channel through the 48-inch concrete outfall at the north end of the channel.

A storm drain investigation was performed in 2008 and 2009 to determine whether the City of Richmond municipal storm drain system was a source of DDT and Dieldrin to the Lauritzen Channel (USEPA, 2011). Field studies were performed to determine the hydraulic connectivity of the storm drain structures to the outfalls at the head of the Lauritzen Channel and Parr Canal, and to characterize the residual sediments in the storm drain system. Additionally, a video survey was performed to assess the integrity of the storm drains that extend under the upland cap. The survey confirmed that seawater intruded into some of the drains at high tide, but the structural integrity, invert elevations, and hydraulic connections could not be determined for all drains because of the large amount of residual sediment in the system.

The sampling results are presented in Table 6-1 and on Figure 6-2. Storm drain sediment samples collected from 2008 to 2012 contained total DDT concentrations ranging from below the detection limit to 52,000 µg/kg. Dieldrin concentrations ranged from below the detection limit to 680 µg/kg. The highest total DDT and Dieldrin concentrations were observed at location SSWL03, which was sampled in July and again during September 2008. These samples were collected from a manhole near the northeast end of the Lauritzen Channel. The SSWL03 structure was cleaned out in December 2008, and was determined to be a catch basin that was not part of the municipal storm drain system and was not connected to the Lauritzen Channel. The inlet to the catch basin was not identified.

The portion of the municipal storm drain system shown in Figure 6-1 has not been cleaned out by the City of Richmond in many years. The DDT-contaminated sediments in the drains may be a remnant of historical operations at the United Heckathorn site and/or may be from tidal intrusion.

Storm drain sediment sampling was also performed by USEPA's START contractor in 2012 to support a potential emergency removal action. Due to cost implications, the removal action was placed on hold and the sampling report was not finalized; therefore, the data are not included in this evaluation.

A flap gate valve was installed in the Parr Canal storm drain outfall in January 2011. A flap gate valve was installed on the Lauritzen Channel municipal outfall by the EPA START contractor in October 2012 to prevent sediment in the channel from washing back into the storm drain system.

**LRTC Stormwater Management System**

The selected remedy for the upland part of the United Heckathorn site included implementing a stormwater monitoring program as a component of the operation and maintenance activities. Stormwater is sampled from the interceptors at the LRTC terminal and because the facility is operating under a State Water Resources Control Board Industrial Activities – Storm Water General Permit. The stormwater monitoring schedule and analytical program are incorporated into the LRTC's existing facility-wide Stormwater Pollution Prevention Plan and Stormwater Monitoring Plan (ETS, 2013a).

Stormwater within the Main Terminal Complex of LRTC is managed using two storm drain systems. Both systems include interceptors constructed with compartments and steel baffles to trap and collect oil and suspended solids before water is discharged. One system includes interceptors SW-1 and SW-2, which collect runoff from the dock and main storage/loading areas, and portions of the paved area to the east and north of the equipment repair building and warehouse. Water collected into these interceptors is released to the Santa Fe Channel after removal of oil and suspended solids.

The second storm drain system in the upland area is a storm drain system that was installed in 1998 to collect runoff from the 5-acre upland cap. Runoff from the cap area is directed into five stormwater interceptors, SW-3 through SW-7, which have been designed to have sufficient capacity to hold most stormwater runoff generated during the rainy season (October through May) to minimize direct discharge into the Lauritzen Channel. Runoff captured by the interceptors is sampled and until 2013 was discharged under permit to the City of Richmond municipal stormwater sewer and directed to the publically owned treatment works. As of the 2013 to 2014 stormwater season, these stormwater discharges to the municipal sewer will no longer be allowed. In 2009, SW-3 was modified to allow for discharge of water to a 20,000 gallon tank for additional sediment removal. LRTC added a second 20,000 gallon stormwater holding and sedimentation tank at interceptor SW-3 for the 2013-2014 stormwater season. Interceptors SW-3 through SW-7 have outfalls to the Lauritzen Channel and all five interceptors now include gate valves, which are normally closed, but can be opened to allow discharge to the Lauritzen Channel (Weiss Associates, 2013).

Should very heavy rainfall occur generating discharge to the Lauritzen Channel, a stormwater outflow sample is collected during a minimum of two discharge events per stormwater season. No discharges occurred in the 2004-2005 or in 2008-2009 reporting periods (ETS, 2006 and 2009), but an unusually heavy rain event on January 27, 2010, resulted in outflow from interceptors SW-3 through SW-6 to the Lauritzen Channel. The annual O&M report indicated that the annual sampling was performed during this event, but no associated analytical results were provided (ETS, 2010). As part of the routine maintenance, the five interceptors are drained, emptied of all sediment, and pressure-washed, as necessary, to prevent outflow of sediments into the Lauritzen Channel (ETS, 2013a).

Inspections of the stormwater drop inlets and interceptors are conducted monthly and are documented in the Annual Report for Stormwater Discharges Associated with Industrial Activities (ETS 2006; 2008; 2009; 2010; and 2013b). According to the annual reports, the stormwater system, in general, has been maintained in good condition, with occasional minor sedimentation observed within the storm drains. Staining and odors have not been observed or detected. The annual reports also indicate that no pesticides (including DDT and Dieldrin) were detected in the composite samples taken from the five stormwater interceptors surrounding the cap from 2008 to

2010; DDT was not tested in storm drain sediment prior to 2007. The discharge and annual monitoring sampling performed in October 2011 and March and May 2012 indicated very low concentrations, less than one part per billion, of DDT isomers and Dieldrin in four samples collected from interceptors SW-6 and SW-7 (ETS, 2013b).

During the October 2011 sampling, ETS field staff observed water flowing into the SW-7 interceptor through its outflow pipe (i.e., the pipe from the interceptor to the channel) while the shutoff valve to the channel was in the closed position. A sample of this inflowing water contained 0.085 µg/L total DDT and 0.15 µg/L Dieldrin; a sample collected from the baffle area of the interceptor at the same time contained 0.044 µg/L Dieldrin. As described below, a subsequent inspection determined that the outflow pipe was cracked, and the water that had entered the interceptor was infiltration from surrounding soils.

A sample collected from interceptor SW-6 on March 14, 2012 contained 0.024 µg/L total DDT. Additional samples were collected from interceptors SW-6 and SW-7 on May 9, 2012. The sample collected from SW-6 contained 0.102 µg/L total DDT and 0.013 µg/L Dieldrin. Water collected from SW-7 contained 0.267 µg/L total DDT. Further inspection of these interceptors revealed a crack in the outflow pipe of SW-7 and a crack in the SW-6 interceptor where the above- and below-ground interceptor walls meet. Interceptor SW-7 was repaired by LRTC by placing a clean segment of 8-inch-diameter PVC pipe inside the existing cracked outflow pipe and sealing the entire length of annular space with concrete. The crack in the SW-6 interceptor was repaired by ETS using an anchoring system and environmentally safe epoxy; the repairs are documented in the 2011-2012 Operations Maintenance Plan, which also indicated that both repairs were successful (ETS, 2013b).

Interceptors SW-3 through SW-7 were sampled more frequently than the required minimum of two storm events per wet season during the 2012-2013 reporting year (Weiss Associates, 2013). Between two and eight samples were collected from each interceptor. Some of these samples represent additional sampling performed during the same multi-day event. Total DDT was detected in samples collected on October 22, 2012, from interceptors SW-3, SW-4, and SW-5 at concentrations of 0.028 µg/L, 0.023 µg/L, and 0.056 µg/L, respectively. The sample from SW-5 also contained 0.19 µg/L Dieldrin. A sample collected from SW-6 on November 30, 2012 contained 0.024 µg/L total DDT. The 2012-2013 annual report noted that the pesticide concentrations detected in storm water discharges were consistent with observations from previous years, except at SW-4, where pesticides were detected after being undetected in the three previous reporting years. The report recommended continued monitoring of stormwater discharges, along with evaluation of the spatial and temporal distribution of pesticide concentrations. Future inspections will be expanded to focus on potential pesticide transport mechanisms that could be introducing pesticides to the stormwater interceptors, particularly in the vicinity of SW-6 (Weiss Associates, 2013).

SECTION 7

# Source Material Outside of the Lauritzen Channel

## 7.1 Objectives and Approach

As part of the source identification study, the previous conclusion that there were no significant sources of DDT contamination from outside of the Lauritzen Channel was revisited. The specific objective of this evaluation was to determine whether a source of DDT or Dieldrin external to the Lauritzen Channel could be acting as an ongoing of source of contamination to sediments within the channel and, if so, to estimate the magnitude of this source.

The evaluation of potential DDT sources outside of the Lauritzen Channel focused on the following lines of evidence:

- A review of nearby hazardous waste sites
- Sediment sampling results for areas outside of the Lauritzen Channel and ambient concentrations of total DDT for San Francisco Bay sediments.

## 7.2 Background

No non-site related sources of DDT and Dieldrin to the Lauritzen Channel or the rest of Inner Richmond Harbor have been identified. The RI report for the marine portion of the site concluded that the main source of total DDT and Dieldrin to the Lauritzen Channel was waste discharges during pesticide processing activities at the United Heckathorn site (White et al., 1994). The total DDT concentration gradients measured during the RI strongly suggested that the Lauritzen Channel was the source of pesticides to the rest of Inner Richmond Harbor. Total DDT concentrations in sediment decreased by two orders of magnitude from the Lauritzen Channel to the Santa Fe Channel, and by another order of magnitude from the Santa Fe Channel to the Inner Harbor Channel. In addition, the analysis of water-sediment ratios in the ecological risk assessment (ERA) indicated that the Lauritzen Channel was the source of contamination to the other channels (Lee et al., 1994).

## 7.3 Lines of Evidence and Findings

### 7.3.1 Nearby Hazardous Waste Sites

Nearby hazardous waste sites were evaluated by reviewing the following national and state hazardous waste site databases:

- The California Department of Toxic Substances Control (DTSC) Hazardous Waste and Substances Site (Cortese) List[8]
- Toxics Release Inventory Facilities Database (National Institute of Health – United States National Library of Medicine)[9]

Three sites in Richmond besides United Heckathorn are listed as having DDT and Dieldrin as contaminants of concern: FMC Corporation (855 Parr Boulevard); the University of California, Berkeley Richmond Field Station (1301 South 46th Street); and Zeneca Richmond Ag Products (1415 South 47th Street). The FMC Corporation site is in North Richmond, approximately 3 miles north of the United Heckathorn site. The Richmond Field Station and Zeneca Ag Products are located approximately 2 miles east-southeast from the site. These sites are all unlikely to be potential sources to the Lauritzen Channel due to the distance and the lack of any apparent transport pathways from any of these sites to the United Heckathorn site.

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8 http://www.dtsc.ca.gov/SiteCleanup/Cortese_List.cfm accessed July 16, 2013. Filtered by city to include Richmond and Berkley.

9 http://toxmap.nlm.nih.gov/toxmap/main/index.jsp accessed July 16. 2013. Search parameters were “Richmond, California”

## 7.3.2 Sediment Chemistry Data

Sediment chemistry data from the Regional Monitoring Program (RMP), the 1994 RI, the 2013 Source Identification Study, and from sampling performed by the United States Corps of Engineers (USACE) were used to evaluate whether sediment being transported into the Lauritzen Channel from San Francisco Bay could be considered a contaminant source.

### 7.3.2.1 Regional Monitoring Program Data and Ambient Sediment Concentrations

The RMP began in 1993 to evaluate the cumulative effects of multiple contaminant contributions on ambient bay conditions. Initially, most of the RMP sampling locations were located as far as possible from the "influence of major contaminant sources and to be as representative as possible of 'background' contaminant concentrations." During later sampling events, locations near tributaries to the Bay have been included in the monitoring program. Surface sediment is collected biennially from a set of historic, fixed locations (to allow for temporal trend analysis) as well as new, randomly selected stations (for more accurate assessment of overall ambient conditions) (San Francisco Estuary Institute [SFEI], 1999).

The RMP data were obtained through the RMP Web Query (http://www.sfei.org/rmp/rmp_data_access.html) on February 12, 2013.[10] A subset of the RMP data set for locations sampled within the central San Francisco Bay region were used and included 199 records, collected between 1993 and 2010, from 57 sampling locations to calculate a regional average background concentration. Total DDT was detected in 187 samples, with concentrations ranging from 0.2 to 30.2 µg/kg. The average and median concentration are 3.67 µg/kg and 2.88 µg/kg, respectively. Dieldrin was detected in 102 samples, with concentrations ranging from 0.01 to 0.51 µg/kg. The average and median detected Dieldrin concentrations were 0.12 and 0.11 µg/kg, respectively.

In addition, ambient threshold values for the San Francisco Bay sediments have been developed by the Regional Water Quality Control Board San Francisco Region (Gandesbery and Hetzel, 1998). The ambient threshold values are based on a statistical evaluation of chemical concentrations in surface sediments collected from the bay (Gandesbery and Hetzel, 1998).[11] The ambient stations were located away from point and non-point pollution sources. The ambient threshold values for total DDT and Dieldrin are as follows:

- Total DDT – 2.8 µg/kg for sediments with less than 40 percent fines and 7 µg/kg for sediments dominated by fines
- Dieldrin – 0.18 µg/kg for sediments with less than 40 percent fines and 0.44 µg/kg for sediments dominated by fines

### 7.3.2.2 Remedial Investigation and 2013 Source Identification Sampling outside of Lauritzen Channel

The 1994 RI report for the marine portion of the United Heckathorn site documented that total DDT concentrations in sediment markedly decreased with distance from the Lauritzen Channel and the median total DDT concentration in the lower Inner Harbor Channel was 19 µg/kg (White et al., 1994). A sediment sample collected at biomonitoring station 303.1 in Richmond Inner Harbor in 2008 had a total DDT concentration of about 7 µg/kg (average of field duplicates) (CH2M HILL, 2008), which is consistent with the ambient threshold value for fine-grained sediments in San Francisco Bay. Dieldrin was not detected, although the detection limit was higher than the ambient threshold value.

Total DDT concentrations in the surface intervals of the three locations in the Santa Fe Channel sampled in 2013 were between 23 and 49 µg/kg. Dieldrin was detected in the surface interval at one of the 2013 Santa Fe Channel

[10] The user interface downloading data had changed between the time of the data query and when this report was drafted. The current web data query tool is located at http://www.sfei.org/tools/wqt

[11] The ASC values were derived using data from the 1991 Pilot and ongoing RMP activities and the Bay Protection and Toxic Cleanup Program's 1995 Reference Study. The data set included 81 records with data for polycyclic aromatic hydrocarbons, polychlorinated biphenyls, metals and metalloids, and selected chlorinated pesticides.

locations, at a concentration of 1.7 µg/kg; the detection limit in the other two surface samples was higher than the ambient threshold value.

#### 7.3.2.3 Richmond Inner Harbor

USACE San Francisco District (SF USACE) conducted sediment sampling in Richmond Inner Harbor in February and July 2012 to determine whether sediment was suitable for ocean disposal. The Inner Harbor dredge area was divided into eleven areas from which two cores were collected and composited. The sediment coring locations were on opposite sides of the channel and at each location sediment was collected from the mudline to an elevation of -40 feet MLLW. The results indicated that total DDT concentrations were greater than the project-specific screening values and the San Francisco Bay ambient concentrations in several samples. The highest concentrations were observed in the composites collected from the reach identified as RIH-6, which is shown in Figure 7-1. The two composite samples from RIH-6, designated as RIH-6A (southern sample) and RIH-6B (northern sample, nearest the site), had total DDT concentrations of 23.8 and 58.1 µg/kg, respectively. Dieldrin was detected in both composites at concentrations of 0.96 and 1.7 µg/kg, respectively (Kinnetic Laboratories, Inc. [KLI], 2012). A summary of the analytical results for parameters relevant to this evaluation is provided in Table 7-1.

SF USACE also collected three discrete samples from each coring locations in RIH-6 in order to evaluate the characteristics of the post-removal surface under different dredging scenarios. The analytical results for the parameters of interest for this evaluation are provided in Table 7-1. Total DDT concentrations in these samples ranged from 0.45 µg/kg to 6,690 µg/kg. The samples from coring location at RIH-6A-1 (Figure 7-1) exhibited the highest total DDT concentrations, with the maximum concentration of 6,690 µg/kg found in the -39.5 to -40.0 feet MLLW sample. Concentrations in the samples above and below this interval were an order of magnitude lower, and concentrations in the samples from the other coring locations were one to two orders of magnitude lower. Dieldrin concentrations in these samples exhibited a similar pattern, with concentrations ranging from below the detection limit to 14 µg/kg (KLI, 2012).

Location RIH-6A-1, which contained the highest total DDT and Dieldrin concentrations, is approximately 800 meters from the mouth of the Lauritzen Channel and is located on a shoal on the eastern side of the channel near the northern end of Terminal 3 of the Port of Richmond, and just to the south of Terminal 2. Terminal 3 is used for the handling, storage, and distribution of break bulk, project cargo, and containers. Terminal 2 is used for the storage and distribution of bulk liquid.[12] The relatively higher DDT and Dieldrin concentrations measured in this area are surrounded by samples with lower concentrations, suggesting that the source is local and limited in extent. Although sediment potentially could be transported away from this area through tidal action, it is unlikely that the magnitude of that transport would be sufficient to result in total DDT concentrations above the remediation goal in the Lauritzen Channel.

[12] Port of Richmond information collected from City of Richmond website: http://www.ci.richmond.ca.us/index.aspx?NID=324 Accessed July 17, 2013.

SECTION 8

# Dredging Residuals

## 8.1 Objectives and Approach

The source identification study objectives related to the evaluation of dredging residuals remaining in the Lauritzen Channel after the 1996-1997 remedial action were as follows:

- Determine whether sediments in undredged or partially dredged areas (i.e., undisturbed residuals) were subsequently redistributed throughout the Lauritzen Channel after the remedy was completed, thereby re-contaminating the channel and acting as an ongoing secondary source of contamination.
- Determine whether contaminated sediments that were re-suspended during dredging or sloughed from the sides of the channel (i.e., generated residuals) were deposited throughout the channel after the remedy was completed.

Sediment core and grab sample data collected from 1998 to 2013 were compared to the remediation goal to infer whether dredging residuals are primarily responsible for the high levels contamination seen in the Lauritzen Channel sediments.

## 8.2 Background

Information and data provided in the completion report (CWM, 1997), EPA remediation oversight report (Kohn, 1998), and other documents indicate that both undisturbed and generated residuals remained in the Lauritzen Channel after the remedy was completed in 1997. Two types of dredging residuals were present:

- Undisturbed residuals – sediments that were not dredged either because of obstructions (e.g., abandoned pilings or sediments beneath the Levin pier) or because they were impractical to remove (e.g., sediments along the embankment or rip-rapped areas); in addition, some patches of undredged sediment remained within the removal footprint but were not detected during verification or confirmation sampling.
- Generated residuals – fine-grained material that was re-suspended during dredging, escaped from the dredge bucket, or ran out of the scow. In addition, sediment underneath the Levin pier continually sloughed into the dredged portions of the channel during remedy implementation (Kohn, 1998).

Areas that were dredged in 1996-1997 are shown in Figure 8-1**.** The target dredging depths in each 50-foot-by-50-foot dredge cell were verified through lead-line soundings and hydrographic surveys. If the removal plan bathymetric contours were achieved, then the dredging was determined to be complete. Completion was verified by either penetrating 6 inches into the OBM with the dredge bucket or by collecting vibracore samples in each grid cell. EPA deemed the grid cell complete if at least three of five cores contained no dredgeable YBM. After completion, confirmatory samples for chemical analysis were collected from a total of 18 locations throughout the Lauritzen Channel (USEPA 1997a and 1997b). The average total DDT concentration was below the remediation goal of 590 µg/kg.

Sand was placed throughout the channel after the confirmatory sampling to facilitate the recovery of the benthic community (the sand layer was not intended to isolate and contain dredging residuals). The sand layer was nominally 6 inches thick, with more sand reportedly placed at the head of the canal and in inaccessible areas that could not be dredged. No sand was placed beneath the Levin pier where the slope was too steep to hold it in place, or in the Levin berths on the southeast side of the channel. The sand layer was most likely variable in thickness because of the uneven bottom (Kohn, 1998). Rock and sand were also placed on the embankments (CWM, 1997). The thickness and extent of the benthic sand layer was not verified after placement.

The sand layer was found in only a subset of sediment cores collected in the Lauritzen Channel in 1999, 2003, and 2007 (Kohn and Gilmore, 2001; Kohn and Evans, 2004; CH2M HILL, 2008). The distribution of the sand layer in

2013 is shown in Figure 8-2. In some instances, the sand was observed immediately above the OBM; in other cases, a sand layer was observed separating two intervals of YBM. The presence of YBM beneath the sand layer in some locations indicates that it was incompletely dredged in 1996-1997.

## 8.3 Lines of Evidence and Findings

The analyses in the previous sections concluded that none of the other potential sources that were identified appear to be contributing sufficient masses of DDT to the Lauritzen Channel to account for the concentrations currently seen in the sediments (although the magnitude of discharges from the municipal stormwater system still needs to be verified). Therefore, the most likely explanation for the consistently high levels of DDT detected in sediments throughout the Lauritzen Channel is the presence of dredging residuals. The pesticide data for YBM sediment and soil samples collected from 1998 to 2007 are provided in Table 8-1, and the 2013 sediment grab and core data are provided in Tables 3-2 and 8-2, respectively. Figure 8-3 shows the total DDT concentrations measured in all of the channel and embankment samples collected since 1997 compared to the remediation goal. These data indicate that sediments and soils with DDT concentrations above the remediation goal of 590 µg/kg have been present in and adjacent to the Lauritzen Channel since the time the remedy was completed. It should be noted that the results from one year to another are not directly comparable because samples were not collected from the same locations in every sample event.

Figures 8-4 and 8-5 show the areal distribution of surface and core maximum DDT concentration at the 2013 sampling locations. The surface data clearly indicate that the highest concentrations are found in samples collected in the undredged and partially dredged areas on the eastern embankment, and in the northern two-thirds of the channel. A comparison of the surface and core maximum results indicates that the surface sediment concentrations are lower than the subsurface sediment concentrations in the dredged parts of the channel, suggesting deposition of less contaminated sediment over time. The nature and extent of contamination in the Lauritzen Channel sediments based on the 2013 sample data will be more fully discussed in the forthcoming FFS report.

Erosion and transport of the contaminated embankment sediment under the Levin pier and along the eastern shoreline do not appear to be responsible for the DDT contamination seen in the rest of the Lauritzen Channel sediments. The Tier 2 sediment transport study indicates that wakes from transiting vessels could remobilize under-pier and shoreline sediments, but that the mass of sediment suspended would be low compared to the sediment suspended behind an operating stationary vessel (Sea Engineering Inc. [SEI], 2014).

SECTION 9

# Conclusions

The source identification study did not identify any ongoing sources of contamination to the Lauritzen Channel that are of sufficient magnitude to account for the high DDT concentrations seen throughout the channel sediments. Dredging residuals, including contaminated embankment sediments that were not removed in either the upland or marine remedial actions, appear to be responsible for the majority of the DDT mass currently found in the channel. However, many of the other sources of contamination that were investigated are still active and may lead to the recontamination of channel sediments, surface water, and biota in the future if not controlled. The general conclusions for each potential source are listed in Table 9-1 and the specific findings are as follows:

- The other pipes, outfalls and seeps that were identified in the 2012 site survey do not appear to be ongoing sources of DDT contamination to the Lauritzen Channel under dry weather conditions. The pipes and outfalls that were identified do not convey dry weather flow, and the one continuously-flowing seep that was sampled contained only low levels of pesticides. However, other pipes and conveyances that are not visible may exist (i.e., features that terminate behind rip rap or sheetpile, or are subtidal). Any of the identified or unidentified pipes and conveyances could have and may still act as preferential pathways for the transport of DDT from the upland area to the Lauritzen Channel, particularly adjacent to the former plant site and former train scale area where highly contaminated soils and groundwater still exist. Additionally, the pipes and outfalls have not been inspected or sampled during wet weather conditions.
- The embankment soil and sediment data indicate that DDT contamination is widespread along the eastern, northern, and northwestern shorelines of the Lauritzen Channel. Only two of the 19 shoreline locations sampled in 2013 had total DDT concentrations below the remediation goal of 590 µg/kg. Although the shoreline is largely armored with rip rap and sheetpile, fine-grained sediments are present in pockets in the rip rap and soils are eroding from under the sheetpile in some areas.
- The highest DDT concentrations measured in sediment grab samples collected along the embankment correspond to the areas where interim removal actions along the embankment were previously completed. These interim soil removal actions did not address sediments below about 0 feet MLLW or embankment soils with DDT concentrations below 100 mg/kg. The dredging remedy extended only to the toe of the slope, and the area around the abandoned pilings was only partially dredged. The high DDT concentrations that persist in this area appear to be attributable to historical contamination that was not addressed in either the upland or the marine remedies.
- The shallow aquifer of the upland area east of the Lauritzen Channel contributes total DDT mass to the Lauritzen Channel sediments. The estimated contribution of total DDT from groundwater (approximately 167 g/year) is not of sufficient magnitude to account for the high levels of DDT in channel sediments. This conclusion is consistent with the previous findings in the 1990 upland RI report (Levine Fricke, 1990). However, groundwater discharge will continue to contribute DDT to sediments, surface water and biota in the Lauritzen Channel if not controlled.
- The abandoned wood pilings along the northeastern shoreline are contaminated with DDT. Mechanical weathering of the pilings is an ongoing source of DDT-contaminated particles to the sediment bed and potentially to biota. DDT is not likely to desorb from the pilings into the sediment and water of the channel.
- The City of Richmond municipal outfall at the head of the Lauritzen Channel cannot be fully evaluated as an ongoing source of contamination to the Lauritzen Channel until the DDT-contaminated residual sediments within the storm drain system are removed. These sediments will be removed a part of the remedy, and monitoring will be performed to verify that the municipal drains are no longer acting as a DDT transport pathway to the Lauritzen Channel.
- The stormwater monitoring data collected for the storm drain system that serves the upland cap on the LRTC property indicates that the system is functioning as designed, with only infrequent direct discharges to the

Lauritzen Channel. Low levels of pesticides are periodically detected in stormwater samples from the interceptors.

- The distance and lack of transport pathways between the three other DDT-contaminated sites in Richmond and the United Heckathorn site suggest that none of these three sites are potential sources to the Lauritzen Channel. The available sediment chemistry data for areas outside of the Lauritzen Channel do not suggest that sediments from the San Francisco Bay would be a source of DDT or Dieldrin to the channel. The San Francisco Bay ambient threshold values, RMP concentrations for Central Bay samples, and samples collected in the Santa Fe Channel as part of the 1994 RI and 2013 source identification study are much lower than the pesticide concentrations observed within the Lauritzen Channel.
- The SF USACE sampling results did include some samples with elevated pesticide concentrations at depth in the upper reaches of Richmond Inner Harbor. The lack of concentration gradient between these locations and the Lauritzen Channel, which are approximately 800 meters apart, the position of the sampling location on a small shoal, and the observation that the highest concentrations were at depth all indicate that the sediments in Richmond Inner Harbor would not act as an additional source of contamination to the Lauritzen Channel.
- Dredging residuals appear to be the primary source of the DDT mass currently found in the Lauritzen Channel. The channel and embankment sample data collected since 1997 indicate that sediments and soils with DDT concentrations above the remediation goal of 590 µg/kg have been present in and near the Lauritzen Channel since the time the remedy was completed.

SECTION 10

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# Tables

TABLE 2-1

**Summary of Vibracore Observations - 2013 Source Identification Investigation**

*United Heckathorn Superfund Site, Richmond, California*

| Location | Field Longitude (X) | Field Latitude (Y) | Measured Water Depth (ft) | Observed/Verified Tide (ft MLLW)[1] | Penetration (ft) | Recovery (ft) | Refusal (Y/N) | Core Barrel Advanced to Full Length (Y/N) | OBM in core (Y/N) | Thickness of YBM (Corrected) (ft)[2] | Elevation of YBM Surface (ft MLLW) | Elevation of OBM [3] (ft MLLW) | Evidence of 1997 Benthic Sand Layer (Y/N) | Additional Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SD13-4 | 6023234.68 | 2164441.03 | 14.6 | 0.74 | 7.17 | 1.50 | Y | N | N | 7.17 | -13.86 | *-21.0* | N | Rocks and riprap were observed along the seafloor on west side of channel. Three attempts at this location all resulted sufficient penetration but minimal recovery. The vibracore head continued to slip downslope due to unfavorable bottom conditions. Attempt 3, located approximately 9.8' east of the target location was retained for sampling. Core was black silt and sand over gravel; petroleum hydrocarbon odor noted, stronger in gravel. The core catcher contained OBM. |
| SD13-5 | 6023274.05 | 2164435.49 | 17.7 | 0.36 | 5.50 | 4.10 | Y | N | N | 4.75 | -17.34 | *-22.1* | N | Fine interval core. Entire core dominantly sticky black clay/silt with trace to minor sand. Increased sand and gravel at bottom of core. Strong hydrocarbon-type odor at 3.3' below TOC. |
| SD13-6 | 6023328.85 | 2164430.36 | 13.5 | 2.41 | 5.33 | 5.00 | Y | N | N | 5.33 | -11.09 | *-16.4* | Y | The first attempt at this location hit a rocky bottom. The boat was moved into deeper water slightly to the west of the proposed location. When the core liner was removed from the core barrel, it was noted that the core catcher contained rocks, not OBM. Since no OBM was observed a third attempt was made to collect a core including the YBM/OBM interface. The third attempt had approximately 4' penetration which was stopped by rock. The senior field staff confirmed that 2 attempts at the offset location were sufficient and the third attempt was discarded. Below 2 feet, core is dominantly sand, increasing gravel and decreasing silt/clay content with depth to 4.2 feet. Below 4.2 feet to BOC no gravel and less clay/silt. |
| SD13-8 | 6023181.39 | 2164245.71 | 19.6 | -0.21 | 7.17 | 5.60 | N | Y | Y | 5.57 | -19.81 | -25.4 | N | Transition zone to OBM from 4 to 4.3 feet from TOC. |
| SD13-9 | 6023248.50 | 2164238.21 | 20.7 | -0.37 | 6.00 | 5.50 | N | N | Y | 3.75 | -21.07 | -24.8 | Y | This location was identified as the fine interval sample. The first core retrieved was allowed to rest horizontally for a brief period of time, during barge movement. Since this location is designated as a fine interval sample, a second core was collected. Nose cone was cut off during processing and not included in processed length. Sand layer observed above 0.6 feet of consolidated, black, clay/silt YBM. Due to OBM observation in first core, second core was stopped once a depth of 6 feet had been reached to minimize consolidation of YBM. |
| SD13-10 | 6023307.69 | 2164238.02 | 12.4 | -0.12 | 6.67 | 6.60 | Y | N | Y | 1.87 | -12.52 | -14.4 | N | Minor sand was observed from 0.9 to 1.8 feet below TOC. |
| SD13-13 | 6023160.53 | 2164049.90 | 14.1 | 1.06 | 7.00 | 2.50 | Y | N | Y | 5.60 | -13.04 | -18.6 | N | Sandy silt/clay observed in top 0.6 feet. Penetration was 7' and the operator felt the vibracore tilt when OBM was encountered. OBM was encountered, so despite a low recovery, no additional attempts were required. Since vibracore head tipped over the penetration is overestimated. |
| SD13-14 | 6023212.77 | 2164041.92 | 20.2 | 0.63 | 6.67 | 6.40 | Y | N | Y | 1.17 | -19.57 | -20.7 | N | Top 0.4 feet of core included coarse, dark gray to black sand with clay and silt, approximately 80% sand. |
| SD13-15 | 6023278.51 | 2164034.84 | 14.3 | 0.1 | 6.25 | 4.90 | Y | N | Y | 3.35 | -14.20 | -17.6 | Y | Dark gray to black medium sand (drier than interval above) observed from 1.6 to 2 feet from TOC. |
| SD13-18 | 6023087.22 | 2163850.25 | 21.6 | 2.05 | 6.42 | 6.50 | Y | N | Y | 1.00 | -19.55 | -20.6 | Y | Observed approximately 1 inch of dark gray, medium sand right above OBM. |
| SD13-19 | 6023185.28 | 2163842.50 | 31.5 | 2.26 | 6.00 | 6.10 | Y | N | Y | 4.00 | -29.24 | -33.2 | Y | From 1.8 to 2.7 feet below TOC transition from black clay/silt to medium, dark gray firm, slightly moist sand - decreasing fines with depth noted. From 2.7 to 4 feet below TOC observed dark gray, fine to medium sand, dry and hard. Minor shell hash from 2.7 to 3 feet. Transition to OBM at 4 feet below TOC. |
| SD13-20 | 6023255.11 | 2163837.51 | 25.1 | 1.7 | 7.25 | 5.17 | N | Y | N | 7.25 | -23.40 | NA | N | YBM included black silt/clay with pockets of gravel or gravel with fine sand throughout. |
| SD13-23 | 6023066.85 | 2163651.19 | 21.4 | 1.21 | 4.33 | 3.70 | Y | N | Y | 4.33 | -20.19 | -24.5 | Y | Sand observed from 0.9 to 1.5 feet from TOC - medium, dark gray, trace to minor fines and trace shell hash. Below 1.5 feet black silt/clay was observed interspersed with hard, fat gray-brown clay. No clear transition observed and there appeared to be fingers of silt/clay that comprises YBM into the firmer, drier OBM. From 3 to 3.7 feet, there was less of the black silt/clay. Slight petroleum hydrocarbon odor (observed as diesel-like odor) was noted at bottom of core. |
| SD13-24 | 6023139.40 | 2163642.13 | 32.5 | 0.78 | 6.92 | 6.00 | Y | N | Y | 6.92 | -31.72 | *-38.6* | N | Top 0.7 feet of core was soft, black clay/silt (clearly YBM) and from 0.7 to 4.1 feet below TOC, sediment appeared to be OBM; however from 4.1 to 5.2 feet below the TOC, material became wet again and gravel observed at bottom of this interval. From 5.2 to 6.0 the sediment was soft clay/silt with gravel and pockets of black silt/clay (presumed to be YBM sediment). Based on DDT results entire core is going to be considered YBM for FFS purposes. |
| SD13-25 | 6023211.18 | 2163646.43 | 33.9 | 1.59 | 6.83 | 5.90 | Y | N | N | 6.83 | -32.31 | *-39.1* | Y | Sand observed in bottom interval of core (5.3 to BOC at 5.9 feet). Transition from YBM to sand was abrupt, material below sand interval not observed. |
| SD13-27 | 6022989.83 | 2163456.36 | 13.2 | -0.2 | 5.00 | 3.10 | Y | N | N | 5.00 | -13.40 | *-18.4* | N | Core appeared to be highly disturbed and contained multiple, relatively thin, layers of sediment ranging from black clay/silt and poorly sorted sand and coarse gravel to very hard, dry clay with gravel. |
| SD13-28 | 6023091.65 | 2163452.79 | 34.3 | 0.22 | 6.50 | 6.00 | Y | N | N | 6.50 | -34.08 | *-40.6* | N | At 3 feet from TOC, an abrupt transition in moisture content and firmness observed. Pockets of dark olive-brown to dark gray silt/clay were observed between 4 and 6 feet. |
| SD13-29 | 6023189.47 | 2163438.66 | 34.2 | 0.06 | 6.67 | 6.20 | Y | N | N | 6.67 | -34.14 | *-40.8* | N | Entire core silt/clay with trace fine sand (YBM). PHC odor noted throughout, but was notably stronger near bottom of core. At 5.7 feet from TOC, increased gravel and sand content observed, but there was not a distinct "sand" layer. |
| SD13-31 | 6022972.31 | 2163263.24 | 14.6 | -0.27 | 4.83 | 5.00 | Y | N | Y | 0.00 | N/A | -15.5 | N | Entire core was OBM; the top 2 feet contained areas of mottled dark gray clay/silt and appeared disturbed compared to the sediment below 2 feet. |
| SD13-32 | 6023070.70 | 2163251.79 | 33.5 | -0.3 | 6.75 | 6.10 | Y | N | N | 6.75 | -33.79 | *-40.5* | N | Entire core silt/clay with trace fine sand (YBM). PHC odor noted throughout. Notable transition at 3 feet; sediment above is very cohesive, wet, and sticky; below material is still silt/clay but less wet. At 4.4 feet from TOC observed a clast of black, organic rich material. |
| SD13-33 | 6023168.50 | 2163239.19 | 33.7 | -0.2 | 6.92 | 6.20 | Y | N | N | 6.92 | -33.90 | *-40.8* | N | Entire core is black silt/clay (YBM) with pockets of firmer gray-brown clay observed below 2 feet. |
| SD13-35 | 6022947.27 | 2163061.12 | 30.7 | 0.62 | 6.58 | 5.80 | Y | N | Y | 6.58 | -30.08 | -36.7 | Y | Medium, dark gray sand observed from 2.6 to 2.9 feet from TOC and from 3.4 to 4.6 feet from TOC; trace shell hash observed in lower interval. From 4.6 feet to BOC soft, wet, black silt clay. Plug of OBM observed at very bottom of core. |

TABLE 2-1

**Summary of Vibracore Observations - 2013 Source Identification Investigation**

*United Heckathorn Superfund Site, Richmond, California*

| Location | Field Longitude (X) | Field Latitude (Y) | Measured Water Depth (ft) | Observed/Verified Tide (ft MLLW)[1] | Penetration (ft) | Recovery (ft) | Refusal (Y/N) | Core Barrel Advanced to Full Length (Y/N) | OBM in core (Y/N) | Thickness of YBM (Corrected) (ft)[2] | Elevation of YBM Surface (ft MLLW) | Elevation of OBM [3] (ft MLLW) | Evidence of 1997 Benthic Sand Layer (Y/N) | Additional Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SD13-36 | 6023044.53 | 2163055.96 | 36.5 | 1.71 | 6.58 | 6.50 | Y | N | N | 6.58 | -34.79 | *-41.4* | Y | Sand layer observed from 4.3 to 4.5 feet and 5.2 to 5.4 feet below TOC. Remainder of core clay/silt with varying degrees of firmness and moisture (all YBM). |
| SD13-37 | 6023145.91 | 2163043.31 | 35.3 | -0.19 | 6.58 | 6.00 | Y | N | N | 6.58 | -35.49 | *-42.1* | N | Gravel and rocks noted at bottom of core during processing. |
| SD13-39 | 6022756.43 | 2162979.33 | 40 | 4.06 | 5.58 | 4.90 | Y | N | Y | 4.08 | -35.94 | -40.0 | N | From 4.8 to 5.2 feet below TOC a layer of coarse, angular gravel with sand and silt observed; YBM present below this layer. At 5.6 feet below TOC there is a layer of black, organic rich material, approximately 3/8" thick that had a strong, chemical-type odor. |
| SD13-40 | 6022921.50 | 2162662.19 | 41.5 | 3.07 | 4.92 | 4.00 | Y | N | Y | 2.92 | -38.43 | -41.4 | N | Penetration likely overestimated due to the very soft nature of the surface sediment. From 3 to 3.4 feet the OBM contained what appeared to be black inclusions of YBM. |
| SD13-41 | 6023057.92 | 2162400.50 | 39.1 | 2.25 | 6.42 | 6.50 | Y | N | Y | 3.92 | -36.85 | -40.8 | N | Transition from YBM to OBM observed at 4 feet below TOC. From 4 to 5 feet the clay was broken into angular, gravel-sized clumps, from 4.9 to 5 feet this transitioned into a hard, dark gray clay. |

Notes:

1. Verified tide data from National Oceanographic and Atmospheric Adminstration Station 9414863, Richmond, California. Accessed May 6, 2013.

2. Thickness of the YBM has been corrected to account for less than 100 percent core recovery.

3. Where OBM was not directly observed in cores that met refusal, the inferred elevation of the OBM surface was calculated by subtracting the corrected thickness of YBM from the YBM surface elevation. The inferred values are italicized.

BOC - bottom of core

ft - feet

MLLW - mean lower low water

N/A - not applicable

OBM - Old Bay Mud

TOC - top of core

YBM - Young Bay Mud

TABLE 2-2

**Groundwater Sampling - Field Water Quality Measurements and Elevations - March 2013**

*United Heckathorn Superfund Site, Richmond, California*

| | | | Well Constructionand Elevation Data | | | | | | Field Water Quality Parameters | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well ID | Groundwater Sample Collection Date & Time | | Well Depth (ft) | X | Y | Screen Interval (ft below surface) | Depth to Water (ft) | Tubing Intake Depth (ft) | Temperature ($^{o}$C) | Field pH | Specific Conductivity (mS) | Conductivity (mS) | Comment |
| MW13-01 | 3/25/2013 | 9:50 | 30 | 6023329.05 | 2163993.83 | 20-30 | 10.5 | 29 | 14.9 | 6.61 | 37.02 | 35.69 | Tan and cloudy |
| MW13-02 | NA | NA | 25 | 6023536.06 | 2163403.65 | 14.5-24.5 | NA | NA | NA | NA | NA | NA | |
| MW13-03 | 3/25/2013 | 15:30 | 33 | 6023282.26 | 2163398.94 | 18-33 | 11.5 | 32 | 15.1 | 6.65 | 34.96 | 34.62 | Tan and cloudy |
| MW13-04 | NA | NA | 30.0 | 6023392.09 | 2163360.93 | 20-30 | NA | NA | NA | NA | NA | NA | |
| GW13-05 | 3/21/2013 | 12:35 | 20 | 6023311.18 | 2164535.44 | 10-20 | 9.8 | NR | 21.6 | 6.66 | 43.50 | 43.5 | |
| GW13-06 | 3/21/2013 | 13:34 | 20 | 6023376.60 | 2164512.24 | 9-19 | 10.8 | NR | 26.2 | 6.61 | 27.67 | 24.07 | |
| GW13-07 | 3/22/2013 | 7:45 | 20 | 6023406.38 | 2164296.89 | 9-19 | 10.2 | NR | 15.06 | 6.54 | 21.54 | 17.67 | |
| GW13-08 | 3/22/2013 | 10:30 | 30 | 6023373.35 | 2164162.65 | 20-30 | 10.3 | NR | 19.7 | 6.36 | 28.96 | 26.01 | |
| GW13-09 | 3/22/2013 | 9:45 | 30 | 6023356.70 | 2164090.13 | 20-30 | 9.5 | NR | 17.2 | 6.45 | 35.32 | 30.07 | |
| GW13-10 | 3/22/2013 | 12:10 | 30 | 6023327.88 | 2163914.65 | 20-30 | 10.4 | 29 | 18.3 | 6.73 | 28.09 | 27.20 | Tan and cloudy |
| GW13-11 | 3/22/2013 | 12:45 | 30 | 6023340.97 | 2163840.06 | 20-30 | 7.5 | 29 | 17.9 | 6.71 | 32.23 | 31.61 | Tan and cloudy |
| GW13-12 | 3/22/2013 | 13:30 | 30 | 6023309.89 | 2163760.18 | 20-30 | 10.1 | 29 | 17.6 | 6.67 | 23.95 | 22.06 | Tan and very slightly cloudy |
| GW13-13 | 3/22/2013 | 11:15 | 30 | 6023310.98 | 2163700.38 | 20-30 | 9.6 | 29 | 17.9 | 6.72 | 27.09 | 24.62 | Tan and slightly cloudy |
| GW13-14 | 3/22/2013 | 10:30 | 30 | 6023250.84 | 2163063.34 | 20-30 | 8.0 | 29 | 16.9 | 6.51 | 32.61 | 30.02 | Tan and slightly cloudy |

**Notes:**

°C - degrees Celsius

ft - feet

mg/L - milligram per liter

mS - milliSiemens

mV - millivolts

NR - not recorded

NTU - nephelometric turbidity unit

TABLE 3-1
**Potential Point Sources of Contamination to the Lauritzen Channel**
*United Heckathorn Superfund Site, Richmond, California*

| Point Source Identifier[a] | Description [b] | Phase 1 Identifier Transect [c] | Phase 1 and 2 Comments and Analytical Results | Bent Number[d] | 2012 Site Survey Comments |
|---|---|---|---|---|---|
| **Pipes Documented Prior to the Phase I Source Investigation** | | | | | |
| LCI-1 | Concrete municipal outfall at north end of Lauritzen Channel<br>Flap gate installed on outfall in October 2012 | -47 | Some water flow observed.<br>Sediment samples from outfall pipe contained 1,060 and 300 µg/kg total DDT.<br>Passive sampler placed in outfall pipe for 4 weeks had 3,779 µg/kg polyethylene total DDT | Head of channel | Lauritzen Outfall was located and flap gate observed. |
| PCI-1 | Concrete municipal outfall at north end of Parr Canal.<br>Flap gate installed on outfall prior to site visit on January 25, 2011. | N/A | N/A | | Pipe was not verified because Parr Canal was not inspected as part of the site survey. |
| P1-1 | 8-in. metal outfall through retaining wall about 2 ft above sediment | -27.5 | Some water dripping observed (pipe is submerged at high tide).<br>Sediment samples collected from outfall pipe had 8,700 µg/kg dry weight and 500 µg/kg wet weight total DDT.<br>Passive sampler placed in outfall pipe for 4 weeks had 123,972 µg/kg polyethylene total DDT.<br>Resident mussels collected from pilings near this outfall in Phase 2 had 929 µg/kg total DDT (wet weight); about 2.5 times higher than the concentration in mussels collected from the mid-channel biomonitoring station (303.3). These were the second highest concentrations detected after mussels collected at the seep (P1-4). | | Pipe was located. Tidal drainage was observed dripping from pipe.<br>Biased surface sediment sample collected adjacent to this outfall in 2013 (location SD13-12) had 75,220 µg/kg total DDT. |
| P1-2 | 5.5-in. metal pipe through retaining wall about 5 ft above present sediment surface, same location as 8-in. pipe above | -27.5 | No sediment in pipe, no water flow, not sampled. | | Pipe was located. |
| P1-3 | L-shaped pipe | -24.5 | Valve closed; not sampled. | | Angled metal pipe was located. Appears to be an abandoned fire main. |
| P4-3 | Described in Phase I as a screened pipe end in riprap near north end of sheetpile wall | | Not found during Phase I field survey | | Pipe was not located. |
| P4-1 | Pipe discharging to west side of channel, identified on City of Richmond drainage map. | | Not found during Phase I field survey | | Pipe was not verified because this portion of the Lauritzen Channel was inaccessible by boat due to barge stationed in the channel. |
| P4-2 | 21-inch pipe discharging beneath Levin Pier, identified on City of Richmond drainage map. | | Pipe this size not found at expected location during Phase I field survey, but several smaller previously undocumented pipes were found beneath pier. | +9.5 | 2-inch diameter corroded metal pipe was located. |
| **Pipes identified in Phase I Source Investigation** | | | | | |
| P1-4 | Concrete pipe at bottom of riprap. Described as the "seep" in Phase 2. Grouted on July 18, 2003 by EPA, after the Phase 2 investigation was completed. | -8.5 | Some flow observed in 2002. Pipe is difficult to see as it blends in with cobbles and rip rap.<br>Channel sediment samples collected 18 m south had 1,280 and 150 µg/kg total DDT. Seep water sample had 4.455 µg/L total DDT, which was more than 100 times higher than surface water samples from the Lauritzen Channel.<br>Three seep[1] water samples collected in Phase 2 had an average of 8.99 µg/L total DDT and 2.74 µg/L dissolved DDT, compared to average concentrations of 0.396 µg/L total DDT and 0.022 µg/L | | Former pipe/seep was not located.<br>Biased surface sediment sample collected adjacent to the former seep in 2013 (location SD13-17) had 91,620 µg/kg total DDT. |

[1] This feature was named the "seep" in Phase 2. The Phase 2 report incorrectly described the seep as being located at T-12.5.

TABLE 3-1
**Potential Point Sources of Contamination to the Lauritzen Channel**
*United Heckathorn Superfund Site, Richmond, California*

| Point Source Identifier[a] | Description [b] | Phase 1 Identifier Transect [c] | Phase 1 and 2 Comments and Analytical Results | Bent Number[d] | 2012 Site Survey Comments |
|---|---|---|---|---|---|
| | | | dissolved DDT in channel surface water at the mid-channel biomonitoring station (303.3).<br>Resident mussels collected near the seep in Phase 2 contained 135,700 µg/kg wet weight total DDT, the highest measured on the site. | | |
| P1-5 | Corroded metal pipe identified during February 6, 2002 deployment, under Levin Pier. | +20 | Appears valved off, end very corroded.<br>Sediment sample collected from nearby channel in Phase 1 had 750 µg/kg total DDT. | +20.5 | 10-inch diameter corroded metal pipe located. |
| P1-6 | 6-inch diameter pipe, under Levin Pier. | +31.5 | Appears to discharge occasionally.<br>Nearby channel sediment sampled (T+31.5B) during Phase 1 contained 2,820 µg/kg total DDT. | +31.5 | Corroded metal pipe was located. |
| P1-7 | 8-inch diameter pipe, under Levin Pier. | +59.5 | Appears valved off, old, unused; not sampled or photographed. | +59.5 | 12-inch diameter pipe located. Appears to be an abandoned fire main. |
| **Pipes identified in Phase 4 Source Investigation** | | | | | |
| SW-3 | NA | NA | NA | +27 | 18-inch diameter HDPE storm water interceptor pipe. Filter cloth is loosely hanging from pipe. |
| SW-4 | NA | NA | NA | 0 | 18-inch diameter HDPE storm water interceptor pipe. Contains 8 inch diameter valve and filter cloth intact. Water was flowing from pipe. |
| SW-5 | NA | NA | NA | -17 | 18-inch diameter HDPE storm water interceptor pipe. Contains 8 inch diameter valve and filter cloth intact. |
| SW-6 | NA | NA | NA | Head of channel, east of LC1-1 | 18-inch diameter HDPE storm water interceptor pipe. Contains 8 inch diameter valve and filter cloth intact. |
| SW-7 | NA | NA | NA | Head of channel, west of LC1-1 | 15-inch diameter HDPE storm water interceptor pipe. Appears to be valved closed. |
| P4-4 | NA | NA | NA | Head of channel, west of SW-7 | 10-inch diameter metal pipe.<br>Surface sediment sample collected near outfalls SW-7 and P4-4 in 2013 (location SD13-01) had 298,920 µg/kg total DDT, the highest concentration measured in 2013 |
| P4-5 | NA | NA | NA | Western side channel across from -33 | 4-inch diameter metal pipe. |
| P4-6 | NA | NA | NA | Western side channel across from -26 | 2 to4-inch diameter metal pipe. |
| P4-7 | NA | NA | NA | Western side channel across from -24 | 4-inch diameter metal pipe. |
| P4-8 | NA | NA | NA | 0 | 8-inch diameter corroded metal pipe located at bottom of rip rap. |
| P4-9 | NA | NA | NA | +20.5 | 9-inch diameter corroded metal U-shaped pipe. Appears to be abandoned fire main. |
| P4-10 | NA | NA | NA | +26.5 | 4-inch diameter corroded metal pipe. See Photograph 7 in Attachment 1. |

TABLE 3-1
**Potential Point Sources of Contamination to the Lauritzen Channel**
*United Heckathorn Superfund Site, Richmond, California*

| Point Source Identifier[a] | Description [b] | Phase 1 Identifier Transect [c] | Phase 1 and 2 Comments and Analytical Results | Bent Number[d] | 2012 Site Survey Comments |
|---|---|---|---|---|---|
| P4-11 | NA | NA | NA | +70.5 | 18-inch diameter metal pipe cemented shut. |
| P4-12 | NA | NA | NA | +72 | 6-inch diameter metal pipe. |
| P4-13 | NA | NA | NA | -14 | 2-inch diameter corroded metal pipe. |
| P4-14 | NA | NA | NA | -11.5 | 2-inch diameter corroded metal pipe. |
| P4-15 | NA | NA | NA | -10.5 | 2-inch diameter long metal pipe. |
| P4-16 | NA | NA | NA | T+37 | Seep identified beneath the Levin pier on April 29, 2013<br>Seep water sampled on July 24, 2013 |
| Conduits 1 and 2 | NA | NA | NA | +30.5 | 2 metal conduits. |

**NOTES:**

NA=Not applicable

[a] Point source identifiers have been assigned for this study. Labels containing a prefix of P1 refer to pipes that were identified in the field during the Phase I Source Investigation (Kohn and Evans, 2002). The prefix P4 refers to pipes that were identified on a storm drain figure from the City of Richmond obtained after the Phase I Source Investigation, one structure P4-3 that was discussed in the Phase I Source Investigation but was not located in the field, and all new structures identified during field activities on 11/29/12 and 12/10/12.

[b] Descriptions from Table 3.1 of the Phase I Source Investigation (Kohn and Evans, 2002).

[c] A transect naming system and navigational baseline were established using the numbers assigned to rows of pier pilings (also known as bent numbers) supporting the Levin pier. Each row of pilings was assigned a whole number starting with +1 at the north end of the pier. The transect numbering system for the rows of pier pilings is presented as Attachment B of the SAP (CH2M HILL, 2012). Transect numbers fall between whole number pier pilings (e.g., +17.5 falls between +17 and +18).

[d] Positive bent numbers are associated with existing rows of pier pilings. Negative bent numbers are associated with historical pier pilings. Bent numbers are spaced approximately 15 feet apart.

TABLE 3-2

**Summary of Pesticide and Organic Carbon Results - 2013 Sediment and Embankment Soil Grab Sample Data**

*United Heckathorn Superfund Site, Richmond, California*

| | | | | | | Pesticide results are µg/kg dry weight | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Location ID** | **Location Description** | **Sample ID** | **Sample Type** | **Top Depth (ft)** | **Bottom Depth (ft)** | **Dieldrin** | **2,4-DDD** | **2,4-DDE** | **2,4-DDT** | **4,4-DDD** | **4,4-DDE** | **4,4-DDT** | **Total DDT** | **Total Organic Carbon (mg/kg)** |
| SD13-01 | unbiased | SD13-01-0005 | N | 0.0 | 0.5 | **140** | **1500** | 3.2 UJ | **9700** | **17000** | **720** | **270000** | **298920** | **21100** |
| SD13-02 | unbiased | SD13-02-0005 | N | 0.0 | 0.5 | **78** | **700** | 3.3 UJ | **190** | **4400** | **330** | **8500** | **14120** | **38000 >** |
| SD13-03 | unbiased | SD13-03-0005 | N | 0.0 | 0.5 | **130** | **430** | **160** | **230** | **790** | **390** | **290** | **2290** | **38000 >** |
| SD13-07 | unbiased | SD13-07-0005 | N | 0.0 | 0.5 | **68 J** | **310** | 3.2 UJ | **150** | **1600** | **290** | **580** | **2930** | **31200** |
| SD13-11 | unbiased | SD13-11-0005 | N | 0.0 | 0.5 | **34 J** | **150 J** | 3.2 UJ | **81 J** | **630** | **98 J** | **490** | **1449** | **9700** |
| SD13-12 | Outfall P1-1 at T(-27.5) | SD13-12-0005 | N | 0.0 | 0.5 | **270** | **3900** | **530** | **390** | **61000** | **1600** | **7800** | **75220** | **18700** |
| SD13-16 | unbiased | SD13-16-0005 | N | 0.0 | 0.5 | **180** | **430** | **97** | **670** | **1300** | **860** | **4200** | **7557** | **11300** |
| SD13-17 | Former seep at T(-8.5) | SD13-17-0005 | N | 0.0 | 0.5 | **450** | **3800** | **220 J** | **8900** | **6300** | **3400** | **69000** | **91620** | **10900** |
| SD13-21 | Unbiased | SD13-21-0005 | N | 0.0 | 0.5 | **310 J** | **2300** | **74 J** | **2400** | **7000** | **420** | **28000** | **40194** | **8250** |
| SD13-21 | Unbiased | SD13-79-0005 | FD | 0.0 | 0.5 | **270 J** | **2300** | **120 J** | **3400** | **21000** | **670** | **50000** | **77490** | -- |
| SD13-22 | Hot spot at north end of Levin pier | SD13-22-0005 | N | 0.0 | 0.5 | **170** | **890** | **22 J** | **3100** | **1900** | **200** | **8800** | **14912** | **7150** |
| SD13-26 | Unbiased | SD13-26-0005 | N | 0.0 | 0.5 | **0.98 J** | **12 J** | **1.9 J** | **72 J** | **38 J** | **30 J** | **280** | **433.9** | **18300** |
| SD13-30 | Unbiased | SD13-30-0005 | N | 0.0 | 0.5 | **21 J** | **53 J** | **13 J** | **250** | **220** | **360** | **1500** | **2396** | **10700** |
| SD13-34 | Unbiased | SD13-34-0005 | N | 0.0 | 0.5 | **51** | **86** | **26 J** | **140 J** | **250** | **180** | **610** | **1292** | **17500** |
| SD13-38 | Unbiased | SD13-38-0005 | N | 0.0 | 0.5 | **68** | **63** | **19 J** | **420** | **140** | **320** | **1400** | **2362** | **12200** |
| EMB13-01 | embankment soil | EMB13-01 | N | -- | -- | **220 J** | **520** | 27 U | **110** | **2100 J** | **370 J** | **11000 J** | **14100** | -- |
| EMB13-02 | embankment soil | EMB13-02 | N | -- | -- | **170** | **430** | 22 U | **650** | **1300** | **500** | **2000** | **4880** | -- |
| EMB13-03 | embankment soil | EMB13-03 | N | -- | -- | **350** | **830** | 16 U | **820** | **2600** | **1100** | **2700** | **8050** | -- |
| EMB13-04 | embankment soil | EMB13-04 | N | -- | -- | **380 J** | **560** | **63** | **1400** | **1600** | **1800** | **5300** | **10723** | -- |
| EMB13-05 | embankment soil | EMB13-05 | N | -- | -- | **27** | **74** | 13 U | **15 J** | **260** | **88** | **93** | **530** | -- |

**Notes:**

**Bold** values indicate detected result.

Embankment soils collected opportunistically from areas where thin layers of sediment were observed between pieces of rip-rap and shoreline armoring. Sediment depth was not recorded.

Total DDT is the sum of the detected isomers.

FD - field duplicate

N - normal sample

ft - feet

g/g - grams per gram

mg/kg - milligrams per kilogram

µg/kg - micrograms per kilogram

J - estimated value

U - not detected above reporting limit shown

> actual value is greater than result shown

TABLE 3-3

**Summary of Pesticide and Total Suspended Solids Results - 2013 Seep Sample**

*United Heckathorn Superfund Site, Richmond, California*

| Location ID | Sample Type | Sample ID | Sample Type | Pesticides (µg/L) | | | | | | | | Total Suspended Solids (mg/L) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Dieldrin | 2,4-DDD | 2,4-DDE | 2,4-DDT | 4,4-DDD | 4,4-DDE | 4,4-DDT | Total DDT | | |
| P4-16 | Filtered | SD13-P4-16F | N | **0.071 J** | **0.00212** | **0.00026** | **0.0030** | **0.0044** | **0.00436** | **0.00948** | **0.024** | NA | |
| P4-16 | Whole water | SD13-P4-16 | N | **0.068 J** | **0.00266** | **0.00035 J** | **0.00414** | **0.00586** | **0.00714** | **0.014** | **0.034** | 10 | U |

**Notes:**

**Bold** values indicate detected result.

Total DDT is the sum of the detected isomers.

FD - field duplicate

J - estimated value

N - normal sample

ug/L - micrograms per liter

U - not detected above reporting limit shown

TABLE 4-1

**1986 Estimates of Groundwater Discharge into the Lauritzen Channel from the Eastern Upland Fill**

*United Heckathorn Superfund Site, Richmond, California*

| Sector/Well Pairs | Sector Width (ft) | Saturated Fill Thickness (ft) | Hydraulic Conductivity (cm/sec) | Horizontal Hydraulic Gradient (ft/ft) | Cross Sectional Area of Saturated Fill ($ft^2$) | Groundwater Seepage Through Saturated Fill (gpd) |
|---|---|---|---|---|---|---|
| **Low Tide** | | | | | | |
| 1. B33 to B34 | 220 | 0.7 | $8.3\times10^{-4}$ | 0.0550 | 154 | 150 |
| 2. B29 to B30 | 330 | 0.0 [a] | $7.3\times10^{-4}$ | Negative [b] | 0 | 0 |
| 3. B5A to B11 | 385 | 0.7 | $8.3\times10^{-4}$ | 0.0092 | 270 | 43 |
| 4. B25 to B26 | 290 | 0.1 | $7.3\times10^{-4}$ | 0.0065 | 29 | 3 |
| 5. B24 to B23 | 130 | 3.4 | $7.3\times10^{-4}$ | 0.0380 | 442 | 260 |
| | | | | | **Low Tide Total** | **456** |
| **High Tide** | | | | | | |
| 1. B33 to B34 | 220 | 0.7 | $8.3\times10^{-4}$ | 0.0470 | 154 | 130 |
| 2. B29 to B30 | 330 | 0.0 [a] | $7.3\times10^{-4}$ | Negative [b] | 0 | 0 |
| 3. B5A to B11 | 385 | 0.7 | $8.3\times10^{-4}$ | 0.0092 | 270 | 43 |
| 4. B25 to B26 | 290 | 0.1 | $7.3\times10^{-4}$ | 0.0065 | 29 | 3 |
| 5. B24 to B23 | 130 | 5.1 | $7.3\times10^{-4}$ | 0.0150 | 663 | 150 |
| | | | | | **High Tide Total** | **326** |

[a] Groundwater within this sector was not present in the fill.

[b] Water-level measurements in wells B29 and B30 indicated groundwater flow away from the channel. This was due to the presence of a sheetpile wall along the embankment.

N**ote:**

Source: HLA (1986)

TABLE 4-2
**Groundwater Sample Analytical Data March 2013**
*United Heckathorn Superfund Site, Richmond, California*

| | Location: | GW13-05 | GW13-05 | GW13-06 | GW13-06 | GW13-07 | GW13-07 | GW13-07 | GW13-07 | GW13-08 | GW13-08 | GW13-09 | GW13-09 | GW13-10 | GW13-10 | GW13-11 | GW13-11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date: | 3/21/2013 | 3/21/2013 | 3/21/2013 | 3/21/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 |
| | Sample Type: | N | N | N | N | N | FD | N | FD | N | N | N | N | N | N | N | N |
| | Basis: | Filtered | Total | Filtered | Total | Filtered | Filtered | Total | Total | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total |
| **Parameter** | **Units** | | | | | | | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | | | | | | | |
| 2,4-DDD | µg/L | **0.0326** | **1.15 J** | **0.0339** | **1.67 J** | **0.00161 J-** | **0.169 J** | **3.85 J+** | **1.24 J** | **0.00837** | **0.0223 J** | **0.44 J** | **2.06 J** | **0.0691 J** | **0.0944** | **3.6 J** | **8.05 J** |
| 2,4-DDE | µg/L | **0.00326** | **0.231** | **0.00878** | **0.915** | **0.0000763 J** | **0.00264** | **0.149 J** | **0.0422 J** | **0.0000721 J** | **0.000362 J** | **0.00132 J** | **0.0123 J** | **0.00255** | **0.00401 J** | **0.0296 J** | **0.221 J** |
| 2,4-DDT | µg/L | **0.0102** | **1.02 J** | **0.0513** | **6.66 J** | 0.0000372 U | **0.000248 J+** | **0.0257 J** | **0.00737 J** | **0.00507** | **0.0254 J** | **0.0146** | **0.171** | **0.324 J** | **0.528 J** | **3.1** | **26.8 J** |
| 4,4-DDD | µg/L | **0.0514** | **2.07 J** | **0.0311** | **1.77 J** | **0.00281 J-** | **0.342 J** | **6.86 J+** | **2.44 J** | **0.0133** | **0.0536** | **1.45 J** | **5.93 J** | **0.111 J** | **0.149** | **4.2 J** | **13.4 J** |
| 4,4-DDE | µg/L | **0.0443** | **3.18 J** | **0.133 J** | **13.4 J** | **0.000958 J-** | **0.0227** | **1.79 J+** | **0.544** | **0.000826** | **0.00593 J** | **0.0132** | **0.151** | **0.0339** | **0.055 J** | **0.24** | **2.87 J** |
| 4,4-DDT | µg/L | **0.0302** | **2.87 J** | **0.168 J** | **19.7 J** | 0.0000194 U | **0.000693 J+** | **0.104 J** | **0.0276 J** | **0.006 J+** | **0.172** | **0.053** | **0.835 J** | **0.5 J** | **1.69 J** | **3.44** | **18.3 J** |
| Dieldrin | µg/L | **0.078 J** | **0.577 J** | **0.206 J** | **1.42 J** | **0.00156 J-** | **0.848 J** | **2.83 J+** | **1.23 J+** | **0.0207** | **0.0305 J** | **0.106** | **0.165** | **1.21 J** | **1.31 J** | **5.75 J** | **0.435 J** |
| Total DDT | µg/L | **0.172** | **10.5** | **0.426** | **44.1** | **0.00545** | **0.537** | **12.8** | **4.3** | **0.0336** | **0.28** | **1.97** | **9.16** | **1.04** | **2.52** | **14.6** | **69.6** |
| **Volatile Organic Compounds** | | | | | | | | | | | | | | | | | |
| 1,1,1-Trichloroethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,1,2,2-Tetrachloroethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,1,2-Trichloro-1,2,2-trifluoroethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,1,2-Trichloroethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,1-Dichloroethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,1-Dichloroethene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 UJ | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,2,3-Trichlorobenzene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,2,4-Trichlorobenzene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,2-Dibromo-3-chloropropane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,2-Dibromoethane (EDB) | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,2-Dichlorobenzene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,2-Dichloroethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | **0.58** | --- | **8.9 J** | --- | **0.18 J** | --- | 0.5 U | --- | 0.5 U |
| 1,2-Dichloropropane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,3-Dichlorobenzene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | **41 J** | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,4-Dichlorobenzene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | **1.3** |
| 2-Butanone (MEK) | µg/L | --- | 5 U | --- | 5 U | --- | --- | 5 U | 5 U | --- | 500 U | --- | 5 U | --- | 5 U | --- | 5 U |
| 2-Hexanone | µg/L | --- | 5 U | --- | 5 U | --- | --- | 5 U | 5 U | --- | 500 U | --- | 5 U | --- | 5 U | --- | 5 U |
| 4-Methyl-2-pentanone (MIBK) | µg/L | --- | 5 U | --- | 5 U | --- | --- | 5 U | 5 U | --- | 500 U | --- | 5 U | --- | 5 U | --- | 5 U |
| Acetone | µg/L | --- | 5 U | --- | 5 U | --- | --- | 5 U | 5 U | --- | 500 U | --- | 5 U | --- | 5 U | --- | 5 U |
| Benzene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 UJ | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | **3.4** |
| Bromochloromethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Bromodichloromethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Bromoform | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Bromomethane | µg/L | --- | 0.5 U | --- | **0.12 J** | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Carbon disulfide | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Carbon tetrachloride | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Chlorobenzene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 UJ | 0.5 U | --- | **6.3 J** | --- | 0.5 U | --- | 0.5 U | --- | **3.1** |
| Chlorodibromomethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Chloroethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Chloroform | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Chloromethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| cis-1,2-Dichloroethene | µg/L | --- | **0.11 J** | --- | 0.5 U | --- | --- | 0.5 U | **1.8** | --- | **7,500** | --- | **0.61** | --- | 0.5 U | --- | 0.5 U |
| cis-1,3-Dichloropropene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |

TABLE 4-2
**Groundwater Sample Analytical Data March 2013**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | | GW13-05 | GW13-05 | GW13-06 | GW13-06 | GW13-07 | GW13-07 | GW13-07 | GW13-07 | GW13-08 | GW13-08 | GW13-09 | GW13-09 | GW13-10 | GW13-10 | GW13-11 | GW13-11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | | 3/21/2013 | 3/21/2013 | 3/21/2013 | 3/21/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 |
| Sample Type: | | N | N | N | N | N | FD | N | FD | N | N | N | N | N | N | N | N |
| Basis: | | Filtered | Total | Filtered | Total | Filtered | Filtered | Total | Total | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total |
| **Parameter** | **Units** | | | | | | | | | | | | | | | | |
| **Volatile Organic Compounds** | | | | | | | | | | | | | | | | | |
| Cyclohexane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Dichlorodifluoromethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Dichloromethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Ethylbenzene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Isopropylbenzene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| m&p-Xylene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Methyl acetate | µg/L | --- | **0.48 J** | --- | **0.48 J** | --- | --- | **0.54** | **0.48 J** | --- | 50 U | --- | **0.5 J** | --- | **0.6** | --- | **0.48 J** |
| Methylcyclohexane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| o-Xylene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Styrene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| tert-Butyl methyl ether (MTBE) | µg/L | --- | **0.2 J** | --- | **0.27 J** | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Tetrachloroethene | µg/L | --- | 0.5 U | --- | **0.12 J** | --- | --- | 0.5 U | **6.7** | --- | **84** | --- | **0.15 J** | --- | 0.5 U | --- | 0.5 U |
| Toluene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 UJ | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| trans-1,2-Dichloroethene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | **29 J** | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| trans-1,3-Dichloropropene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Trichloroethene | µg/L | --- | 0.5 U | --- | **0.19 J** | --- | --- | 0.5 UJ | **9.4** | --- | **1,300** | --- | **0.16 J** | --- | 0.5 U | --- | 0.5 U |
| Trichlorofluoromethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | 50 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Vinyl chloride | µg/L | --- | 0.5 U | --- | 0.5 U | --- | --- | 0.5 U | 0.5 U | --- | **370** | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| **Semivolatile Organic Compounds** | | | | | | | | | | | | | | | | | |
| 1,1'-Biphenyl | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 1,2,4,5-Tetrachlorobenzene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2,2'-Oxybis(1-chloropropane) | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2,3,4,6-Tetrachlorophenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2,4,5-Trichlorophenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2,4,6-Trichlorophenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2,4-Dichlorophenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2,4-Dimethylphenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2,4-Dinitrophenol | µg/L | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2,4-Dinitrotoluene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2,6-Dinitrotoluene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2-Chloronaphthalene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2-Chlorophenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2-Methylnaphthalene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2-Methylphenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2-Nitroaniline | µg/L | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2-Nitrophenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 3,3'-Dichlorobenzidine | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 3-Nitroaniline | µg/L | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 4,6-Dinitro-2-methylphenol | µg/L | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 4-Bromophenyl phenyl ether | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 4-Chloro-3-methylphenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 4-Chloroaniline | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |

TABLE 4-2
**Groundwater Sample Analytical Data March 2013**
*United Heckathorn Superfund Site, Richmond, California*

| | Location: | GW13-05 | GW13-05 | GW13-06 | GW13-06 | GW13-07 | GW13-07 | GW13-07 | GW13-07 | GW13-08 | GW13-08 | GW13-09 | GW13-09 | GW13-10 | GW13-10 | GW13-11 | GW13-11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date: | 3/21/2013 | 3/21/2013 | 3/21/2013 | 3/21/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 |
| | Sample Type: | N | N | N | N | N | FD | N | FD | N | N | N | N | N | N | N | N |
| | Basis: | Filtered | Total | Filtered | Total | Filtered | Filtered | Total | Total | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total |
| **Parameter** | **Units** | | | | | | | | | | | | | | | | |
| **Semivolatile Organic Compounds** | | | | | | | | | | | | | | | | | |
| 4-Chlorophenyl phenyl ether | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 4-Methylphenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 4-Nitroaniline | µg/L | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 4-Nitrophenol | µg/L | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| Acenaphthalene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Acenaphthene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Acetophenone | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Anthracene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Atrazine | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Benzaldehyde | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| benzo(a) anthracene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| benzo(a) pyrene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| benzo(b) fluoranthene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| benzo(g,h,i) perylene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| benzo(k) fluoranthene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Bis(2-chloroethoxy)methane | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Bis(2-chloroethyl)ether | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| bis(2-ethylhexyl)phthalate | µg/L | 5 U | 5 U | 5 U | **4 J** | **3.1 J** | 5 U | **4.1 J** | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Butyl benzyl phthalate | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Caprolactam | µg/L | 5 U | 5 U | **6.7** | 5 U | 5 U | **41** | 5 U | 5 U | **60** | 5 U | **72** | 5 U | **79** | 5 U | **83** | 5 U |
| Carbazole | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Chrysene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| dibenzo(a,h) anthracene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Dibenzofuran | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Diethyl phthalate | µg/L | **5 J** | **4.9 J** | 5 U | 5 U | **8.8** | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Dimethyl phthalate | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Di-n-butyl phthalate | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Di-n-octyl phthalate | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Fluoranthene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Fluorene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Hexachlorobenzene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Hexachlorobutadiene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Hexachlorocyclopentadiene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Hexachloroethane | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| indeno(1,2,3-cd) pyrene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Isophorone | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Naphthalene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Nitrobenzene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| N-Nitroso-di-n-propylamine | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| N-Nitrosodiphenylamine | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Pentachlorophenol | µg/L | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| Phenanthrene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |

TABLE 4-2
**Groundwater Sample Analytical Data March 2013**
*United Heckathorn Superfund Site, Richmond, California*

| | Location: | GW13-05 | GW13-05 | GW13-06 | GW13-06 | GW13-07 | GW13-07 | GW13-07 | GW13-07 | GW13-08 | GW13-08 | GW13-09 | GW13-09 | GW13-10 | GW13-10 | GW13-11 | GW13-11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date: | 3/21/2013 | 3/21/2013 | 3/21/2013 | 3/21/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 |
| | Sample Type: | N | N | N | N | N | FD | N | FD | N | N | N | N | N | N | N | N |
| | Basis: | Filtered | Total | Filtered | Total | Filtered | Filtered | Total | Total | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total |
| **Parameter** | **Units** | | | | | | | | | | | | | | | | |
| **Semivolatile Organic Compounds** | | | | | | | | | | | | | | | | | |
| Phenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | **8.6** | 5 U | 5 U | 5 U | 5 U | 5 U | **10** | 5 U |
| Pyrene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |

TABLE 4-2
**Groundwater Sample Analytical Data March 2013**
*United Heckathorn Superfund Site, Richmond, California*

| | Location: | GW13-12 | GW13-12 | GW13-13 | GW13-13 | GW13-14 | GW13-14 | MW13-01 | MW13-01 | MW13-03 | MW13-03 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date: | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/25/2013 | 3/25/2013 | 3/25/2013 | 3/25/2013 |
| | Sample Type: | N | N | N | N | N | N | N | N | N | N |
| | Basis: | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total |
| **Parameter** | **Units** | | | | | | | | | | |
| **Pesticides** | | | | | | | | | | | |
| 2,4-DDD | µg/L | **0.0142** | **0.0284 J** | **0.0173** | **0.113** | **0.0033** | **0.00529 J** | **0.0541 J** | **0.075 J** | **0.0163** | **0.0202** |
| 2,4-DDE | µg/L | **0.0000878 J** | **0.00036 J** | **0.000122 J** | **0.00215 J** | **0.000138 J** | **0.000239 J** | **0.000213 J** | **0.000447 J** | **0.000121 J** | **0.000326 J** |
| 2,4-DDT | µg/L | **0.00773** | **0.03 J** | **0.0119** | **0.322** | **0.0306** | **0.127** | **0.00299 J** | **0.00737 J** | **0.00884 J** | **0.024** |
| 4,4-DDD | µg/L | **0.0348 J** | **0.0695 J** | **0.0435 J** | **0.366 J** | **0.00984** | **0.0173 J** | **0.118** | **0.171** | **0.0244** | **0.0503 J** |
| 4,4-DDE | µg/L | **0.000698** | **0.00394** | **0.00113** | **0.0358 J** | **0.00221** | **0.00426 J** | **0.00156 J** | **0.00431 J** | **0.00136 J** | **0.00499 J** |
| 4,4-DDT | µg/L | **0.0331** | **0.143 J** | **0.0484** | **2.47 J** | **0.107 J** | **0.441** | **0.00715 J+** | **0.0379** | **0.0194** | **0.165 J** |
| Dieldrin | µg/L | **0.0876 J** | **0.0765 J** | **0.00876** | **0.0684** | **0.00165** | **0.00124 J** | **0.165** | **0.163** | **0.0656 J** | **0.0612 J** |
| Total DDT | µg/L | **0.0906** | **0.275** | **0.122** | **3.31** | **0.153** | **0.595** | **0.184013** | **0.296027** | **0.070421** | **0.264816** |
| **Volatile Organic Compounds** | | | | | | | | | | | |
| 1,1,1-Trichloroethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,1,2,2-Tetrachloroethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,1,2-Trichloro-1,2,2-trifluoroethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,1,2-Trichloroethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,1-Dichloroethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,1-Dichloroethene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,2,3-Trichlorobenzene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,2,4-Trichlorobenzene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,2-Dibromo-3-chloropropane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,2-Dibromoethane (EDB) | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,2-Dichlorobenzene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,2-Dichloroethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,2-Dichloropropane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,3-Dichlorobenzene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 1,4-Dichlorobenzene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| 2-Butanone (MEK) | µg/L | --- | 5 U | --- | 5 U | --- | 5 U | --- | 5 U | --- | 5 U |
| 2-Hexanone | µg/L | --- | 5 U | --- | 5 U | --- | 5 U | --- | 5 U | --- | 5 U |
| 4-Methyl-2-pentanone (MIBK) | µg/L | --- | 5 U | --- | 5 U | --- | 5 U | --- | 5 U | --- | 5 U |
| Acetone | µg/L | --- | 5 U | --- | 5 U | --- | 5 U | --- | 5 U | --- | 5 U |
| Benzene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Bromochloromethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Bromodichloromethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Bromoform | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | **0.15 J** | --- | 0.5 U |
| Bromomethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Carbon disulfide | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Carbon tetrachloride | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Chlorobenzene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Chlorodibromomethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | **0.16 J** | --- | **0.07 J** |
| Chloroethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Chloroform | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Chloromethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| cis-1,2-Dichloroethene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| cis-1,3-Dichloropropene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |

TABLE 4-2
**Groundwater Sample Analytical Data March 2013**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | | GW13-12 | GW13-12 | GW13-13 | GW13-13 | GW13-14 | GW13-14 | MW13-01 | MW13-01 | MW13-03 | MW13-03 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/25/2013 | 3/25/2013 | 3/25/2013 | 3/25/2013 |
| Sample Type: | | N | N | N | N | N | N | N | N | N | N |
| Basis: | | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total |
| **Parameter** | **Units** | | | | | | | | | | |
| **Volatile Organic Compounds** | | | | | | | | | | | |
| Cyclohexane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Dichlorodifluoromethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Dichloromethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Ethylbenzene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Isopropylbenzene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| m&p-Xylene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Methyl acetate | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | **0.86** | --- | **0.84** |
| Methylcyclohexane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| o-Xylene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Styrene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| tert-Butyl methyl ether (MTBE) | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | **0.08 J** | --- | 0.5 U |
| Tetrachloroethene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Toluene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| trans-1,2-Dichloroethene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| trans-1,3-Dichloropropene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Trichloroethene | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Trichlorofluoromethane | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| Vinyl chloride | µg/L | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U | --- | 0.5 U |
| **Semivolatile Organic Compounds** | | | | | | | | | | | |
| 1,1'-Biphenyl | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 1,2,4,5-Tetrachlorobenzene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2,2'-Oxybis(1-chloropropane) | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2,3,4,6-Tetrachlorophenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2,4,5-Trichlorophenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2,4,6-Trichlorophenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2,4-Dichlorophenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2,4-Dimethylphenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2,4-Dinitrophenol | µg/L | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2,4-Dinitrotoluene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2,6-Dinitrotoluene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2-Chloronaphthalene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2-Chlorophenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 UJ |
| 2-Methylnaphthalene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2-Methylphenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 2-Nitroaniline | µg/L | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2-Nitrophenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 3,3'-Dichlorobenzidine | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 3-Nitroaniline | µg/L | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 4,6-Dinitro-2-methylphenol | µg/L | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 4-Bromophenyl phenyl ether | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 4-Chloro-3-methylphenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 4-Chloroaniline | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |

TABLE 4-2
**Groundwater Sample Analytical Data March 2013**
*United Heckathorn Superfund Site, Richmond, California*

| Location: | | GW13-12 | GW13-12 | GW13-13 | GW13-13 | GW13-14 | GW13-14 | MW13-01 | MW13-01 | MW13-03 | MW13-03 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/25/2013 | 3/25/2013 | 3/25/2013 | 3/25/2013 |
| Sample Type: | | N | N | N | N | N | N | N | N | N | N |
| Basis: | | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total |
| **Parameter** | **Units** | | | | | | | | | | |
| **Semivolatile Organic Compounds** | | | | | | | | | | | |
| 4-Chlorophenyl phenyl ether | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 4-Methylphenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 4-Nitroaniline | µg/L | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 4-Nitrophenol | µg/L | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| Acenaphthalene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Acenaphthene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Acetophenone | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Anthracene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Atrazine | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Benzaldehyde | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| benzo(a) anthracene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| benzo(a) pyrene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| benzo(b) fluoranthene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| benzo(g,h,i) perylene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| benzo(k) fluoranthene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Bis(2-chloroethoxy)methane | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Bis(2-chloroethyl)ether | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| bis(2-ethylhexyl)phthalate | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | **3.2 J** | 5 U | 5 U | 5 U |
| Butyl benzyl phthalate | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Caprolactam | µg/L | **65** | 5 U | **74** | 5 U | **33** | 5 U | 5 U | 5 U | 5 U | 5 U |
| Carbazole | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Chrysene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| dibenzo(a,h) anthracene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Dibenzofuran | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Diethyl phthalate | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Dimethyl phthalate | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Di-n-butyl phthalate | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Di-n-octyl phthalate | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Fluoranthene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Fluorene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Hexachlorobenzene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Hexachlorobutadiene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Hexachlorocyclopentadiene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Hexachloroethane | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| indeno(1,2,3-cd) pyrene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Isophorone | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Naphthalene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Nitrobenzene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| N-Nitroso-di-n-propylamine | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| N-Nitrosodiphenylamine | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Pentachlorophenol | µg/L | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| Phenanthrene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |

TABLE 4-2
**Groundwater Sample Analytical Data March 2013**
*United Heckathorn Superfund Site, Richmond, California*

| | Location: | GW13-12 | GW13-12 | GW13-13 | GW13-13 | GW13-14 | GW13-14 | MW13-01 | MW13-01 | MW13-03 | MW13-03 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date: | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/22/2013 | 3/25/2013 | 3/25/2013 | 3/25/2013 | 3/25/2013 |
| | Sample Type: | N | N | N | N | N | N | N | N | N | N |
| | Basis: | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total | Filtered | Total |
| **Parameter** | **Units** | | | | | | | | | | |
| **Semivolatile Organic Compounds** | | | | | | | | | | | |
| Phenol | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Pyrene | µg/L | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |

Notes:

Detected results are bolded
--= not analyzed
FD = field duplicate
J = Concentration or reporting limit estimated by laboratory or data validation.
J- = Concentration or reporting limit estimated by laboratory or data validation, biased low
J+ =Concentration or reporting limit estimated by laboratory or data validation, biased high
mg/L = milligrams per liter
N = primary sample
U = Not detected at listed reporting limit
µg/L = micrograms per liter

TABLE 4-3
**Statistical Summary of Analytical Results for Groundwater Samples, March 2013**
*United Heckathorn Superfund Site, Richmond, California*

| Analyte | Units | Range of NonDetect RLs | Minimum Detect | Maximum Detect | Average Result | Number of Detects | Number of Samples | Location of Maximum Detect |
|---|---|---|---|---|---|---|---|---|
| **Dissolved Pesticides** | | | | | | | | |
| 2,4-DDD | µg/L | -- | 0.0033 | 3.6 J | 0.372 | 12 | 12 | GW13-11 |
| 2,4-DDE | µg/L | -- | 0.0000721 J | 0.0296 J | 0.00408 | 12 | 12 | GW13-11 |
| 2,4-DDT | µg/L | -- | 0.000248 J+ | 3.1 | 0.297 | 12 | 12 | GW13-11 |
| 4,4-DDD | µg/L | -- | 0.00984 | 4.2 J | 0.536 | 12 | 12 | GW13-11 |
| 4,4-DDE | µg/L | -- | 0.000698 | 0.24 | 0.0412 | 12 | 12 | GW13-11 |
| 4,4-DDT | µg/L | -- | 0.000693 J+ | 3.44 | 0.368 | 12 | 12 | GW13-11 |
| Dieldrin | µg/L | -- | 0.00165 | 5.75 J | 0.712 | 12 | 12 | GW13-11 |
| Total DDT | µg/L | -- | 0.0336 | 14.6 | 1.62 | 12 | 12 | GW13-11 |
| **Total Pesticides** | | | | | | | | |
| 2,4-DDD | µg/L | -- | 0.00529 J | 8.05 J | 1.43 | 12 | 12 | GW13-11 |
| 2,4-DDE | µg/L | -- | 0.000239 J | 0.915 | 0.128 | 12 | 12 | GW13-06 |
| 2,4-DDT | µg/L | -- | 0.00737 J | 26.8 J | 2.98 | 12 | 12 | GW13-11 |
| 4,4-DDD | µg/L | -- | 0.0173 J | 13.4 J | 2.58 | 12 | 12 | GW13-11 |
| 4,4-DDE | µg/L | -- | 0.00394 | 13.4 J | 1.79 | 12 | 12 | GW13-06 |
| 4,4-DDT | µg/L | -- | 0.0379 | 19.7 J | 3.91 | 12 | 12 | GW13-06 |
| Dieldrin | µg/L | -- | 0.00124 J | 2.83 J+ | 0.595 | 12 | 12 | GW13-07 |
| Total DDT | µg/L | -- | 0.264816 | 69.6 | 12.8 | 12 | 12 | GW13-11 |
| **Total Volatile Organic Compounds** | | | | | | | | |
| 1,1,1-Trichloroethane | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| 1,1,2,2-Tetrachloroethane | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| 1,1,2-Trichloro-1,2,2-trifluoroethane | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| 1,1,2-Trichloroethane | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| 1,1-Dichloroethane | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| 1,1-Dichloroethene | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| 1,2,3-Trichlorobenzene | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| 1,2,4-Trichlorobenzene | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| 1,2-Dibromo-3-chloropropane | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| 1,2-Dibromoethane (EDB) | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| 1,2-Dichlorobenzene | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| 1,2-Dichloroethane | µg/L | 0.5 U | 0.18 J | 8.9 J | 0.805 | 3 | 12 | GW13-08 |
| 1,2-Dichloropropane | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| 1,3-Dichlorobenzene | µg/L | 0.5 U | 41 J | 41 J | 3.42 | 1 | 12 | GW13-08 |
| 1,4-Dichlorobenzene | µg/L | 0.5 U - 50 U | 1.3 | 1.3 | 0.108 | 1 | 12 | GW13-11 |
| 2-Butanone (MEK) | µg/L | 5 U - 500 U | -- | -- | -- | 0 | 12 | NA |

TABLE 4-3
**Statistical Summary of Analytical Results for Groundwater Samples, March 2013**
*United Heckathorn Superfund Site, Richmond, California*

| Analyte | Units | Range of NonDetect RLs | Minimum Detect | Maximum Detect | Average Result | Number of Detects | Number of Samples | Location of Maximum Detect |
|---|---|---|---|---|---|---|---|---|
| **Total Volatile Organic Compounds** | | | | | | | | |
| 2-Hexanone | µg/L | 5 U - 500 U | -- | -- | -- | 0 | 12 | NA |
| 4-Methyl-2-pentanone (MIBK) | µg/L | 5 U - 500 U | -- | -- | -- | 0 | 12 | NA |
| Acetone | µg/L | 5 U - 500 U | -- | -- | -- | 0 | 12 | NA |
| Benzene | µg/L | 0.5 U - 50 U | 3.4 | 3.4 | 0.283 | 1 | 12 | GW13-11 |
| Bromochloromethane | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| Bromodichloromethane | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| Bromoform | µg/L | 0.5 U - 50 U | 0.15 J | 0.15 J | 0.0125 | 1 | 12 | MW13-01 |
| Bromomethane | µg/L | 0.5 U - 50 U | 0.12 J | 0.12 J | 0.01 | 1 | 12 | GW13-06 |
| Carbon disulfide | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| Carbon tetrachloride | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| Chlorobenzene | µg/L | 0.5 U | 3.1 | 6.3 J | 0.783 | 2 | 12 | GW13-08 |
| Chlorodibromomethane | µg/L | 0.5 U - 50 U | 0.07 J | 0.16 J | 0.0192 | 2 | 12 | MW13-01 |
| Chloroethane | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| Chloroform | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| Chloromethane | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| cis-1,2-Dichloroethene | µg/L | 0.5 U | 0.11 J | 7,500 | 625 | 4 | 12 | GW13-08 |
| cis-1,3-Dichloropropene | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| Cyclohexane | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| Dichlorodifluoromethane | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| Dichloromethane | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| Ethylbenzene | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| Isopropylbenzene | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| m&p-Xylene | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| Methyl acetate | µg/L | 0.5 U - 50 U | 0.48 J | 0.86 | 0.398 | 8 | 12 | MW13-01 |
| Methylcyclohexane | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| o-Xylene | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| Styrene | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| tert-Butyl methyl ether (MTBE) | µg/L | 0.5 U - 50 U | 0.08 J | 0.27 J | 0.0458 | 3 | 12 | GW13-06 |
| Tetrachloroethene | µg/L | 0.5 U | 0.12 J | 84 | 7.58 | 4 | 12 | GW13-08 |
| Toluene | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| trans-1,2-Dichloroethene | µg/L | 0.5 U | 29 J | 29 J | 2.42 | 1 | 12 | GW13-08 |
| trans-1,3-Dichloropropene | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |
| Trichloroethene | µg/L | 0.5 U | 0.16 J | 1,300 | 109 | 4 | 12 | GW13-08 |
| Trichlorofluoromethane | µg/L | 0.5 U - 50 U | -- | -- | -- | 0 | 12 | NA |

TABLE 4-3
**Statistical Summary of Analytical Results for Groundwater Samples, March 2013**
*United Heckathorn Superfund Site, Richmond, California*

| Analyte | Units | Range of NonDetect RLs | Minimum Detect | Maximum Detect | Average Result | Number of Detects | Number of Samples | Location of Maximum Detect |
|---|---|---|---|---|---|---|---|---|
| **Total Volatile Organic Compounds** | | | | | | | | |
| Vinyl chloride | µg/L | 0.5 U | 370 | 370 | 30.8 | 1 | 12 | GW13-08 |
| **Dissolved Semivolatile Organic Compounds** | | | | | | | | |
| 1,1'-Biphenyl | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 1,2,4,5-Tetrachlorobenzene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2,2'-Oxybis(1-chloropropane) | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2,3,4,6-Tetrachlorophenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2,4,5-Trichlorophenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2,4,6-Trichlorophenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2,4-Dichlorophenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2,4-Dimethylphenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2,4-Dinitrophenol | µg/L | 10 U | -- | -- | -- | 0 | 12 | NA |
| 2,4-Dinitrotoluene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2,6-Dinitrotoluene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2-Chloronaphthalene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2-Chlorophenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2-Methylnaphthalene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2-Methylphenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2-Nitroaniline | µg/L | 10 U | -- | -- | -- | 0 | 12 | NA |
| 2-Nitrophenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 3,3'-Dichlorobenzidine | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 3-Nitroaniline | µg/L | 10 U | -- | -- | -- | 0 | 12 | NA |
| 4,6-Dinitro-2-methylphenol | µg/L | 10 U | -- | -- | -- | 0 | 12 | NA |
| 4-Bromophenyl phenyl ether | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 4-Chloro-3-methylphenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 4-Chloroaniline | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 4-Chlorophenyl phenyl ether | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 4-Methylphenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 4-Nitroaniline | µg/L | 10 U | -- | -- | -- | 0 | 12 | NA |
| 4-Nitrophenol | µg/L | 10 U | -- | -- | -- | 0 | 12 | NA |
| Acenaphthalene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Acenaphthene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Acetophenone | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Anthracene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Atrazine | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |

TABLE 4-3
**Statistical Summary of Analytical Results for Groundwater Samples, March 2013**
*United Heckathorn Superfund Site, Richmond, California*

| Analyte | Units | Range of NonDetect RLs | Minimum Detect | Maximum Detect | Average Result | Number of Detects | Number of Samples | Location of Maximum Detect |
|---|---|---|---|---|---|---|---|---|
| **Dissolved Semivolatile Organic Compounds** | | | | | | | | |
| Benzaldehyde | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| benzo(a) anthracene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| benzo(a) pyrene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| benzo(b) fluoranthene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| benzo(g,h,i) perylene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| benzo(k) fluoranthene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Bis(2-chloroethoxy)methane | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Bis(2-chloroethyl)ether | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| bis(2-ethylhexyl)phthalate | µg/L | 5 U | 3.1 J | 3.2 J | 0.525 | 2 | 12 | MW13-01 |
| Butyl benzyl phthalate | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Caprolactam | µg/L | 5 U | 6.7 | 83 | 42.8 | 9 | 12 | GW13-11 |
| Carbazole | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Chrysene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| dibenzo(a,h) anthracene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Dibenzofuran | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Diethyl phthalate | µg/L | 5 U | 5 J | 8.8 | 1.15 | 2 | 12 | GW13-07 |
| Dimethyl phthalate | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Di-n-butyl phthalate | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Di-n-octyl phthalate | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Fluoranthene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Fluorene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Hexachlorobenzene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Hexachlorobutadiene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Hexachlorocyclopentadiene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Hexachloroethane | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| indeno(1,2,3-cd) pyrene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Isophorone | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Naphthalene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Nitrobenzene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| N-Nitroso-di-n-propylamine | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| N-Nitrosodiphenylamine | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Pentachlorophenol | µg/L | 10 U | -- | -- | -- | 0 | 12 | NA |
| Phenanthrene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Phenol | µg/L | 5 U | 8.6 | 10 | 1.55 | 2 | 12 | GW13-11 |

TABLE 4-3
**Statistical Summary of Analytical Results for Groundwater Samples, March 2013**
*United Heckathorn Superfund Site, Richmond, California*

| Analyte | Units | Range of NonDetect RLs | Minimum Detect | Maximum Detect | Average Result | Number of Detects | Number of Samples | Location of Maximum Detect |
|---|---|---|---|---|---|---|---|---|
| **Dissolved Semivolatile Organic Compounds** | | | | | | | | |
| Pyrene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| **Total Semivolatile Organic Compounds** | | | | | | | | |
| 1,1'-Biphenyl | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 1,2,4,5-Tetrachlorobenzene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2,2'-Oxybis(1-chloropropane) | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2,3,4,6-Tetrachlorophenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2,4,5-Trichlorophenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2,4,6-Trichlorophenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2,4-Dichlorophenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2,4-Dimethylphenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2,4-Dinitrophenol | µg/L | 10 U | -- | -- | -- | 0 | 12 | NA |
| 2,4-Dinitrotoluene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2,6-Dinitrotoluene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2-Chloronaphthalene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2-Chlorophenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2-Methylnaphthalene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2-Methylphenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 2-Nitroaniline | µg/L | 10 U | -- | -- | -- | 0 | 12 | NA |
| 2-Nitrophenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 3,3'-Dichlorobenzidine | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 3-Nitroaniline | µg/L | 10 U | -- | -- | -- | 0 | 12 | NA |
| 4,6-Dinitro-2-methylphenol | µg/L | 10 U | -- | -- | -- | 0 | 12 | NA |
| 4-Bromophenyl phenyl ether | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 4-Chloro-3-methylphenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 4-Chloroaniline | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 4-Chlorophenyl phenyl ether | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 4-Methylphenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| 4-Nitroaniline | µg/L | 10 U | -- | -- | -- | 0 | 12 | NA |
| 4-Nitrophenol | µg/L | 10 U | -- | -- | -- | 0 | 12 | NA |
| Acenaphthalene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Acenaphthene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Acetophenone | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Anthracene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Atrazine | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |

TABLE 4-3
**Statistical Summary of Analytical Results for Groundwater Samples, March 2013**
*United Heckathorn Superfund Site, Richmond, California*

| Analyte | Units | Range of NonDetect RLs | Minimum Detect | Maximum Detect | Average Result | Number of Detects | Number of Samples | Location of Maximum Detect |
|---|---|---|---|---|---|---|---|---|
| **Total Semivolatile Organic Compounds** | | | | | | | | |
| Benzaldehyde | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| benzo(a) anthracene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| benzo(a) pyrene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| benzo(b) fluoranthene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| benzo(g,h,i) perylene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| benzo(k) fluoranthene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Bis(2-chloroethoxy)methane | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Bis(2-chloroethyl)ether | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| bis(2-ethylhexyl)phthalate | µg/L | 5 U | 4 J | 4.1 J | 0.675 | 2 | 12 | GW13-07 |
| Butyl benzyl phthalate | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Caprolactam | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Carbazole | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Chrysene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| dibenzo(a,h) anthracene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Dibenzofuran | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Diethyl phthalate | µg/L | 5 U | 4.9 J | 4.9 J | 0.408 | 1 | 12 | GW13-05 |
| Dimethyl phthalate | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Di-n-butyl phthalate | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Di-n-octyl phthalate | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Fluoranthene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Fluorene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Hexachlorobenzene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Hexachlorobutadiene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Hexachlorocyclopentadiene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Hexachloroethane | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| indeno(1,2,3-cd) pyrene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Isophorone | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Naphthalene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Nitrobenzene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| N-Nitroso-di-n-propylamine | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| N-Nitrosodiphenylamine | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Pentachlorophenol | µg/L | 10 U | -- | -- | -- | 0 | 12 | NA |
| Phenanthrene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |
| Phenol | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |

TABLE 4-3

**Statistical Summary of Analytical Results for Groundwater Samples, March 2013**

*United Heckathorn Superfund Site, Richmond, California*

| Analyte | Units | Range of NonDetect RLs | Minimum Detect | Maximum Detect | Average Result | Number of Detects | Number of Samples | Location of Maximum Detect |
|---|---|---|---|---|---|---|---|---|
| **Total Semivolatile Organic Compounds** | | | | | | | | |
| Pyrene | µg/L | 5 U | -- | -- | -- | 0 | 12 | NA |

Notes:

Average concentrations reported at 3 significant figures. Zero was used for nondetect results.

J = Concentration or reporting limit estimated by laboratory or data validation.

J- = Concentration or reporting limit estimated by laboratory or data validation, biased low

J+ =Concentration or reporting limit estimated by laboratory or data validation, biased high

NA= Not applicable

NE = Not established

U = Not detected at listed reporting limit

µg/L = micrograms per liter

TABLE 4-4

**Summary of Hydraulic Conductivity Estimates**

*United Heckathorn Superfund Site, Richmond, California*

| Location | Hydraulic Conductivity (cm/sec) | Lithology in Well Screen Interval | Source |
|---|---|---|---|
| Between B33 and B34 | $8.3\times10^{-4}$ [a] | Fill and Upper Bay Mud | HLA (1986) |
| Between B29 and B30 | $7.3\times10^{-4}$ [a] | Fill and Upper Bay Mud | HLA (1986) |
| Between B5A and B11 | $8.3\times10^{-4}$ [a] | Fill and Upper Bay Mud | HLA (1986) |
| Between B25 and B26 | $7.3\times10^{-4}$ [a] | Fill and Upper Bay Mud | HLA (1986) |
| Between B24 and B23 | $7.3\times10^{-4}$ [a] | Fill and Upper Bay Mud | HLA (1986) |
| MW13-01 (slug in) | $7.5\times10^{-5}$ | Upper Bay Mud | CH2M HILL |
| MW13-01 (slug out) | $6.1\times10^{-5}$ | Upper Bay Mud | CH2M HILL |
| MW13-02 (slug in) | $4.3\times10^{-4}$ | Upper Bay Mud | CH2M HILL |
| MW13-02 (slug out) | $8.9\times10^{-5}$ | Upper Bay Mud | CH2M HILL |
| MW13-03 (slug in) | $3.2\times10^{-4}$ | Upper Bay Mud | CH2M HILL |
| MW13-03 (slug out) | $2.5\times10^{-4}$ | Upper Bay Mud | CH2M HILL |
| MW13-04 (slug in) | $2.5\times10^{-4}$ | Upper Bay Mud | CH2M HILL |
| MW13-04 (slug out) | $1.4\times10^{-4}$ | Upper Bay Mud | CH2M HILL |

[a] Value also listed in Table 4-1.

Note:

The geometric mean of the hydraulic conductivity values is $2.96\times10^{-4}$ cm/sec.

TABLE 4-5

**2013 Tidal Study Summary Statistics**

*United Heckathorn Superfund Site, Richmond, California*

| Monitoring Location | Minimum Water Level (ft NAVD88) | Mean Water Level (ft NAVD88) [a] | Maximum Water Level (ft NAVD88) |
|---|---|---|---|
| Stilling Well (Lauritzen Channel) | -0.86 | 2.62 | 5.85 |
| MW13-01 | 2.16 | 3.49 | 5.01 |
| MW13-02 | 2.39 | 3.36 | 4.37 |
| MW13-03 | 0.07 | 3.14 | 6.05 |
| MW13-04 | 1.60 | 3.65 | 5.69 |

[a] Computed using the tidal filtering method described in Serfes (1991).

**Note:**

Values are representative of the processed water levels for the first 71 hours of the tidal study.
Hourly water level data are tabulated in Appendix A.

TABLE 4-6

**Parameters and Results Associated with the Groundwater Discharge and DDT Mass Flux Evaluation**

*United Heckathorn Superfund Site, Richmond, California*

| Parameter | Estimate | Units | Comments |
|---|---|---|---|
| Hydraulic Conductivity, K | $2.96\times10^{-4}$ | cm/sec | Estimate represents the geometric mean of the K values published by HLA (1986) and estimated by CH2M HILL. These K values are listed in Table 4-4. |
| Hydraulic Gradient, i | $4.80\times10^{-3}$<br>0 to 0.016 [a] | foot/foot | Estimate of $4.8\times10^{-3}$ foot/foot represents the hydraulic gradient computed using the mean groundwater levels at MW13-04 and MW13-03 during the 2013 tidal study. Hydraulic gradients toward the channel from this well pair were used because they were larger than those estimated using the MW13-02 and MW13-01 well pair groundwater levels. MW13-04 and MW13-03 are spaced 105.4 feet apart.<br>Time-varying hydraulic gradients between these well pairs toward the channel were also computed using the water-level data collected at 5-minute intervals during the 2013 tidal study. Time-varying landward hydraulic gradient values were replaced with a value of zero, given that DDT would not discharge to the channel during periods of landward flow. |
| Saturated Thickness of Freshwater-bearing Sediments [b] | 32 | feet | Value represents the thickness of the freshwater-bearing sediments according to the Ghyben-Herzberg relation. This relation indicates that the freshwater-seawater interface occurs below the water table of an unconfined coastal aquifer by 41 times the water table height above the sea level (Freeze and Cherry, 1979). The mean sea level in Lauritzen Channel was 2.62 feet NAVD88 during the tidal study and the average of the mean groundwater levels of the four monitoring wells is 3.41 feet NAVD88 (Table 4-5). Subtracting 2.62 feet from 3.41 feet yields an average water level height above the mean sea level of 0.79 feet. Thus, 41 times 0.79 feet yields a depth to the freshwater-seawater interface of approximately 32 feet. |
| Transmissivity, T [b] | 27 | $ft^2$/day | Product of the hydraulic conductivity and saturated thickness. |
| Length of Eastern Lauritzen Channel Shoreline, w [b] | 1,500 | feet | Approximate length of shoreline between GW13-06 and GW13-14 (Figure 2-2). |
| Volumetric Groundwater Discharge to Lauritzen Channel from the Eastern Upland Area, Q [b] | 4<br>0 to 13 [a] | L/min | Computed via Darcy's Law using the transmissivity, hydraulic gradient, and length of shoreline. Groundwater discharge is assumed to occur perpendicular to the shoreline. This value is much higher than the estimates provided in Table 4-1 because HLA only considered the discharge from the saturated fill.<br>Time-varying groundwater discharge rates to the channel using time-varying hydraulic gradients between the well pairs were also computed using the water-level data collected at 5-minute intervals during the 2013 tidal study. |
| Unfiltered Total DDT Concentration, C | 69.6 | µg/L | Value represents the maximum unfiltered concentration detected during the March 2013 monitoring event (see GW13-11 data in Table 4-2). |

TABLE 4-6

**Parameters and Results Associated with the Groundwater Discharge and DDT Mass Flux Evaluation**

*United Heckathorn Superfund Site, Richmond, California*

| Parameter | Estimate | Units | Comments |
|---|---|---|---|
| Annual Total DDT Mass Flux to Lauritzen Channel from the Eastern Upland Fill, AMF [b] | 146<br>167 [a] | g/yr | Product of the volumetric groundwater discharge and the unfiltered total DDT concentration.<br>Alternatively, time-varying mass fluxes of total DDT were computed for 5-minute intervals during the 2013 tidal study using the time varying groundwater discharge rates between the well pairs, and summed to estimate the total flux over the 3-day tidal study period. The total DDT mass flux for the 3-day 2013 tidal study was then multiplied by a factor of 365.25 ÷ 3 to estimate the annual total DDT mass flux. |

[a] Hydraulic gradients and volumetric groundwater discharge to Lauritzen Channel were also computed using tidal study data at 5-minute intervals to account for time-varying hydraulic gradients during the 2013 tidal study.

[b] Value rounded to the nearest whole number.

Notes:

cm/sec = centimeters per second

$ft^2$/day = square feet per day

L/min = liters per minute

µg/L = micrograms per liter

g/yr = grams per year

TABLE 5-1

**Summary of Analytical Results for Creosote-Treated Wood from Pilings**

*United Heckathorn Superfund Site, Richmond, California*

| | Concentrations in µg/kg dry weight | | | | | |
|---|---|---|---|---|---|---|
| **Location** | **Total DDT** | **Dieldrin** | **DDE** | **DDD** | **DDT** | **Aroclor 1254** |
| CR-30 | 200530 | 24100 | 14100 | 185000 | 1430 | 316 U |
| CR-31 | 63200 | 26700 | 4710 | 55900 | 2590 | 316 U |
| CR-32 | 50340 | 10200 | 3270 | 45700 | 1370 | 316 U |
| CR-33 | 1720 | 22.6 U | 15.8 U | 1720 | 80.7 U | 316 U |
| CR-34 | 155350 | 6850 | 8880 | 145000 | 1470 | 316 U |
| CR-35 | NA | NA | NA | NA | NA | NA |

Notes:

Data from Kohn, N.P. and T.J. Gilmore. 2001 *Field Investigation to Determine the Extent of Sediment Recontamination at the United Heckathorn Superfund Site, Richmond, California.* November. PNNL-13730

NA - Sample not analyzed, field immunoassay results indicated that CR-35 was similar to CR-33.

U - parameter not detected above the reporting limit shown

µg/kg - micrograms per kilogram (part per billion)

TABLE 6-1

**Summary of Storm Drain Sediment Analytical Results**

*United Heckathorn Superfund Site, Richmond, California*

| Location | A-4 | B-1 | B-3 | LC-05 | LC-06 | SSWL01 | SSWL02 | SSWL03 | SSWL03 | SSWP02 |
|---|---|---|---|---|---|---|---|---|---|---|
| SampleID | A-4_09152008 | B-1_09152008 | B-3_09152008 | LC-05-0609 | LC-06-0609 | SSWL01 | SSWL02 | SSWL03 | SSWL03_09152008 | SSWP02 |
| Matrix | Sed | Sed | Sed | Sed | Sed | Sed | Sed | Sed | Sed | Sed |
| Sample Date | 9/15/2008 | 9/15/2008 | 9/15/2008 | 6/26/2009 | 6/26/2009 | 7/15/2008 | 7/15/2008 | 7/15/2008 | 9/15/2008 | 7/15/2008 |
| Sample Type | Normal | Normal | Normal | Normal | Normal | Normal | Normal | Normal | Normal | Normal |
| ***Parameter (µg/kg dry weight)*** | | | | | | | | | | |
| **Dieldrin** | **70** | 13 U | **150** | **26 J** | 2.2 UJ | 20 U | 21 U | **680** | **640** | 23 U |
| **2,4-DDD** | **310** | 13 U | **170** | **52 J** | 2.2 UJ | 20 U | 21 U | **6100** | **9500** | 23 U |
| **2,4-DDE** | 25 U | 13 U | 25 U | 3.4 UJ | **4.1 J** | 20 U | 21 U | 25 U | 21 U | 23 U |
| **2,4-DDT** | 25 U | 13 U | 25 U | **3.5 J** | 2.2 UJ | 20 U | 21 U | **1100** | **1000** | 23 U |
| **4,4-DDD** | **1300** | 13 U | **580** | **130** | 2.2 UJ | 20 U | 21 U | **21000** | **29000** | 23 U |
| **4,4-DDE** | **470** | 13 U | **210** | **70 J** | 2.2 UJ | 20 U | 21 U | **4300** | **7000** | 23 U |
| **4,4-DDT** | **120** | **17 J** | **110** | **18 J** | **4.2 J** | 20 U | 21 U | **6000** | **5600** | 23 U |
| **Total DDT** | **2200** | **17** | **1070** | **273.5** | **8.3** | ND | ND | **38500** | **52100** | ND |

**Notes:**

J - estimated value

ND - not detected

U - not detected above analytical reporting limit shown

TABLE 7-1

**Sediment Chemistry Data Collected by SF USACE - Richmond Inner Harbor**

*United Heckathorn Superfund Site, Richmond, California*

| | | Concentrations are in µg/kg | | |
|---|---|---|---|---|
| **Station ID** | **Depth Interval** | **Total DDT** | **Dieldrin** | **Total PCBs** |
| RIH-6A Composite | NA - Composite | 23.8 | 0.96 J | 18.7 |
| RIH-6B Composite | NA - Composite | 58.1 | 1.7 J | 8.7 |
| RIH-6A-1 | -39.0 to -39.5 MLLW | 903 | 11 | 14.4 |
| | -39.5 to -40.0 MLLW | 6686 | 14 | 6.6 |
| | -40.0 to -40.5 MLLW | 105 | 4.1 | 91.4 |
| RIH-6A-2 | -39.0 to -39.5 MLLW | 37 | 2.8 | 4.3 |
| | -39.5 to -40.0 MLLW | 48 | 2.4 | 31.3 |
| | -40.0 to -40.5 MLLW | 187 | 5.7 | 44.0 |
| RIH-6B-1 | -39.0 to -39.5 MLLW | 57 | 1.7 J | 24.6 |
| | -39.5 to -40.0 MLLW | 31 | 0.64 J | 3.0 |
| | -40.0 to -40.5 MLLW | 1.2 | <0.46 | 2.3 |
| RIH-6B-2 | -39.0 to -39.5 MLLW | 65 | 1.6 J | 14.1 |
| | -39.5 to -40.0 MLLW | 34 | <0.57 | 2.0 |
| | -40.0 to -40.5 MLLW | 0.45 | <0.45 | 6.9 |

**Notes:**

J - estimated value

< value is not detected above the detection limit shown

MLLW - Mean Lower Low Water

µg/kg - micrograms per kilogram

Total PCBs are the sum of detected congeners

Data from *Port of Richmond Inner Harbor 2012 Maintenance Dredging Higher Resolution Sediment Testing - Sampling and Analytical Results* prepared for U.S. Army Corps of Engineers, San Francisco District. Prepared by Kinnetic Laboratories, Inc., Santa Cruz, CA.

TABLE 8-1

**Summary of Historical Sediment Data used in Source Identification Evaluations**

*United Heckathorn Superfund Site, Richmond, California*

| | | | ***Pesticide concentrations in µg/kg dry weight*** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SampleID** | **LocationID** | **Sample Type** | **Dieldrin** | **2,4-DDD** | **2,4-DDE** | **2,4-DDT** | **4,4-DDD** | **4,4-DDE** | **4,4-DDT** | **Total DDT** | **Sample Vertical Interval (ft, unless otherwise noted)** | **Sample Description** | **Study** |
| HECK-99-10 | SW-15 | N | **217** | -- | -- | -- | **3,000** | **205** | **2,460** | **5,665** | 0-0.5 | Sand | 1999 Sediment Investigation |
| HECK-99-11 | SW-15 | N | **45.6** | -- | -- | -- | **495** | **31.1** | **510** | **1,036** | 0.5-1.2 | OBM-Dist | 1999 Sediment Investigation |
| HECK-99-12 | SW-16 | N | **887** | -- | -- | -- | **16,200** | **953** | **26,200** | **43,353** | 0-0.5 | YBM | 1999 Sediment Investigation |
| HECK-99-14 | SW-17 | N | **701** | -- | -- | -- | **12,600** | **681** | **7,270** | **20,551** | 0-0.8 | YBM | 1999 Sediment Investigation |
| HECK-99-16 | BC-18 | N | **881** | -- | -- | -- | **7,080** | **1,150** | **45,900** | **54,130** | 0-0.7 | YBM | 1999 Sediment Investigation |
| HECK-99-17 | BC-18 | N | **3,400** | -- | -- | -- | **85,200** | **3,240** | **92,400** | **180,840** | 0.8-1.3 | YBM | 1999 Sediment Investigation |
| HECK-99-19 | BC-19 | N | **531** | -- | -- | -- | **7,820** | **1,030** | **33,500** | **42,350** | 0-1.2 | YBM | 1999 Sediment Investigation |
| HECK-99-22 | BC-21 | N | **193** | -- | -- | -- | **3,400** | **220** | **3,150** | **6,770** | 0-1.5 | YBM | 1999 Sediment Investigation |
| HECK-99-25 | BC-23 | N | **90.9** | -- | -- | -- | **1,160** | **95.3** | **1,000** | **2,255** | 0-1.6 | YBM | 1999 Sediment Investigation |
| HECK-99-26 | BC-24 | N | **132** | -- | -- | -- | **2,040** | **141** | **1,270** | **3,451** | 0-2.7 | YBM | 1999 Sediment Investigation |
| HECK-99-27 | UL-14 | N | **3,000** | -- | -- | -- | **40,100** | **1,940** | **62,300** | **104,340** | 0-0.3 | YBM | 1999 Sediment Investigation |
| HECK-99-30 | UL-10 | N | 22.2 U | -- | -- | -- | **239** | 15.4 U | 78.9 U | **239** | 0-1.0 | YBM | 1999 Sediment Investigation |
| HECK-99-31 | UL-13 | N | **317** | -- | -- | -- | **5,600** | **254** | **2,910** | **8,764** | 0-1.1 | YBM | 1999 Sediment Investigation |
| HECK-99-32 | UL-09 | N | **1,910** | -- | -- | -- | **36,300** | **2,410** | **6,510** | **45,220** | 0-0.9 | YBM | 1999 Sediment Investigation |
| HECK-99-35 | PL-08 | N | **2,590** | -- | -- | -- | **8,340** | **1,420** | **20,300** | **30,060** | 0-0.2 | YBM | 1999 Sediment Investigation |
| HECK-99-36 | PL-08 | N | **1,650** | -- | -- | -- | **6,230** | **1,110** | **14,500** | **21,840** | 0.2-0.6 | OBM-Dist | 1999 Sediment Investigation |
| HECK-99-37 | PL-07 | N | 18.1 U | -- | -- | -- | **26.3** | 12.6 U | 64.6 U | **26.3** | 0.3-1.0 | YBM | 1999 Sediment Investigation |
| HECK-99-39 | PL-06 | N | **272** | -- | -- | -- | **708** | **220** | **2,330** | **3,258** | 0-0.2 | OBM | 1999 Sediment Investigation |
| HECK-99-40 | PL-05 | N | **107** | -- | -- | -- | **1,720** | **202** | **186** | **2,108** | 0-0.6 | YBM | 1999 Sediment Investigation |
| HECK-99-41 | PL-03 | N | **68** | -- | -- | -- | **21,100** | **449** | **2,650** | **24,199** | 0-1.3 | YBM | 1999 Sediment Investigation |
| HECK-99-43 | PL-03 | N | 17.4 U | -- | -- | -- | **3,260** | **58.7** | **200** | **3,519** | 1.7-2.2 | YBM | 1999 Sediment Investigation |
| HECK-99-44 | PL-02 | N | **1,220** | -- | -- | -- | **18,100** | **1,160** | **18,600** | **37,860** | 0-0.5 | YBM | 1999 Sediment Investigation |
| HECK-99-47 | PL-01 | N | **3,200** | -- | -- | -- | **51,500** | **2,940** | **30,600** | **85,040** | 0-2.0 | YBM | 1999 Sediment Investigation |
| HECK-99-48 | SF-28 | N | 36 U | -- | -- | -- | **257** | **28.3** | **297** | **582.3** | 0-0.4 | YBM | 1999 Sediment Investigation |
| LC-1-1286-4 | LC-1 | N | **3,270** | -- | -- | -- | **15,700** | **84,400** | **30,100** | **130,200** | 0-0.1 | YBM | EPA, in Battelle 2001 Sediment Recontamination Study Report |
| LC-2-1286-3 | LC-2 | N | **382** | -- | -- | -- | **3,150** | **383** | **10,400** | **13,933** | 0-0.1 | YBM | EPA, in Battelle 2001 Sediment Recontamination Study Report |
| LC-3-1286-2 | LC-3 | N | **171** | -- | -- | -- | **4,080** | **323** | **5,850** | **10,253** | 0-0.1 | YBM | EPA, in Battelle 2001 Sediment Recontamination Study Report |
| LC-4-1286-1 | LC-4 | N | **52** | -- | -- | -- | **1,190** | **94** | **1,450** | **2,734** | 0-0.1 | YBM | EPA, in Battelle 2001 Sediment Recontamination Study Report |
| 0702-S1 | 0702-S1 (T-4_5) | N | **20 J** | **60** | 40 U | **40** | **100** | 40 U | **600** | **800** | surface | YBM OBM | Phase I Source Investigation |
| 0702-S11 | 0702-S11 (T 4_5) | N | **400 J** | **1600 J** | 200 U | **2200 J** | **5000 J** | **600 J** | **25000 J** | **34,400** | surface | YBM | Phase I Source Investigation |
| 0702-S12 | 0702-S12 (T 3_5) | N | **1,400** | **8,700** | **200** | **20,000** | **12,000** | **2,400** | **120,000** | **163,300** | surface | YBM OBM | Phase I Source Investigation |
| 0702-S13 | 0702-S13 (T 2_5) | N | 200 U | **300** | 200 U | **3,600** | **900** | **200** | **12,000** | **17,000** | surface | not recorded | Phase I Source Investigation |
| 0702-S14 | 0702-S14 (T 2_5) | N | **6,500** | **10,000** | **600** | **110,000** | **60,000** | **10,000** | **1400000 J** | **1,590,600** | surface | rocky | Phase I Source Investigation |
| 0702-S15 | 0702-S15 (T 2) | N | 300 U | **400 J** | 300 U | **800 J** | **1100 J** | 300 U | **6000 J** | **8,300** | surface | YBM | Phase I Source Investigation |
| 0702-S17 | 0702-S17 (1_5) | N | 1000 U | **1000 J** | 2000 U | **4,000** | **3,000** | 2000 U | **17,000** | **25,000** | surface | Sand | Phase I Source Investigation |
| 0702-S18 | 0702-S18 (1_5) | FD | **300** | **1,200** | 200 U | **2,600** | **1,400** | **200** | **8,000** | **13,400** | surface | Sand | Phase I Source Investigation |
| 0702-S2-Y | 0702-S2-YBM (T-4_5) | N | 300 U | **200 J** | 300 U | 300 U | **500** | 300 U | **2,500** | **3,200** | surface | YBM | Phase I Source Investigation |
| 0702-S4 | 0702-S4 (T-2_5) | N | **3000 J** | **3000 J** | 4000 U | **22,000** | **9,000** | 4000 U | **110,000** | **144,000** | surface | YBM OBM | Phase I Source Investigation |
| 0702-S5 | 0702-S5 (T 10_5) | N | 300 U | **200 J** | 300 U | **300** | **600** | **300** | **2,200** | **3,600** | surface | YBM OBM | Phase I Source Investigation |
| 0702-S6 | 0702-S6 (T 10_5) | N | **200 J** | **700 J** | 300 U | **1400 J** | **2300 J** | **500 J** | **10000 J** | **14,900** | surface | not recorded | Phase I Source Investigation |
| 0702-S8 | 0702-S8 (T 8_5) | N | 300 U | **800 J** | 300 U | **1000 J** | **2600 J** | **400 J** | **29000 J** | **33,800** | surface | YBM | Phase I Source Investigation |
| 0702-S9 | 0702-S9 (T 6_5) | N | 2000 U | **2000 J** | 3000 U | **3,000** | **5,000** | 3000 U | **29,000** | **39,000** | surface | YBM | Phase I Source Investigation |
| T(+11_5)C1 | T(+11_5)C1 | N | **90** | **480** | **40 J** | **2,000** | **2,000** | **350** | **12,000** | **16,870** | surface | sediment | Phase I Source Investigation |
| T(+2_5)C1 | T(+2_5)C1 | N | **50,000** | **150,000** | **10,000** | **3,000,000** | **900,000** | **130,000** | **19,000,000** | **23,190,000** | surface | sediment | Phase I Source Investigation |
| T(+23_5)C1 | T(+23_5)C1 | N | **20 J** | **60 J** | **20 J** | **60 J** | **200 J** | **60 J** | **860** | **1,260** | surface | sediment | Phase I Source Investigation |

TABLE 8-1

**Summary of Historical Sediment Data used in Source Identification Evaluations**

*United Heckathorn Superfund Site, Richmond, California*

| | | | ***Pesticide concentrations in µg/kg dry weight*** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SampleID** | **LocationID** | **Sample Type** | **Dieldrin** | **2,4-DDD** | **2,4-DDE** | **2,4-DDT** | **4,4-DDD** | **4,4-DDE** | **4,4-DDT** | **Total DDT** | **Sample Vertical Interval (ft, unless otherwise noted)** | **Sample Description** | **Study** |
| T(+39_5)C1 | T(+39_5)C1 | N | **20 J** | **80 J** | **30 J** | **200 J** | **320 J** | **60 J** | **2,000** | **2,690** | surface | sediment | Phase I Source Investigation |
| T(+55_5)C1 | T(+55_5)C1 | N | **60 J** | **200 J** | **50** | **20 J** | **1100 J** | **200 J** | **200 J** | **1,770** | surface | sediment | Phase I Source Investigation |
| T(-0_5)C1 | T(-0_5)C1 | N | **200 J** | **1,000** | **30 J** | **800** | **3,500** | **200 J** | **5,200** | **10,730** | surface | sediment | Phase I Source Investigation |
| T(-12_5)C1 | T(-12_5)C1 | N | **70** | **300** | **20 J** | **800** | **1,000** | **100** | **3,700** | **5,920** | surface | sediment | Phase I Source Investigation |
| T(-24_5)C1 | T(-24_5)C1 | N | **200 J** | **1,000** | **40 J** | **200 J** | **4,300** | **370** | **3,000** | **8,910** | surface | sediment | Phase I Source Investigation |
| T(-4_5)C1 | T(-4_5)C1 | N | **800** | **1,000** | **80 J** | **1,000** | **3,000** | **600** | **4,700** | **10,380** | surface | sediment | Phase I Source Investigation |
| 0702-S19 | 0702-S19 (T 8_5) | N | **1000 U** | **2000 U** | **2000 U** | **4,000** | **2000 U** | **2,000** | **29,000** | **35,000** | surface | embankment soil | Phase I Source Investigation |
| T(+11_5)B | T(+11_5)B | N | **20 J** | **60** | **80** | **3,000** | **200** | **2,000** | **27,000** | **32,340** | surface | embankment soil | Phase I Source Investigation |
| T(+2_5)B | T(+2_5)B | N | **1000 J** | **3,000** | **600 J** | **30,000** | **7,000** | **13,000** | **160,000** | **213,600** | surface | embankment soil | Phase I Source Investigation |
| T(+31_5)B | T(+31_5)B | N | **50 J** | **80 J** | **30 J** | **280** | **200** | **230** | **2000 J** | **2,820** | surface | embankment soil | Phase I Source Investigation |
| T(-0_5)B | T(-0_5)B | N | **2,000** | **2,000** | **200** | **7,000** | **3,000** | **3,000** | **31,000** | **46,200** | surface | embankment soil | Phase I Source Investigation |
| T(-12_5)C1 | T(-12_5)C1 | N | **70** | **300** | **20 J** | **800** | **1,000** | **100** | **3,700** | **5,920** | surface | sediment | Phase I Source Investigation |
| T(-19_5)B | T(-19_5)B | N | **200** | **200 J** | **20 J** | **70 J** | **1,000** | **100** | **400 J** | **1,790** | surface | embankment soil | Phase I Source Investigation |
| T(-32_5)B | T(-32_5)B | N | **6,000** | **2,000** | **400** | **7,000** | **3,000** | **8,000** | **33,000** | **53,400** | surface | embankment soil | Phase I Source Investigation |
| T(-4_5)B | T(-4_5)B | N | **12,000** | **9,000** | **2,000** | **46,000** | **20,000** | **20,000** | **220,000** | **317,000** | surface | embankment soil | Phase I Source Investigation |
| H03-01_0_S | H03-01 | N | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **252,400** | 0-12 | Black YBM, fine silt, clay smo | Phase II Source Investigation |
| H03-03_0_S | H03-03 | N | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **12,700** | 0-10 | YBM, silty clay, smooth, black | Phase II Source Investigation |
| H03-03_10_S | H03-03 | N | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **62,100** | 10-16 | YBM, black silty clay with son | Phase II Source Investigation |
| H03-03_24_5_S | H03-03 | N | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **400** | 24.5-30 | sand mixed with clay, reddish | Phase II Source Investigation |
| H03-05_0_S | H03-05 | N | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **7,500** | 0-1 | YBM, Clay, soft | Phase II Source Investigation |
| H03-05_1_S | H03-05 | N | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **14,800** | 1-24 | YBM, Clay, soft | Phase II Source Investigation |
| H03-05_24_S | H03-05 | N | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **15,400** | 24-27 | Olive Green Sand | Phase II Source Investigation |
| H03-05_27_S | H03-05 | N | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **150,600** | 27-34 | YBM, black | Phase II Source Investigation |
| Heck03-001 | T(-35)old scale | N | **49 U** | **180** | **49 U** | **160** | **680** | **170** | **430** | **1,620** | 0-0.3 | Bank Soil | Phase II Source Investigation |
| Heck03-002 | T(-35)old scale | N | **570 U** | **2,100** | **570 U** | **570 U** | **7,700** | **1,800** | **2,500** | **14,100** | 0.5-1 | Bank Soil | Phase II Source Investigation |
| Heck03-003 | T(-29) 36ft N of 8" pipe | N | **3,200** | **9,300** | **1100 U** | **1900 J** | **45000 J** | **3,800** | **15,000** | **75,000** | 0.5-1 | Bank Soil | Phase II Source Investigation |
| Heck03-004 | T(-29) 36ft N of 8" pipe | N | **5,900** | **2,700** | **520 U** | **5,500** | **8,600** | **5,300** | **46000 J** | **68,100** | 0-0.5 | Bank Soil | Phase II Source Investigation |
| Heck03-005 | T(-12_5) Bank | N | **24 U** | **24 U** | **24 U** | **24 U** | **24 U** | **24 U** | **24 U** | **24 U** | 0.5-1 | Bank Soil | Phase II Source Investigation |
| Heck03-006 | T(-12_5) Bank | N | **940 U** | **940 U** | **940 U** | **1,900** | **2,200** | **940 U** | **8,800** | **12,900** | 0-0.2 | Bank Soil | Phase II Source Investigation |
| Heck03-007 | T(-11_5) Seep 1-ft N | N | **220 U** | **220 U** | **220 U** | **780** | **220 U** | **220 U** | **3,400** | **4,180** | 0-0.2 | Bank Soil | Phase II Source Investigation |
| Heck03-008 | T(-11_5) Seep 1-ft N | N | **25 U** | **25 U** | **25 U** | **25 U** | **25 U** | **25 U** | **28 J** | **28** | 0.5-1 | Bank Soil | Phase II Source Investigation |
| Heck03-009 | T(-11_5) Seep 1-ft N | N | **22000 J** | **370000 J** | **5100 J** | **120000 J** | **1500000 J** | **39000 J** | **1600000 J** | **3,634,100** | NA (pipe sed) | Bank Soil | Phase II Source Investigation |
| Heck03-010 | T(-4_5) Bank | N | **23 U** | **23 U** | **23 U** | **23 U** | **23 U** | **23 U** | **23 U** | **23 U** | 0.5-1 | Bank Soil | Phase II Source Investigation |
| Heck03-011 | T(-4_5) Bank | N | **210 U** | **330 J** | **210 U** | **340 J** | **830** | **410** | **1,900** | **3,810** | 0-0.2 | Bank Soil | Phase II Source Investigation |
| Heck03-012 | T(+2_25) Bank | N | **270 UJ** | **270 UJ** | **270 UJ** | **520 J** | **270 UJ** | **270 UJ** | **3000 J** | **3,520** | 0-0.2 | Bank Soil | Phase II Source Investigation |
| Heck03-013 | T(+2_25) Bank | N | **4600 J** | **2600 U** | **2600 U** | **11,000** | **4200 J** | **2600 U** | **120,000** | **135,200** | 0.5-1 | Bank Soil | Phase II Source Investigation |
| Heck03-014 | H03-06 | N | **14 U** | **14 U** | **15 J** | **14 U** | **52** | **14 U** | **25 J** | **92** | 0-1.4 | YBM | Phase II Source Investigation |
| Heck03-015 | H03-08 | N | **57 U** | **140** | **57 U** | **57 U** | **600** | **57 U** | **140** | **880** | 0-0.7 | YBM | Phase II Source Investigation |
| Heck03-016 | H03-11 | N | **11 U** | **13 J** | **11 U** | **11 U** | **58** | **11 U** | **14 J** | **85** | 0-0.7 | YBM | Phase II Source Investigation |
| Heck03-017 | H03-1-N | N | **120 U** | **120 U** | **120 U** | **120 U** | **120 U** | **120 U** | **920** | **920** | 0-0.4 | 0.1 ft YBM on 0.3 ft OBM | Phase II Source Investigation |
| Heck03-022 | H03-2-NE | N | **1200 U** | **2,500** | **1200 U** | **10,000** | **3,100** | **1200 U** | **10,000** | **25,600** | 0-0.25 | YBM | Phase II Source Investigation |
| Heck03-024 | H03-1-NW | N | **800 U** | **1,700** | **800 U** | **1500 J** | **4,500** | **800 U** | **21,000** | **28,700** | 0-1.7 | YBM | Phase II Source Investigation |
| Heck03-025 | H03-1-C | N | **13000 J** | **20000 J** | **2800 U** | **110000 J** | **54000 J** | **6500 J** | **970000 J** | **1,160,500** | 0-1.0 | YBM | Phase II Source Investigation |
| Heck03-026 | H03-1-NE | N | **540 U** | **1,200** | **540 U** | **4,200** | **3,600** | **540 U** | **34,000** | **43,000** | 0-0.75 | YBM | Phase II Source Investigation |
| Heck03-027 | H03-1-W | N | **820 U** | **2,800** | **820 U** | **17,000** | **9,100** | **1100 J** | **160000 J** | **190,000** | 0-1.5 | YBM | Phase II Source Investigation |
| Heck03-028 | H03-2-W | N | **1800 U** | **2800 J** | **1800 U** | **36,000** | **5,700** | **1800 U** | **150,000** | **194,500** | 0-1.5 | YBM | Phase II Source Investigation |
| Heck03-029 | H03-1-S | N | **1200 U** | **4,300** | **1200 U** | **5,200** | **8,700** | **1400 J** | **34,000** | **53,600** | 0-0.6 | YBM | Phase II Source Investigation |

TABLE 8-1

**Summary of Historical Sediment Data used in Source Identification Evaluations**

*United Heckathorn Superfund Site, Richmond, California*

| | | | ***Pesticide concentrations in µg/kg dry weight*** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SampleID** | **LocationID** | **Sample Type** | **Dieldrin** | **2,4-DDD** | **2,4-DDE** | **2,4-DDT** | **4,4-DDD** | **4,4-DDE** | **4,4-DDT** | **Total DDT** | **Sample Vertical Interval (ft, unless otherwise noted)** | **Sample Description** | **Study** |
| Heck03-030 | H03-1-SE | N | **1400 U** | **2400 J** | **1400 U** | **3,600** | **5,600** | **1400 U** | **40,000** | **51,600** | 0-0.5 | 0.25 ft YBM on 0.25 ft OBM | Phase II Source Investigation |
| Heck03-031 | H03-1-SW | N | **870 U** | **1500 J** | **870 U** | **2,300** | **4,000** | **870 U** | **19,000** | **26,800** | 0-1.5 | YBM | Phase II Source Investigation |
| Heck03-032 | H03-2-S | N | **700 U** | **1,400** | **700 U** | **1300 J** | **2,400** | **700 U** | **17,000** | **22,100** | 0-0.4 | YBM | Phase II Source Investigation |
| Heck03-033 | H03-2-SE | N | **660 U** | **2,100** | **660 U** | **2,400** | **3,900** | **660 U** | **18,000** | **26,400** | 0-0.75 | YBM w/few blobs OBM | Phase II Source Investigation |
| Heck03-034 | H03-T(+4_5)-E | N | **27 U** | **49 J** | **27 U** | **100** | **120** | **51 J** | **530** | **850** | 0-0.9 | 0.1 ft YBM on 0.8 ft OBM | Phase II Source Investigation |
| Heck03-035 | H03-T(+3_5)-E | N | **66 U** | **82 J** | **66 U** | **68 J** | **120 J** | **66 U** | **930** | **1,200** | 0-0.5 | 0.25 ft YBM on 0.25 ft OBM | Phase II Source Investigation |
| Heck03-036 | H03-T(+2_5)-E | N | **580 U** | **580 U** | **580 U** | **670 J** | **580 U** | **580 U** | **5,200** | **5,870** | 0-0.7 | 0.2 ft YBM on 0.5 ft OBM | Phase II Source Investigation |
| Heck03-037 | H03-T(+1_5)-E | N | **670 U** | **670 U** | **670 U** | **1000 J** | **670 U** | **670 U** | **5,500** | **6,500** | 0-1.0 | 0.5 ft YBM on 0.5 ft OBM | Phase II Source Investigation |
| Heck03-038 | H03-12 | N | **44 U** | **250** | **44 U** | **44 U** | **1,100** | **87** | **680** | **2,117** | 0-3.8 | YBM | Phase II Source Investigation |
| Heck03-039 | H03-10 | N | **210 U** | **1,400** | **210 U** | **210 U** | **6,300** | **300 J** | **4,500** | **12,500** | 0-3.4 | YBM | Phase II Source Investigation |
| Heck03-040 | H03-02 | N | **75 U** | **190** | **75 U** | **120 J** | **890** | **75 U** | **1,300** | **2,500** | 0-0.3 | 0.1 ft YBM on 0.2 ft OBM | Phase II Source Investigation |
| Heck03-043 | H03-05 | N | **380 UJ** | **1600 J** | **380 UJ** | **700 J** | **6700 J** | **380 UJ** | **7000 J** | **16,000** | 0-2.8 | YBM | Phase II Source Investigation |
| Heck03-044 | H03-01 | N | **2300 J** | **16,000** | **1900 U** | **3200 J** | **66,000** | **2200 J** | **69,000** | **156,400** | 0-1.0 | YBM | Phase II Source Investigation |
| Heck03-045 | H03-03 | N | **700 U** | **3,500** | **700 U** | **700 U** | **8,800** | **700 U** | **14,000** | **26,300** | 0-1.3 | YBM | Phase II Source Investigation |
| Heck03-046 | H03-04 | N | **140 UJ** | **650 J** | **140 UJ** | **190 J** | **3100 J** | **160 J** | **3000 J** | **7,100** | 0-1.5 | YBM | Phase II Source Investigation |
| Heck03-047 | H03-04 | N | **680 U** | **2,300** | **680 U** | **680 U** | **12000 J** | **860 J** | **12000 J** | **27,160** | 1.9-3.1 | OBM-disturbed | Phase II Source Investigation |
| Heck03-048 | H03-07 | N | **1500 U** | **3,600** | **1500 U** | **1500 U** | **20000 J** | **1500 U** | **30,000** | **53,600** | 0-1.3 | YBM | Phase II Source Investigation |
| B1600A | B16+00 | N | **67** | **310** | **9.1** | **82** | **1,700** | **100** | **460** | **2,661** | sediment surface | YBM | 2007 Data Gap Evaluation |
| B1600a0807 | B16+00 | N | **70 NJ** | **440** | **40 NJ** | **110** | **1,900** | **150** | **1,500** | **4,140** | sediment surface | YBM | 2007 Data Gap Evaluation |
| B1600B | B16+00 | N | **33** | **300** | **13** | **36** | **1,300** | **60** | **640** | **2,349** | between surface and interface | Sand | 2007 Data Gap Evaluation |
| B1600b0807 | B16+00 | N | **140** | **1,200** | **67 NJ** | **200** | **5,100** | **250** | **4,400** | **11,217** | between surface and interface | Sand | 2007 Data Gap Evaluation |
| B1600C | B16+00 | N | **190** | **1,700** | **62** | **45** | **6,500** | **220** | **1,600** | **10,127** | YBM/OBM interface | Interface | 2007 Data Gap Evaluation |
| B1600c0807 | B16+00 | N | **320** | **1,700** | **150 NJ** | **250 NJ** | **6,700** | **810** | **11,000** | **20,610** | YBM/OBM interface | Interface | 2007 Data Gap Evaluation |
| C0400A | C4+00 | N | **7.2 J** | **13** | 4.6 U | 4.6 U | **51** | **8.8 J** | **43** | **115.8** | sediment surface | Surface | 2007 Data Gap Evaluation |
| C0400B | C4+00 | N | 2.5 U | 2.5 U | 2.5 U | 2.5 U | **3.4 J** | 2.5 U | 2.5 U | **3.4** | -41 MLLW | Interface | 2007 Data Gap Evaluation |
| C0400b0807 | C4+00 | N | **1.8 NJ** | **12** | 5.2 U | 5.2 U | **46** | **4.7 J** | **30** | **92.7** | -41 MLLW | Interface | 2007 Data Gap Evaluation |
| C0800a0807 | C8+00 | N | **62** | **65** | **19 NJ** | **21 NJ** | **350 J** | **37** | **340 J** | **832** | sediment surface | YBM | 2007 Data Gap Evaluation |
| C0800b0807 | C8+00 | N | **32** | **350** | **64 J** | **120** | **1,500** | **76** | **1,100** | **3,210** | -41 MLLW | Interface | 2007 Data Gap Evaluation |
| C0900a0807 | C9+00 | N | **15** | **37** | **9.8 NJ** | **18 NJ** | **260** | **22** | **390** | **736.8** | sediment surface | YBM | 2007 Data Gap Evaluation |
| C0900b0807 | C9+00 | N | **19 J** | **130** | **15 NJ** | **53 NJ** | **510** | **30 J** | **1,400** | **2,138** | -41 MLLW | Interface | 2007 Data Gap Evaluation |
| C1400a0807 | C14+00 | N | **260 J** | **3,900** | 590 U | **510 NJ** | **17,000** | **310 J** | **4,900** | **26,620** | sediment surface | YBM | 2007 Data Gap Evaluation |
| C1400c0807 | C14+00 | N | **3.9 J** | **23** | **3.1 J** | 4.1 U | **100** | **2.8 J** | **24** | **152.9** | YBM/OBM interface | Interface | 2007 Data Gap Evaluation |
| C1800a0807 | C18+00 | N | **2,800** | **14,000** | **730 NJ** | **1800 NJ** | **51,000** | **4,300** | **17,000** | **88,830** | sediment surface | YBM | 2007 Data Gap Evaluation |
| C1800b0807 | C18+00 | N | **660** | **2,300** | **820 NJ** | 92 U | **4,100** | **11,000** | **480** | **18,700** | between surface and interface | YBM | 2007 Data Gap Evaluation |
| C1800c0807 | C18+00 | N | **15 J** | **110** | **3.5 NJ** | **8.7 NJ** | **440 J** | **19** | **96** | **677.2** | YBM/OBM interface | Sand | 2007 Data Gap Evaluation |
| C2 1800a0807 | C218+00 | N | **590** | **2,700** | **230 NJ** | **45 NJ** | **9,000** | **1,100** | **1,900** | **14,975** | sediment surface | YBM | 2007 Data Gap Evaluation |
| C2 1800b0807 | C218+00 | N | **11** | **58** | **12 NJ** | **2.8 NJ** | **330** | **17** | **7.1** | **426.9** | between surface and interface | YBM | 2007 Data Gap Evaluation |
| C2 1800c0807 | C218+00 | N | **1100 NJ** | **5600 NJ** | **930 NJ** | 100 U | **1,000** | **25,000** | **3,300** | **35,830** | YBM/OBM interface | YBM | 2007 Data Gap Evaluation |
| C8600a0807 | C14+00 | FD | **110** | **570** | **63 NJ** | **390 NJ** | **3600 J** | **160 NJ** | **4600 J** | **9,383** | sediment surface | YBM | 2007 Data Gap Evaluation |
| C9100b0807 | C9+00 | FD | **16 J** | **110** | **17 NJ** | **35 J** | **440** | **27 J** | **1,100** | **1,729** | -41 MLLW | Interface | 2007 Data Gap Evaluation |
| C9600a0807 | C4+00 | N | **40 J** | **1,300** | 94 U | 94 U | **6,000** | **100 NJ** | **150** | **7,550** | sediment surface | YBM | 2007 Data Gap Evaluation |
| CB0650A | CB6+50 | N | **9.7** | **8.5 J** | 4.7 U | 4.7 U | **31** | 4.7 U | **47** | **86.5** | sediment surface | YBM | 2007 Data Gap Evaluation |
| CB0650B | CB6+50 | N | **12** | **80** | **6.9** | **11** | **330** | **27** | **140** | **594.9** | -41 MLLW | Interface | 2007 Data Gap Evaluation |
| CB650a0807 | CB6+50 | N | **75** | **50** | **3.7 NJ** | **36** | **170 J** | **34 NJ** | **340 J** | **633.7** | sediment surface | YBM | 2007 Data Gap Evaluation |
| CB650b0807 | CB6+50 | N | **55** | **290** | **36 NJ** | **100 NJ** | **1,700** | **120** | **2,400** | **4,646** | -41 MLLW | Interface | 2007 Data Gap Evaluation |
| CB950A | CB9+50 | N | **15** | **110** | **7 J** | **140** | **460** | **51** | **2,000** | **2,768** | sediment surface | YBM | 2007 Data Gap Evaluation |
| CB950a0807 | CB9+50 | N | **610** | **1500 J** | **110 NJ** | **4600 J** | **3000 J** | **640** | **23000 J** | **32,850** | sediment surface | YBM | 2007 Data Gap Evaluation |

TABLE 8-1

**Summary of Historical Sediment Data used in Source Identification Evaluations**

*United Heckathorn Superfund Site, Richmond, California*

| | | | ***Pesticide concentrations in µg/kg dry weight*** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SampleID** | **LocationID** | **Sample Type** | **Dieldrin** | **2,4-DDD** | **2,4-DDE** | **2,4-DDT** | **4,4-DDD** | **4,4-DDE** | **4,4-DDT** | **Total DDT** | **Sample Vertical Interval (ft, unless otherwise noted)** | **Sample Description** | **Study** |
| CB950B | CB9+50 | N | **22** | **120** | **22** | **310** | **520** | **44** | **1,900** | **2,916** | -41 MLLW | YBM | 2007 Data Gap Evaluation |
| CB950b0807 | CB9+50 | N | **160** | **860** | **190** | **1500 J** | **3,300** | **390** | **11,000** | **17,240** | -41 MLLW | YBM | 2007 Data Gap Evaluation |
| D0600a0807 | D6+00 | N | **19** | **30** | **6.7 NJ** | **42** | **220** | **20** | **780** | **1,099** | sediment surface | YBM | 2007 Data Gap Evaluation |
| D0600b0807 | D6+00 | N | **51** | **190** | **96** | **120** | **1,000** | **110** | **1,900** | **3,416** | -41 MLLW | Interface | 2007 Data Gap Evaluation |
| D1000a0807 | D10+00 | N | **25 NJ** | **150** | **36 NJ** | **24 J** | **780** | **59** | **910** | **1,959** | sediment surface | YBM | 2007 Data Gap Evaluation |
| D1000b0807 | D10+00 | N | 4.5 U | 4.5 U | 4.5 U | 4.5 U | **3.2 J** | 4.5 U | **3.6 J** | **6.8** | -41 MLLW | Interface | 2007 Data Gap Evaluation |
| D1300a0807 | D13+00 | N | **33** | **240** | **12 NJ** | **52** | **1,000** | **64** | **980 J** | **2,348** | sediment surface | YBM | 2007 Data Gap Evaluation |
| D1300b0807 | D13+00 | N | **14** | **140** | **6.4 NJ** | **7.4 NJ** | **510** | **21** | **150** | **834.8** | between surface and interface | YBM | 2007 Data Gap Evaluation |
| D1300c0807 | D13+00 | N | **0.97 NJ** | **6.9** | **0.92 NJ** | 4.1 U | **26** | **1.3 J** | **7** | **42.12** | YBM/OBM interface | Interface | 2007 Data Gap Evaluation |
| D1500a0807 | D15+00 | N | **53 NJ** | **340** | **38 NJ** | **68** | **1,500** | **120** | **1,400** | **3,466** | sediment surface | YBM | 2007 Data Gap Evaluation |
| D1500b0807 | D15+00 | N | **320** | **2,500** | **120 NJ** | **440 NJ** | **9,700** | **560** | **12,000** | **25,320** | between surface and interface | YBM | 2007 Data Gap Evaluation |
| D1500c0807 | D15+00 | N | **36** | **330** | **10 NJ** | **11 NJ** | **1,300** | **35** | **120** | **1,806** | YBM/OBM interface | Interface | 2007 Data Gap Evaluation |
| D1700a0807 | D17+00 | N | **220** | **1,700** | **88 NJ** | **140 NJ** | **6,800** | **680** | **4,800** | **14,208** | sediment surface | YBM | 2007 Data Gap Evaluation |
| D1700c0807 | D17+00 | N | **39** | **210** | **16 NJ** | 8.6 U | **710** | **59** | **81** | **1,076** | YBM/OBM interface | Sand | 2007 Data Gap Evaluation |
| D8300c0807 | D17+00 | FD | **21** | **160** | **11 NJ** | 4.3 U | **600** | **33** | **21** | **825** | YBM/OBM interface | Sand | 2007 Data Gap Evaluation |
| E0325a0807 | E3+25 | N | **6.1 J** | **12** | **4.8 NJ** | **4.1 NJ** | **38** | **8.1 NJ** | **45** | **112** | sediment surface | YBM | 2007 Data Gap Evaluation |
| E0325b0807 | E3+25 | N | **9 NJ** | **47** | **17 NJ** | **28** | **170** | **29** | **150** | **441** | -41 MLLW | YBM | 2007 Data Gap Evaluation |
| E0950a0807 | E9+50 | N | **200** | **1,400** | **83 NJ** | **360** | **7,100** | **320** | **8,800** | **18,063** | sediment surface | YBM | 2007 Data Gap Evaluation |
| E0950b0807 | E9+50 | N | **3.3 J** | **20** | **4.4 NJ** | 4.1 U | **93** | 4.1 U | **43** | **160.4** | -41 MLLW | Sand | 2007 Data Gap Evaluation |
| F0525a0807 | F5+25 | N | 4.7 U | **2.2 J** | 4.7 U | 4.7 U | **9.2** | **1.1 J** | **11** | **23.5** | sediment surface | YBM | 2007 Data Gap Evaluation |
| F0700a0807 | F7+00 | N | **1.3 J** | **6** | **2.1 J** | 4.9 U | **26** | **2.2 J** | **4.8 J** | **41.1** | sediment surface | Sand | 2007 Data Gap Evaluation |
| F0800a0807 | F8+00 | N | **34** | **130** | **11 NJ** | **7.9 NJ** | **640** | **40** | **400** | **1,229** | sediment surface | YBM | 2007 Data Gap Evaluation |
| F0800c0807 | F8+00 | N | **61** | **230** | **25 NJ** | **26 NJ** | **1,400** | **71** | **300** | **2,052** | 1 foot below -41 MLLW | Interface | 2007 Data Gap Evaluation |
| F9300a0807 | F7+00 | FD | **2.4 J** | **9.3** | **3.4 J** | 5 U | **35** | **2.8 J** | **3.6 J** | **54.1** | sediment surface | Sand | 2007 Data Gap Evaluation |
| G0300a0807 | G3+00 | N | **9.6 NJ** | **35** | **4.1 NJ** | **19** | **120** | **26** | **140** | **344.1** | sediment surface | YBM | 2007 Data Gap Evaluation |
| G0300b0807 | G3+00 | N | **18** | **79** | **13 NJ** | **53 NJ** | **370** | **51** | **320** | **886** | -41 MLLW | Sand | 2007 Data Gap Evaluation |
| G9700a0807 | G3+00 | FD | **7.7** | **42** | **8.2 NJ** | **5.2 NJ** | **250** | **24** | **280** | **609.4** | sediment surface | YBM | 2007 Data Gap Evaluation |
| M30320807 | 303_2S | N | **6.2 NJ** | **8.9 NJ** | **2 NJ** | **11** | **32** | **9 J** | **53** | **115.9** | sediment surface | YBM | 2007 Data Gap Evaluation |
| M30330807 | 303_3S | N | **490** | **370** | **22 NJ** | **1,500** | **850** | **240** | **11,000** | **13,982** | sediment surface | YBM | 2007 Data Gap Evaluation |
| M30340807 | 303_4S | N | **2.4 NJ** | **3.3 NJ** | **2.7 NJ** | **3.3 J** | **16** | **7.2 J** | **120** | **152.5** | sediment surface | YBM | 2007 Data Gap Evaluation |
| SF29a0807 | SF-29 | N | **4 NJ** | **11 NJ** | **1.9 NJ** | **3.8 NJ** | **49** | **7.9 J** | **60** | **133.6** | sediment surface | YBM | 2007 Data Gap Evaluation |
| SF29b0807 | SF-29 | N | **3.5 J** | **15** | **2.8 NJ** | 6 U | **63** | **9** | **140** | **229.8** | -41 MLLW | Interface | 2007 Data Gap Evaluation |
| SF31a0807 | SF-31 | N | 18 U | **7.9 NJ** | 18 UJ | **9 J** | **55** | **11 NJ** | **830** | **912.9** | sediment surface | YBM | 2007 Data Gap Evaluation |
| SF31b0807 | SF-31 | N | **8.4 NJ** | **28** | **7.2 NJ** | **5.1 NJ** | **110** | **22** | **30** | **202.3** | -41 MLLW | Interface | 2007 Data Gap Evaluation |
| SF32a0807 | SF-32 | N | **4.3 NJ** | **11** | **4 NJ** | 7.2 U | **38** | **8.7** | **17** | **78.7** | sediment surface | YBM | 2007 Data Gap Evaluation |
| SF32b0807 | SF-32 | N | **2.7 J** | **4.9 NJ** | **2.6 NJ** | 5 U | **21** | **4.9 J** | **2.5 NJ** | **35.9** | -41 MLLW | Interface | 2007 Data Gap Evaluation |
| SF34a0807 | SF-34 | N | **5.4 NJ** | **6.6 J** | **4.5 NJ** | 8.7 U | **21** | **9.9 NJ** | **14 NJ** | **56** | sediment surface | YBM | 2007 Data Gap Evaluation |
| T1001a0807 | Embankment Transect 100 | N | **8.9 NJ** | **23 NJ** | **12 NJ** | **4.1 NJ** | **69** | **21** | **67** | **196.1** | 0-0.5' | Shell hash | 2007 Data Gap Evaluation |
| T1002a0807 | Embankment Transect 100 | N | **4.8 NJ** | **16 NJ** | **6.3 NJ** | **1.8 NJ** | **50** | **13** | **12** | **99.1** | 0-0.5' | Shell hash | 2007 Data Gap Evaluation |
| T1003a0807 | Embankment Transect 100 | N | **6.3 NJ** | **8.1** | **6.4 NJ** | 5.7 U | **22** | **8.5 NJ** | **14 NJ** | **59** | 0-0.5' | Shell hash | 2007 Data Gap Evaluation |
| T3001a0807 | Embankment Transect 300 | N | **24** | **30 NJ** | **19 NJ** | **4.3 NJ** | **100** | **37** | **85** | **275.3** | 0-0.5' | Shell hash | 2007 Data Gap Evaluation |
| T3001b0807 | Embankment Transect 300 | N | **24** | **39 NJ** | **22 NJ** | **1.8 NJ** | **210** | **38** | **170** | **480.8** | 2.5-3.0' | Shell hash | 2007 Data Gap Evaluation |
| T3002a0807 | Embankment Transect 300 | N | **8.7 NJ** | **22** | **14 NJ** | **6.6** | **130** | **23** | **36** | **231.6** | 0-0.5' | Shell hash | 2007 Data Gap Evaluation |
| T3002b0807 | Embankment Transect 300 | N | **15 NJ** | **41** | **18 J** | 4.7 U | **190** | **51 NJ** | **23** | **323** | 2.5-3.0' | Shell hash | 2007 Data Gap Evaluation |
| T3003a0807 | Embankment Transect 300 | N | **25** | **99** | **35** | **4.3 NJ** | **490** | **57** | **17** | **702.3** | 0-0.5' | Shell hash | 2007 Data Gap Evaluation |
| T3003b0807 | Embankment Transect 300 | N | 5 U | **2 J** | **1.1 NJ** | 5 U | **7.1** | **1.5 J** | **15** | **26.7** | 2.5-3.0' | Shell hash | 2007 Data Gap Evaluation |
| T5001a0807 | Embankment Transect 500 | N | **55** | **400** | **65 NJ** | 12 U | **1,300** | **220** | **91 J** | **2,076** | 0-0.5' | Shell hash | 2007 Data Gap Evaluation |

TABLE 8-1

**Summary of Historical Sediment Data used in Source Identification Evaluations**

*United Heckathorn Superfund Site, Richmond, California*

| | | | ***Pesticide concentrations in µg/kg dry weight*** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SampleID** | **LocationID** | **Sample Type** | **Dieldrin** | **2,4-DDD** | **2,4-DDE** | **2,4-DDT** | **4,4-DDD** | **4,4-DDE** | **4,4-DDT** | **Total DDT** | **Sample Vertical Interval (ft, unless otherwise noted)** | **Sample Description** | **Study** |
| T5001b0807 | Embankment Transect 500 | N | **26 NJ** | **130** | **80 J** | **45** | **760 J** | **110 NJ** | **3400 J** | **4,525** | 2.5-3.0' | Shell hash | 2007 Data Gap Evaluation |
| T5002a0807 | Embankment Transect 500 | N | **97** | **320** | **65 NJ** | **4.9 NJ** | **1,100** | **340** | **260** | **2,090** | 0-0.5' | Shell hash | 2007 Data Gap Evaluation |
| T5002b0807 | Embankment Transect 500 | N | **49 NJ** | **270** | **57 NJ** | **7.2 NJ** | **1,000** | **250** | **80** | **1,664** | 2.5-3.0' | Shell hash | 2007 Data Gap Evaluation |
| T5003a0807 | Embankment Transect 500 | N | **4.1 NJ** | **16** | **13 NJ** | 4.5 U | **53** | **18** | **7.9 NJ** | **107.9** | 0-0.5' | Shell hash | 2007 Data Gap Evaluation |
| T5003b0807 | Embankment Transect 500 | N | **56 NJ** | **180 NJ** | **73** | **70 NJ** | **630** | **270** | **450** | **1,673** | 2.5-3.0' | Shell hash | 2007 Data Gap Evaluation |

**Notes:**

**Bold** values indicate detected result.

Total DDT is the sum of the detected isomers.

FD - field duplicate

ft - feet

MLLW - mean lower low water level

N (sample type) - normal sample

N (data qualifier) - This flag indicates presumptive evidence of a compound.

OBM - Older Bay Mud

YBM - Younger Bay Mud

µg/kg - micrograms per kilogram

J - estimated value

U - not detected above reporting limit shown

-- not analyzed / not reported

TABLE 8-2

**Summary of Pesticide and Organic Carbon Results - 2013 Sediment Core Data**

*United Heckathorn Superfund Site, Richmond, California*

| | | | | | Pesticide results are µg/kg dry weight | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location ID | Sample ID | Sample Type | Top Depth (ft) | Bottom Depth (ft) | Dieldrin | 2,4-DDD | 2,4-DDE | 2,4-DDT | 4,4-DDD | 4,4-DDE | 4,4-DDT | Total DDT | Total Organic Carbon (mg/kg) |
| SD13-04 | SD13-04-0005 | N | 0.0 | 0.5 | 1100 | 5900 | 850 | 3.2 U | 33000 | 1100 | 2000 | 42850 | 25300 |
| SD13-04 | SD13-04-0515 | N | 0.5 | 1.5 | 880 | 4600 | 990 | 97 J | 31000 | 1200 | 11000 | 48887 | 32900 |
| SD13-05 | SD13-05-0002 | N | 0.0 | 0.2 | 19 | 110 J | 3.2 U | 3.2 U | 600 | 120 | 200 | 1030 | 37600 |
| SD13-05 | SD13-05-0203 | N | 0.2 | 0.3 | 8.9 J | 60 J | 3.3 U | 22 J | 220 | 40 | 120 | 462 | 35900 |
| SD13-05 | SD13-05-0305 | N | 0.3 | 0.5 | 24 | 74 | 3.3 U | 3.3 U | 360 | 79 | 220 | 733 | 36900 |
| SD13-05 | SD13-05-0507 | N | 0.5 | 0.7 | 62 J | 150 J | 3.3 U | 140 J | 640 | 130 J | 440 | 1500 | 38900 |
| SD13-05 | SD13-05-0708 | N | 0.7 | 0.8 | 46 J | 110 J | 3 U | 3 U | 310 | 100 | 210 | 730 | 38000 > |
| SD13-05 | SD13-05-0810 | N | 0.8 | 1.0 | 47 J | 210 | 240 | 500 | 940 | 420 | 1100 | 3410 | 38000 > |
| SD13-05 | SD13-05-1020 | N | 1.0 | 2.0 | 110 | 700 | 1000 | 3.3 U | 2700 | 1100 | 2300 | 7800 | 38100 |
| SD13-05 | SD13-05-2040 | N | 2.0 | 4.0 | 120 | 340 | 460 | 94 | 2500 | 680 | 1000 | 5074 | 38000 > |
| SD13-06 | SD13-06-0005 | N | 0.0 | 0.5 | 100 J | 320 | 3.2 U | 3.2 U | 1200 | 260 | 1300 | 3080 | 31200 |
| SD13-06 | SD13-06-0520 | N | 0.5 | 2.0 | 110 J | 380 | 3.3 U | 93 | 1200 | 260 | 460 | 2393 | 38700 |
| SD13-06 | SD13-06-2040 | N | 2.0 | 4.0 | 120 J | 430 | 150 | 27 J | 1700 | 160 | 190 | 2657 | 14200 |
| SD13-06 | SD13-06-4050 | N | 4.0 | 5.0 | 190 | 870 | 3.2 U | 1400 | 5000 | 260 | 5600 | 13130 | 28200 |
| SD13-08 | SD13-08-0005 | N | 0.0 | 0.5 | 23 J | 44 J | 3.3 U | 3.3 U | 150 J | 15 J | 130 J | 339 | 26700 |
| SD13-08 | SD13-08-0520 | N | 0.5 | 2.0 | 41 J | 140 | 3.3 U | 3.3 U | 650 | 93 J | 850 | 1733 | 28100 |
| SD13-08 | SD13-92-0520 | FD | 0.5 | 2.0 | 14 J | 67 J | 3.3 U | 3.3 U | 490 | 36 J | 700 | 1293 | -- |
| SD13-08 | SD13-08-2040 | N | 2.0 | 4.0 | 140 | 1100 | 3.3 U | 95 | 5800 | 310 | 8000 J | 15305 | 22200 |
| SD13-08 | SD13-08-4655 | N | 4.6 | 5.5 | 3.3 U | 2 J | 3.3 U | 3.3 U | 8.1 | 3.3 U | 4.9 | 15 | 1250 |
| SD13-09 | SD13-09-0002 | N | 0.0 | 0.2 | 5.7 J | 38 J | 3.3 U | 8.7 J | 260 | 22 J | 230 | 558.7 | 25500 |
| SD13-09 | SD13-09-0203 | N | 0.2 | 0.3 | 15 J | 59 J | 3.3 U | 20 J | 390 | 39 J | 460 | 968 | 26100 |
| SD13-09 | SD13-09-0305 | N | 0.3 | 0.5 | 9.2 J | 62 J | 3.2 U | 51 J | 460 | 33 J | 400 | 1006 | 26500 |
| SD13-09 | SD13-09-0507 | N | 0.5 | 0.7 | 26 J | 91 J | 3.3 U | 44 J | 500 | 63 J | 580 | 1278 | 28800 |
| SD13-09 | SD13-09-0708 | N | 0.7 | 0.8 | 27 J | 97 J | 3.3 U | 56 J | 350 | 47 J | 820 | 1370 | 23400 |
| SD13-09 | SD13-09-0810 | N | 0.8 | 1.0 | 21 J | 54 J | 3.2 U | 42 J | 160 | 25 J | 200 | 481 | 23000 |
| SD13-09 | SD13-09-1020 | N | 1.0 | 2.0 | 31 J | 140 | 3.2 U | 34 J | 770 | 69 J | 730 | 1743 | 25600 |
| SD13-09 | SD13-09-2040 | N | 2.0 | 4.0 | 390 | 2800 | 700 | 140 | 15000 | 720 | 3100 | 22460 | 13000 |
| SD13-09 | SD13-09-4055 | N | 4.0 | 5.5 | 150 | 1300 | 250 | 91 | 7400 | 180 | 2200 | 11421 | 4150 |
| SD13-10 | SD13-10-0005 | N | 0.0 | 0.5 | 150 J | 610 | 140 J | 130 J | 3500 | 580 | 590 | 5550 | 20600 |
| SD13-10 | SD13-10-0520 | N | 0.5 | 2.0 | 1300 | 7000 | 1700 | 120 J | 29000 | 2000 | 5200 | 45020 | 33000 |
| SD13-10 | SD13-10-2040 | N | 2.0 | 4.0 | 3.2 U | 26 | 3.2 U | 3.2 U | 110 | 20 | 13 | 169 | 7000 |
| SD13-10 | SD13-10-4066 | N | 4.0 | 6.6 | 3.2 U | 6.2 | 3.2 U | 3.2 U | 15 | 2.2 J | 1 J | 24.4 | 5500 |
| SD13-10 | SD13-10-6066 | N | 6.0 | 6.6 | 3.2 U | 2.1 J | 3.2 U | 3.2 U | 8.3 | 3.2 U | 3.2 U | 10.4 | -- |
| SD13-13 | SD13-13-0005 | N | 0.0 | 0.5 | 11 J | 72 J | 3.2 U | 200 | 160 | 37 J | 430 | 899 | 9700 |
| SD13-13 | SD13-87-0005 | FD | 0.0 | 0.5 | 19 J | 44 J | 3.2 U | 38 J | 2500 | 28 J | 360 | 2970 | -- |

TABLE 8-2

**Summary of Pesticide and Organic Carbon Results - 2013 Sediment Core Data**

*United Heckathorn Superfund Site, Richmond, California*

| | | | | | Pesticide results are µg/kg dry weight | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location ID | Sample ID | Sample Type | Top Depth (ft) | Bottom Depth (ft) | Dieldrin | 2,4-DDD | 2,4-DDE | 2,4-DDT | 4,4-DDD | 4,4-DDE | 4,4-DDT | Total DDT | Total Organic Carbon (mg/kg) |
| SD13-13 | SD13-13-0520 | N | 0.5 | 2.0 | **26** | **46** | 3.2 U | **34** | **130** | **19** | **210** | **439** | **2450** |
| SD13-13 | SD13-13-2025 | N | 2.0 | 2.5 | 3.2 U | **1.8 J** | 3.2 U | **1.7 J** | **7.7** | **1.1 J** | **2.7 J** | **15** | **970** |
| SD13-13 | SD13-87-2025 | FD | 2.0 | 2.5 | 3.2 U | **1.6 J** | 3.2 U | 3.2 U | **6.2** | 3.2 U | **2.2 J** | **10** | -- |
| SD13-14 | SD13-14-0005 | N | 0.0 | 0.5 | **140** | **1000** | **230** | **120 J** | **7200** | **150** | **3600** | **12300** | **12500** |
| SD13-14 | SD13-14-0509 | N | 0.5 | 0.9 | **110** | **900** | **230** | **90 J** | **5600 J** | **140 J** | **8000** | **14960** | **15700** |
| SD13-14 | SD13-14-1020 | N | 1.0 | 2.0 | 3.2 U | **1.2 J** | 3.2 U | 3.2 U | **1.5 J** | 3.2 U | **1.5 J** | **4.2** | **3050** |
| SD13-14 | SD13-14-2040 | N | 2.0 | 4.0 | **8.2** | **54** | 3.2 U | **11** | **170** | **14** | **8.4** | **257.4** | **2950** |
| SD13-15 | SD13-15-0005 | N | 0.0 | 0.5 | **86** | **300** | **50** | **660** | **1200 J** | **420** | **3000 J** | **5630** | **19200** |
| SD13-15 | SD13-15-0520 | N | 0.5 | 2.0 | **96** | **220** | **85** | **140** | **1100 J** | **270** | **7900** | **9715** | **7700** |
| SD13-15 | SD13-15-2040 | N | 2.0 | 4.0 | **1.1 J** | **2.4 J** | 3.2 U | 3.2 U | **15** | **1.3 J** | **4.4** | **23.1** | **2350** |
| SD13-15 | SD13-15-4049 | N | 4.0 | 4.9 | 3.2 U | 3.2 U | 3.2 U | 3.2 U | **5.1** | 3.2 U | 3.2 U | **5.1** | **580** |
| SD13-18 | SD13-18-0005 | N | 0.0 | 0.5 | **45 J** | **170** | 3.2 U | **170** | **820 J** | **74 J** | **750** | **1984** | **14200** |
| SD13-18 | SD13-18-0510 | N | 0.5 | 1.0 | **280** | **1300** | **330** | **400** | **4900** | **270** | **4400** | **11600** | **10100** |
| SD13-18 | SD13-18-1530 | N | 1.5 | 3.0 | 3.3 U | 3.3 U | 3.3 U | 3.3 U | 3.3 U | 3.3 U | 3.3 U | 0 U | **760** |
| SD13-18 | SD13-82-1530 | FD | 1.5 | 3.0 | 3.2 U | 3.2 U | 3.2 U | 3.2 U | **2.3 J** | 3.2 U | **1.4 J** | **3.7** | -- |
| SD13-19 | SD13-19-0005 | N | 0.0 | 0.5 | **41 J** | **140** | 3.3 U | **1000** | **650 J** | **69 J** | **2700** | **4559** | **16300** |
| SD13-19 | SD13-19-0520 | N | 0.5 | 2.0 | **95** | **440** | 3.2 U | **320** | **2300 J** | **130** | **8600** | **11790** | **10100** |
| SD13-19 | SD13-19-2040 | N | 2.0 | 4.0 | **77** | **440** | **64** | **620** | **1900 J** | **100** | **2500** | **5624** | **1350** |
| SD13-19 | SD13-19-4560 | N | 4.5 | 6.0 | **86** | **170** | 3.2 U | **240** | **820 J** | **86** | **2800** | **4116** | **1600** |
| SD13-20 | SD13-20-0005 | N | 0.0 | 0.5 | 3.3 U | 3.3 U | 3.3 U | 3.3 U | 3.3 U | 3.3 U | **2.8 J** | **2.8** | **9600** |
| SD13-20 | SD13-20-0520 | N | 0.5 | 2.0 | **110** | **400** | 3.2 U | **1500** | **1300** | **310** | **17000** | **20510** | **7800** |
| SD13-20 | SD13-20-2040 | N | 2.0 | 4.0 | **100** | **600** | 3.2 U | **16000** | **8200** | **350** | **80000** | **105150** | **6350** |
| SD13-20 | SD13-20-4052 | N | 4.0 | 5.2 | **320** | **1200** | **98 J** | **1300** | **1300** | **450** | **13000** | **17348** | **9750** |
| SD13-23 | SD13-23-0005 | N | 0.0 | 0.5 | **180** | **740** | 3.2 U | **2500** | **3500** | **260** | **23000** | **30000** | **10800** |
| SD13-23 | SD13-23-0520 | N | 0.5 | 2.0 | **360** | **1600** | **390** | **1000** | **8200 J** | **370** | **8100** | **19660** | **7150** |
| SD13-23 | SD13-77-0520 | FD | 0.5 | 2.0 | **520** | **430** | **430** | **900** | **2200** | **310** | **2500** | **6770** | -- |
| SD13-23 | SD13-23-2037 | N | 2.0 | 3.7 | **630** | **6900** | **1600** | **1900** | **2300** | **1300** | **3500** | **17500** | **13600** |
| SD13-24 | SD13-24-0005 | N | 0.0 | 0.5 | **14 J** | **51 J** | 3.2 U | **36 J** | **260** | **25 J** | **770** | **1142** | **17100** |
| SD13-24 | SD13-24-0520 | N | 0.5 | 2.0 | **10 J** | **55 J** | 3.2 U | **15 J** | **100 J** | **20 J** | **86 J** | **276** | **4050** |
| SD13-24 | SD13-24-2040 | N | 2.0 | 4.0 | 3.3 U | **17** | 3.3 U | **15** | **72** | **6.1** | **47** | **157.1** | **3750** |
| SD13-24 | SD13-24-4060 | N | 4.0 | 6.0 | **40** | **350** | **79** | **210** | **1700** | **100** | **4700** | **7139** | **6200** |
| SD13-25 | SD13-25-0005 | N | 0.0 | 0.5 | 3.3 U | **31 J** | 3.3 U | **41 J** | **120** | **15 J** | **740** | **947** | **21100** |
| SD13-25 | SD13-25-0520 | N | 0.5 | 2.0 | **27 J** | **110** | 3.2 U | **260** | **620** | **45 J** | **2800** | **3835** | **20700** |
| SD13-25 | SD13-25-2040 | N | 2.0 | 4.0 | **16 J** | **140** | 3.2 U | **190** | **690** | **60 J** | **3600** | **4680** | **24300** |
| SD13-25 | SD13-75-2040 | FD | 2.0 | 4.0 | **20 J** | **180** | 3.3 U | **650** | **730** | **86 J** | **3500** | **5146** | -- |

TABLE 8-2

**Summary of Pesticide and Organic Carbon Results - 2013 Sediment Core Data**

*United Heckathorn Superfund Site, Richmond, California*

| | | | | | Pesticide results are µg/kg dry weight | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location ID | Sample ID | Sample Type | Top Depth (ft) | Bottom Depth (ft) | Dieldrin | 2,4-DDD | 2,4-DDE | 2,4-DDT | 4,4-DDD | 4,4-DDE | 4,4-DDT | Total DDT | Total Organic Carbon (mg/kg) |
| SD13-25 | SD13-25-4059 | N | 4.0 | 5.9 | **70 J** | **110** | **92 J** | **180** | **900** | **190 J** | **3100** | **4572** | **12300** |
| SD13-27 | SD13-27-0005 | N | 0.0 | 0.5 | **13** | **34** | **17** | **2.1 J** | **210** | **13** | **97** | **373.1** | **5950** |
| SD13-27 | SD13-27-0520 | N | 0.5 | 2.0 | **5** | **35** | **17** | **0.99 J** | **240** | **15** | **8.4** | **316.39** | **1550** |
| SD13-27 | SD13-27-2031 | N | 2.0 | 3.1 | 3.2 U | 3.2 U | 3.2 U | 3.2 U | **4.9** | 3.2 U | 3.2 U | **4.9** | **570** |
| SD13-28 | SD13-28-0005 | N | 0.0 | 0.5 | **5.4 J** | **25 J** | 3.3 U | **15 J** | **110 J** | **12 J** | **250** | **412** | **20500** |
| SD13-28 | SD13-28-0520 | N | 0.5 | 2.0 | **4.5 J** | **14 J** | 3.3 U | **9.3 J** | **220** | **7.8 J** | **670** | **921.1** | **18900** |
| SD13-28 | SD13-28-2040 | N | 2.0 | 4.0 | **9** | **46** | 3.2 U | **79** | **200** | **17** | **570** | **912** | **17300** |
| SD13-28 | SD13-28-4060 | N | 4.0 | 6.0 | **52** | **290** | **160** | **85** | **1600** | **93** | **2900** | **5128** | **19600** |
| SD13-29 | SD13-29-0005 | N | 0.0 | 0.5 | **4.8 J** | **14 J** | 3.3 U | **18 J** | **66 J** | **8.1 J** | **240** | **346.1** | **23500** |
| SD13-29 | SD13-29-0520 | N | 0.5 | 2.0 | **14 J** | **36 J** | 3.2 U | **67 J** | **100 J** | **24 J** | **500** | **727** | **24300** |
| SD13-29 | SD13-71-0520 | FD | 0.5 | 2.0 | **12 J** | **40 J** | 3.2 U | **54 J** | **130** | **24 J** | **280 J** | **528** | -- |
| SD13-29 | SD13-29-2040 | N | 2.0 | 4.0 | 3.3 U | **31 J** | 3.3 U | 3.3 U | **150 J** | **20 J** | **120 J** | **321** | **23800** |
| SD13-29 | SD13-29-4060 | N | 4.0 | 6.0 | 3.3 U | **60 J** | **16 J** | **18 J** | **230** | **35 J** | **130 J** | **489** | **23300** |
| SD13-31 | SD13-31-0005 | N | 0.0 | 0.5 | 3.2 U | **1.2 J** | 3.2 U | 3.2 U | **4.9** | **1 J** | **4.9** | **12** | **1700** |
| SD13-31 | SD13-31-0520 | N | 0.5 | 2.0 | 3.2 U | 3.2 U | 3.2 U | 3.2 U | **1.5 J** | 3.2 U | 3.2 U | **1.5** | **930** |
| SD13-31 | SD13-31-2040 | N | 2.0 | 4.0 | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 3.2 U | **0.69 J** | **0.69** | **810** |
| SD13-31 | SD13-69-2040 | FD | 2.0 | 4.0 | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 3.2 U | **0.69 J** | **0.69** | -- |
| SD13-32 | SD13-32-0005 | N | 0.0 | 0.5 | 3.2 U | 3.2 U | 3.2 U | **4.6 J** | **24** | 3.2 U | **150 J** | **178.6** | **17100** |
| SD13-32 | SD13-32-0520 | N | 0.5 | 2.0 | **4.1 J** | **18 J** | 3.2 U | **23 J** | **100 J** | **8.6 J** | **91 J** | **240.6** | **16700** |
| SD13-32 | SD13-32-2040 | N | 2.0 | 4.0 | **3.5 J** | **24 J** | 3.3 U | **17 J** | **130** | **9.1 J** | **170 J** | **350.1** | **17700** |
| SD13-32 | SD13-32-4060 | N | 4.0 | 6.0 | **33 J** | **120** | **57 J** | **48 J** | **630** | **56 J** | **1000 J** | **1911** | **11300** |
| SD13-33 | SD13-33-0005 | N | 0.0 | 0.5 | **5.5 J** | **19 J** | 3.2 U | **15 J** | **68 J** | **12 J** | **91 J** | **205** | **20400** |
| SD13-33 | SD13-33-0520 | N | 0.5 | 2.0 | 3.2 U | **48 J** | 3.2 U | **69 J** | **120** | **29 J** | **140 J** | **406** | **20400** |
| SD13-33 | SD13-33-2040 | N | 2.0 | 4.0 | **4.2 J** | **12 J** | 3.3 U | **18 J** | **89 J** | **11 J** | **130 J** | **260** | **25300** |
| SD13-33 | SD13-33-4060 | N | 4.0 | 6.0 | **2.1 J** | **14 J** | 3.2 U | 3.2 U | **39 J** | **6.4 J** | **140 J** | **199.4** | **24500** |
| SD13-35 | SD13-35-0005 | N | 0.0 | 0.5 | **6.1 J** | **22 J** | 3.2 U | **8.1 J** | **80 J** | **11 J** | **71 J** | **192.1** | **14200** |
| SD13-35 | SD13-65-0005 | FD | 0.0 | 0.5 | **1.7 J** | **5.3** | 3.3 U | **2.4 J** | **28** | **4.1** | **61** | **100.8** | -- |
| SD13-35 | SD13-35-0520 | N | 0.5 | 2.0 | **4.9** | **40** | 3.3 U | 3.3 U | **130** | **13** | **50** | **233** | **14200** |
| SD13-35 | SD13-35-2040 | N | 2.0 | 4.0 | **16** | **86** | **26** | 3.2 U | **310** | **36** | **130** | **588** | **7050** |
| SD13-35 | SD13-35-4058 | N | 4.0 | 5.8 | **15** | **120** | **38** | 3.2 U | **390** | **25** | **130** | **703** | **6500** |
| SD13-36 | SD13-36-0005 | N | 0.0 | 0.5 | 3.3 U | **4.2 J** | 3.3 U | 3.3 U | **16 J** | **2.7 J** | **33 J** | **55.9** | **16100** |
| SD13-36 | SD13-36-0520 | N | 0.5 | 2.0 | **5.1** | **53** | **19** | **18** | **270** | **15** | **330** | **705** | **16500** |
| SD13-36 | SD13-36-2040 | N | 2.0 | 4.0 | **39** | **550** | **180** | **17** | **3300** | **100** | **2000** | **6147** | **13000** |
| SD13-36 | SD13-36-4065 | N | 4.0 | 6.5 | 3.2 U | **11 J** | 3.2 U | **3.7 J** | **73 J** | **14 J** | **56 J** | **157.7** | **10400** |
| SD13-37 | SD13-37-0005 | N | 0.0 | 0.5 | 3.2 U | **4.5 J** | 3.2 U | **3.3 J** | **28 J** | **6.2 J** | **31 J** | **73** | **21200** |

TABLE 8-2

**Summary of Pesticide and Organic Carbon Results - 2013 Sediment Core Data**

*United Heckathorn Superfund Site, Richmond, California*

| | | | | | Pesticide results are µg/kg dry weight | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Location ID** | **Sample ID** | **Sample Type** | **Top Depth (ft)** | **Bottom Depth (ft)** | **Dieldrin** | **2,4-DDD** | **2,4-DDE** | **2,4-DDT** | **4,4-DDD** | **4,4-DDE** | **4,4-DDT** | **Total DDT** | **Total Organic Carbon (mg/kg)** |
| SD13-37 | SD13-63-0005 | FD | 0.0 | 0.5 | **4.3 J** | **10 J** | 3.2 U | **1 J** | **45 J** | **6.5 J** | **60 J** | **122.5** | -- |
| SD13-37 | SD13-37-0520 | N | 0.5 | 2.0 | 3.2 U | **4.2 J** | 3.2 U | 3.2 U | **24 J** | **5.4 J** | **21 J** | **54.6** | **20800** |
| SD13-37 | SD13-37-2040 | N | 2.0 | 4.0 | **6.3 J** | **31 J** | **27 J** | 3.2 U | **160** | **34 J** | **110** | **362** | **24100** |
| SD13-37 | SD13-37-4060 | N | 4.0 | 6.0 | 3.2 U | **7 J** | 3.2 U | 3.2 U | **23 J** | **3.6 J** | **23 J** | **56.6** | **21400** |
| SD13-39 | SD13-39-0005 | N | 0.0 | 0.5 | 3.2 U | 3.2 U | 3.2 U | 3.2 U | **12 J** | **2.4 J** | **8.6 J** | **23** | **16400** |
| SD13-39 | SD13-39-0520 | N | 0.5 | 2.0 | 3.8 U | **4** | 3.8 U | 3.8 U | **26** | **5.2** | **23** | **58.2** | **17300** |
| SD13-39 | SD13-39-2034 | N | 2.0 | 3.4 | 3.3 U | **7.9** | **3.5** | 3.3 U | **21** | **3.7** | **17** | **53.1** | **15900** |
| SD13-39 | SD13-39-4049 | N | 4.0 | 4.9 | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 3.2 U | **1.1 J** | **1.1** | **4050** |
| SD13-40 | SD13-40-0005 | N | 0.0 | 0.5 | **1.7 J** | **3.8 J** | **6.3 J** | 3.3 U | **24 J** | **3.6 J** | **11 J** | **48.7** | **15400** |
| SD13-40 | SD13-40-0520 | N | 0.5 | 2.0 | **3.5 J** | **4.7 J** | 3.2 U | 3.2 U | **14 J** | **4.2 J** | **9.1 J** | **32** | **13200** |
| SD13-40 | SD13-40-2040 | N | 2.0 | 4.0 | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 3.2 U | 0 U | **1350** |
| SD13-41 | SD13-41-0005 | N | 0.0 | 0.5 | 3.2 U | **2.5 J** | 3.2 U | 3.2 U | **9.3 J** | **3.7 J** | **8.4 J** | **23.9** | **18100** |
| SD13-41 | SD13-41-0520 | N | 0.5 | 2.0 | **3.5 J** | **32 J** | **9 J** | **3.5 J** | **100 J** | **16 J** | **30 J** | **190.5** | **14900** |
| SD13-41 | SD13-41-2040 | N | 2.0 | 4.0 | 3.2 U | **8.1 J** | 3.2 U | 3.2 U | **48 J** | **9.3 J** | **94 J** | **159.4** | **14200** |
| SD13-41 | SD13-41-4049 | N | 4.0 | 4.9 | 3.2 U | 3.2 U | 3.2 U | 3.2 U | **2.4 J** | 3.2 U | 3.2 U | **2.4** | **1400** |
| SD13-41 | SD13-59-4049 | FD | 4.0 | 4.9 | 3.2 U | 3.2 U | 3.2 U | 3.2 UJ | **3 J** | **0.78 J** | **1.7 J** | **5.48** | -- |
| SD13-41 | SD13-41-5565 | N | 5.5 | 6.5 | 3.2 U | 3.2 U | 3.2 U | 3.2 UJ | 3.2 U | 3.2 U | **1.2 J** | **1.2** | -- |

**Notes:**

**Bold** values indicate detected result.

Total DDT is the sum of the detected isomers.

FD - field duplicate

N - normal sample

ft - feet

g/g - grams per gram

mg/kg - milligrams per kilogram

µg/kg - micrograms per kilogram

J - estimated value

U - not detected above reporting limit shown

> actual value is greater than result shown

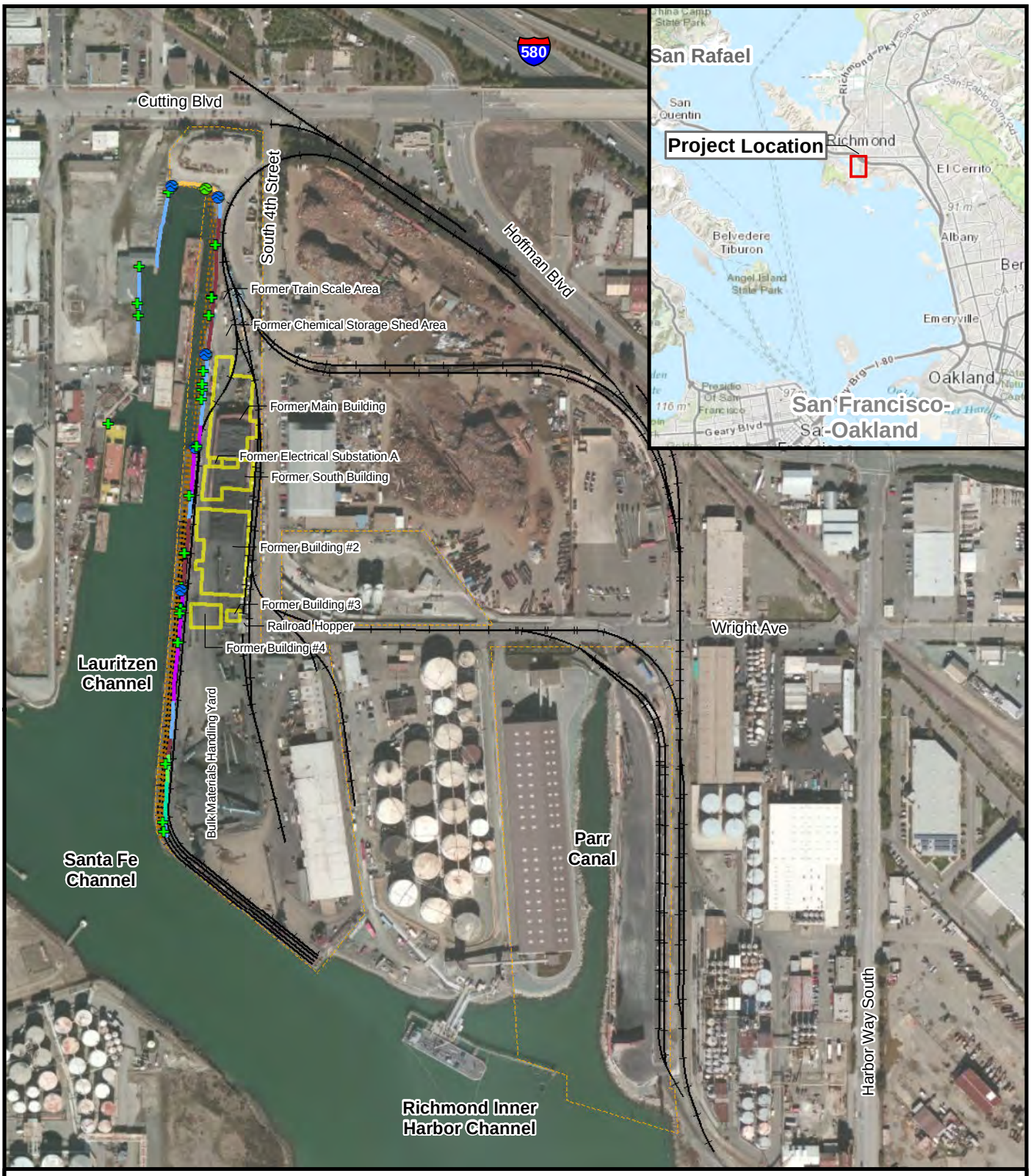
TABLE 9-1

**Conclusions of Source Identification Study**

*United Heckathorn Superfund Site, Richmond, California*

| Potential Ongoing Source | Character of Potential Source |
|---|---|
| Embankment Areas | Pipes and outfalls are unlikely to be significant sources of pesticides to the Lauritzen Channel during dry weather conditions because they do not convey dry weather flow. One seep that was sampled contained low levels of pesticides. Pipes and outfalls have not been inspected or sampled during wet weather conditions. Some of the identified and possible unidentified pipes and conveyances could have and may still act as preferential pathways for contaminant transport from upland areas with DDT-contaminated soil and groundwater to the Lauritzen Channel.<br><br>DDT contamination above the remediation goal is widespread along the eastern, northern, and northwestern shorelines of the channel. Although the shoreline is largely armored with rip rap, concrete, and sheetpile, fine-grained sediments are present in pockets in the rip rap and soils are eroding from under the sheetpile in some areas. |
| Groundwater Seepage | Estimated contribution to channel is 167 g DDT per year, which is not sufficient to account for concentrations currently observed in sediments but continues to impact channel sediments, surface water, and biota. |
| Wood Pilings | Desorption is not a significant source of DDT to surface water or sediment. Mechanical weathering of the pilings could result in incorporation of DDT-contaminated particles into the sediment bed and potentially into the food web. |
| Stormwater Outfalls | The municipal storm drain system cannot be fully evaluated as an ongoing source of contamination until DDT-contaminated residual sediments are removed from the system.<br><br>The storm drain system that serves the upland cap on the Levin Richmond Terminal property is generally functioning as designed. Low levels of pesticides are periodically detected in stormwater samples. |
| Source Material Outside of the Lauritzen Channel | There were no sources of DDT outside of the Lauritzen Channel that were identified as having potential to act as an outside source to the site. |
| Areas Not Previously Dredged | Dredging residuals appear to be the primary source of present day contamination in the Lauritzen Channel. |

# Figures




**LEGEND**

- LRTC Stormwater Outfalls
- Municipal Stormwater Outfall
- Other Pipe and Seep Locations
- Former Pier Pilings
- Pier Pilings
- Railroad
- Former United Heckathorn Buildings
- Levin Richmond Terminal Corp Property Line

**Shoreline Material**

- Concrete
- Rock/Rip Rap
- Rock/Rip Rap and Concrete
- Shotcrete
- Sheet Pile
- Sheet Pile and Concrete

0 175 350 700 Feet

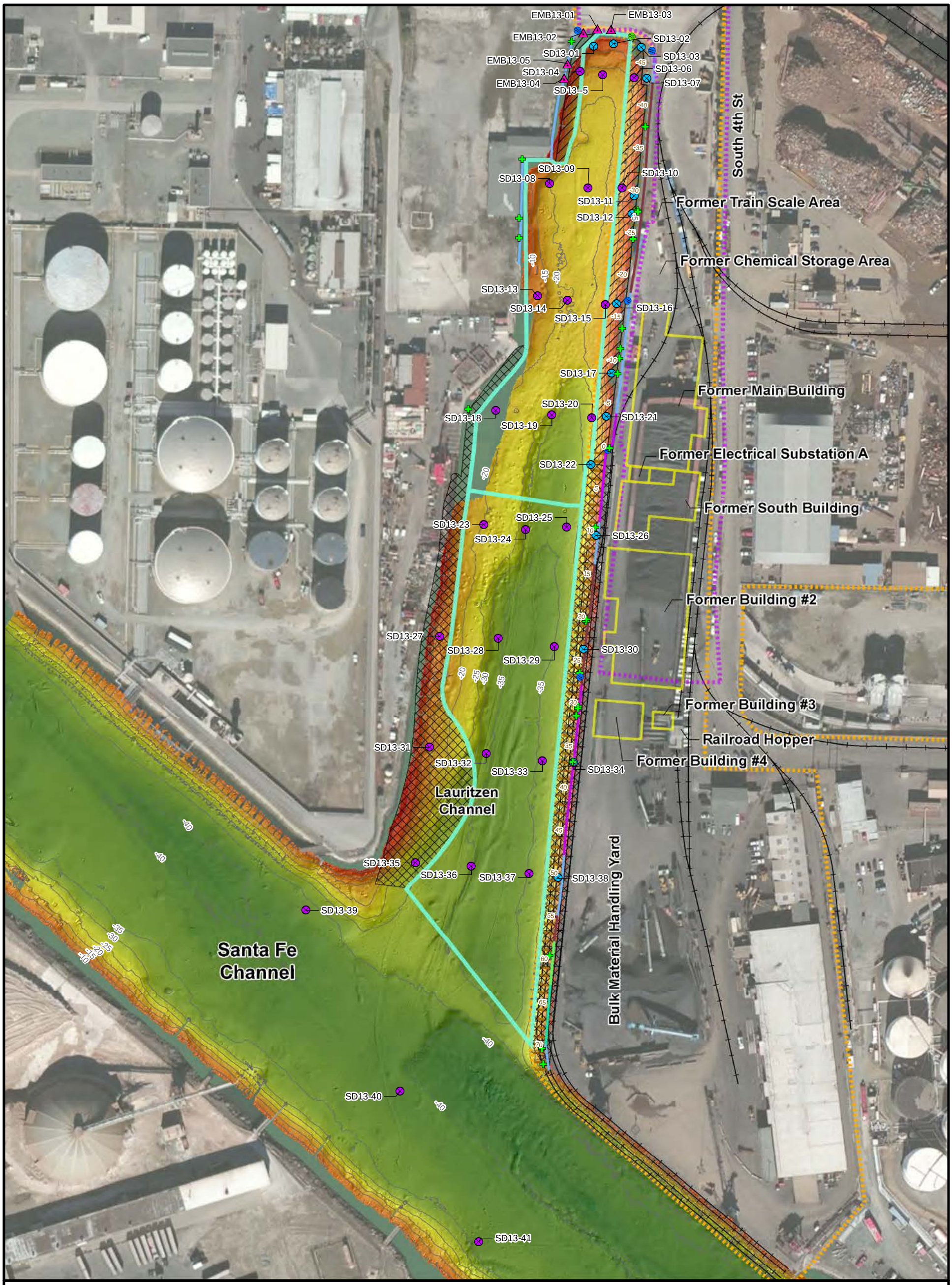
N

**FIGURE 1-1**
**Site Location Map**

United Heckathorn Superfund Site, Richmond, California

CH2MHILL

Document Path: D:\Projects\EPA_UnitedHeckathorn\MapFiles\2013\August\SiteLocationMap8.5x11.mxd




**LEGEND**

- Sediment Grab Sample Location
- Vibracore Sample Location
- Embankment Soil Grab Sample Location

**Bathymetry**

1 ft — 44 ft

-40 — Bathymetric Contour (5 foot Interval)

Contour depth label

- LRTC Stormwater Outfalls
- Municipal Stormwater Outfall
- Other Pipe and Seep Locations
- 10 Former Pier Pilings (bent number)
- -10 Pier Pilings (bent number)
- Railroad
- Former Buildings
- Dredged Area
- Partially Dredged Area
- Un-Dredged Area

- Concrete
- Rock/Rip Rap
- Rock/Rip Rap and Concrete
- Shotcrete
- Sheet Pile
- Sheet Pile and Concrete

N

0 60 120 240 Feet

**FIGURE 2-1**
**2013 Sediment Sampling Locations**
*United Heckathorn Superfund Site*
*Richmond, California*

CH2MHILL

BAO \\ZINFANDEL\PROJ\USENVIRONMENTALPROTE\340138UHFS\GIS\EPA_UNITED_HECKATHORN\MAPFILES\2013\AUGUST\SEDIMENTSAMPLELOCATIONS.MXD JCARR3 11/18/2013 1:41:28 PM

**LEGEND**

- Groundwater Sample Location
- Groundwater Monitoring Well - Sampled
- Groundwater Monitoring Well
- Removed Groundwater Well
- B24 = Removed Groundwater Well Name
- GW13-14 = Sample Location ID
- Railroad
- Pier Pilings (bent number) — 10
- Former Pier Pilings (bent number) — -10
- Buildings
- Concrete
- Rock/Rip Rap
- Rock/Rip Rap and Concrete
- Shotcrete
- Steel Pile
- Steel Sheets and Concrete

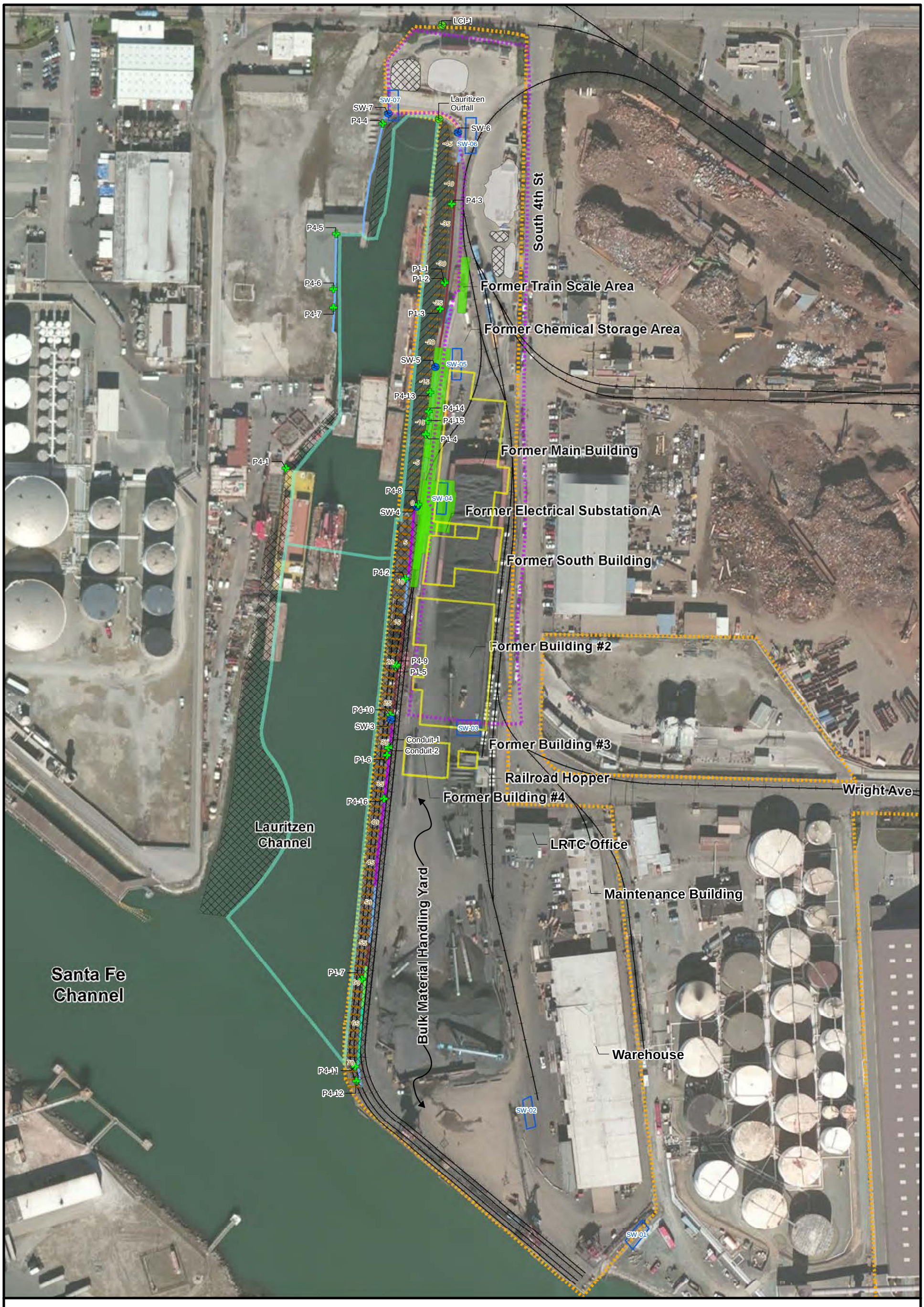
0 50 100 200 Feet

Note:
Groundwater samples were collected at MW13-01 and MW13-03.
These wells were also used for groundwater hydrogeologic evaluations.
MW13-02 and MW13-04 were only used for groundwater hydrogeologic evaluation.

**Figure 2-2**
**2013 Groundwater Sampling Locations**
United Heckathorn Superfund Site
Richmond, California

CH2MHILL

BAO \\ZINFANDEL\PROJ\USENVIRONMENTALPROTE\340138UHFS\GIS\EPA_UNITED_HECKATHORN\MAPFILES\2013\AUGUST\GROUNDWATERSAMPLING_2013.MXD JCARR3 2/28/2014 10:39:21 AM




**LEGEND**

- LRTC Stormwater Outfalls
- Municipal Stormwater Outfall
- Other Pipe and Seep Locations
- Former Pier Pilings
- Pier Pilings
- Levin Richmond Terminal Corp Property Line
- Railroad
- Former Buildings
- Approximate Extent of Upland Cap
- Dredged Area
- Partially Dredged Area
- Un-Dredged Area
- Approximate Location of Stormwater Interceptor
- Former Excavation Area

**Shoreline Material**

- Concrete
- Rock/Rip Rap
- Rock/Rip Rap and Concrete
- Shotcrete
- Sheet Pile
- Sheet Pile and Concrete

- Historical soil stockpile with total pesticide concentrations greater than 1,000 mg/kg.
- Historical soil stockpile with total pesticide concentrations less than than 1,000 mg/kg.

0 75 150 300 Feet

**Note:**
Stockpile locations determined from Removal of Pesticide-Affected Soils, United Heckathorn Site, Richmond, California (Levine-Fricke, 1991). Prepared for Levin Richmond Terminal Corporation. May. Stockpiles were generated during interim remedial actions in 1990 - 1991.

**Figure 3-1**
**Site Features**
United Heckathorn Superfund Site, Richmond, California



CH2MHILL

## LEGEND

- LRTC Stormwater Outfalls
- Municipal Stormwater Outfall
- Other Pipe and Seep Locations
- Former Pier Pilings
- Pier Pilings
- Railroad
- Former Buildings
- Approximate Extent of Upland Cap
- Sampling Grid
- Dredged Area
- Partially Dredged Area
- Un-Dredged Area
- Concrete
- Rock/Rip Rap
- Rock/Rip Rap and Concrete
- Shotcrete
- Sheet Pile
- Sheet Pile and Concrete

**Sample Depth**

- 0 - 6"
- 7" - 2 feet
- 2.1 - 4 feet
- > 4 feet

**Result Concentration (µg/kg)**

- 0-590 (Remediation Goal)
- 591-2,950 (5 x RG)
- 2,951 - 29,500 (50 x RG)
- 29,501 - 295,000 (500 x RG)
- 295,001 - >590,000 (1,000 x RG)

**Sample Year**

- 1999
- 2002
- 2003
- 2007

Results reported by Stanford. ΣDDT reported values are the sum of the o,p' and p,p' isomers of DDT and DDD and the p,p' isomer of DDE and DDMU

N

0 35 70 140 Feet

**FIGURE 3-2A**
**DDT Results (prior to 2013) in the Northern Reach of the Lauritzen Channel**
United Heckathorn Superfund Site
Richmond, California

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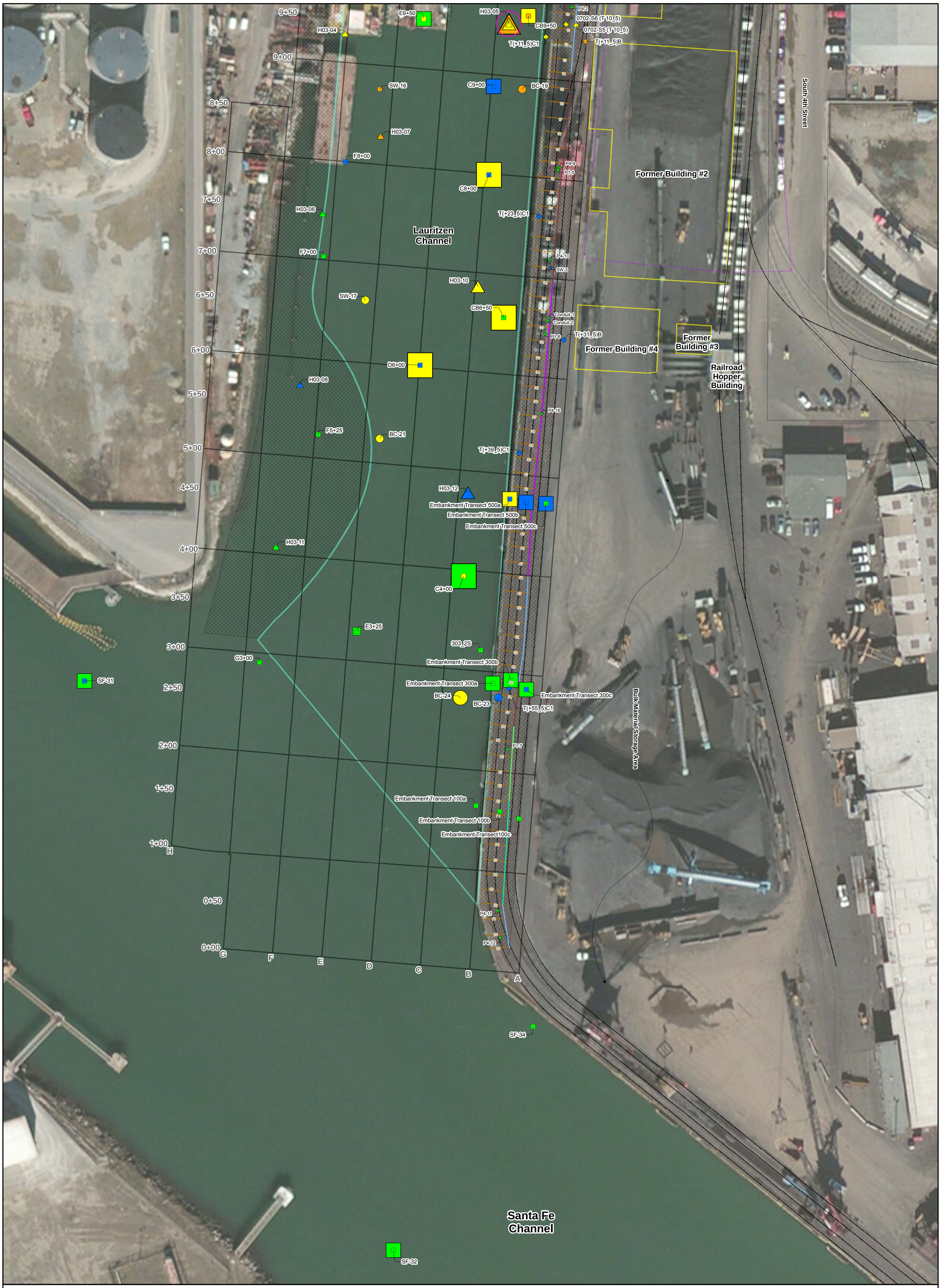


## LEGEND

- LRTC Stormwater Outfalls
- Municipal Stormwater Outfall
- Other Pipe and Seep Locations
- Former Pier Pilings
- Pier Pilings
- Railroad
- Property Line
- Approximate Upland Cap Area
- Former Building
- Sampling Grid
- Dredged Area
- Partially Dredged Area
- Un-Dredged Area
- Concrete
- Rock/Rip Rap
- Rock/Rip Rap and Concrete
- Shotcrete
- Sheet Pile
- Sheet Pile and Concrete

**Sample Depth**

- 0 - 6"
- 7" - 2 feet
- 2.1 - 4 feet
- > 4 feet

**Result Concentration (µg/kg)**

- 0-590 (Remediation Goal)
- 591-2,950 (5 x RG)
- 2,951 - 29,500 (50 x RG)
- 29,501 - 295,000 (500 x RG)
- 295,001 - >590,000 (1,000 x RG)

**Sample Year**

- 1999
- 2002
- 2003
- 2007

Results reported by Stanford. ΣDDT reported values are the sum of the o,p' and p,p' isomers of DDT and DDD and the p,p' isomer of DDE and DDMU

N

0 40 80 160 Feet

**FIGURE 3-2B**
**DDT Results (prior to 2013) in the Southern Reach of the Lauritzen Channel**

United Heckathorn Superfund Site
Richmond, California

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**LEGEND**

- Wood Chip Sample Location
- LRTC Stormwater Outfalls
- Municipal Stormwater Outfall
- Other Pipe and Seep Locations
- Former Pier Pilings
- Pier Pilings
- Levin Richmond Terminal Corp Property Line
- Railroad
- Former Buildings
- Approximate Extent of Upland Cap
- Dredged Area
- Partially Dredged Area
- Un-Dredged Area

**Shoreline Material**

- Concrete
- Rock/Rip Rap
- Rock/Rip Rap and Concrete
- Shotcrete
- Sheet Pile
- Sheet Pile and Concrete

**Notes**

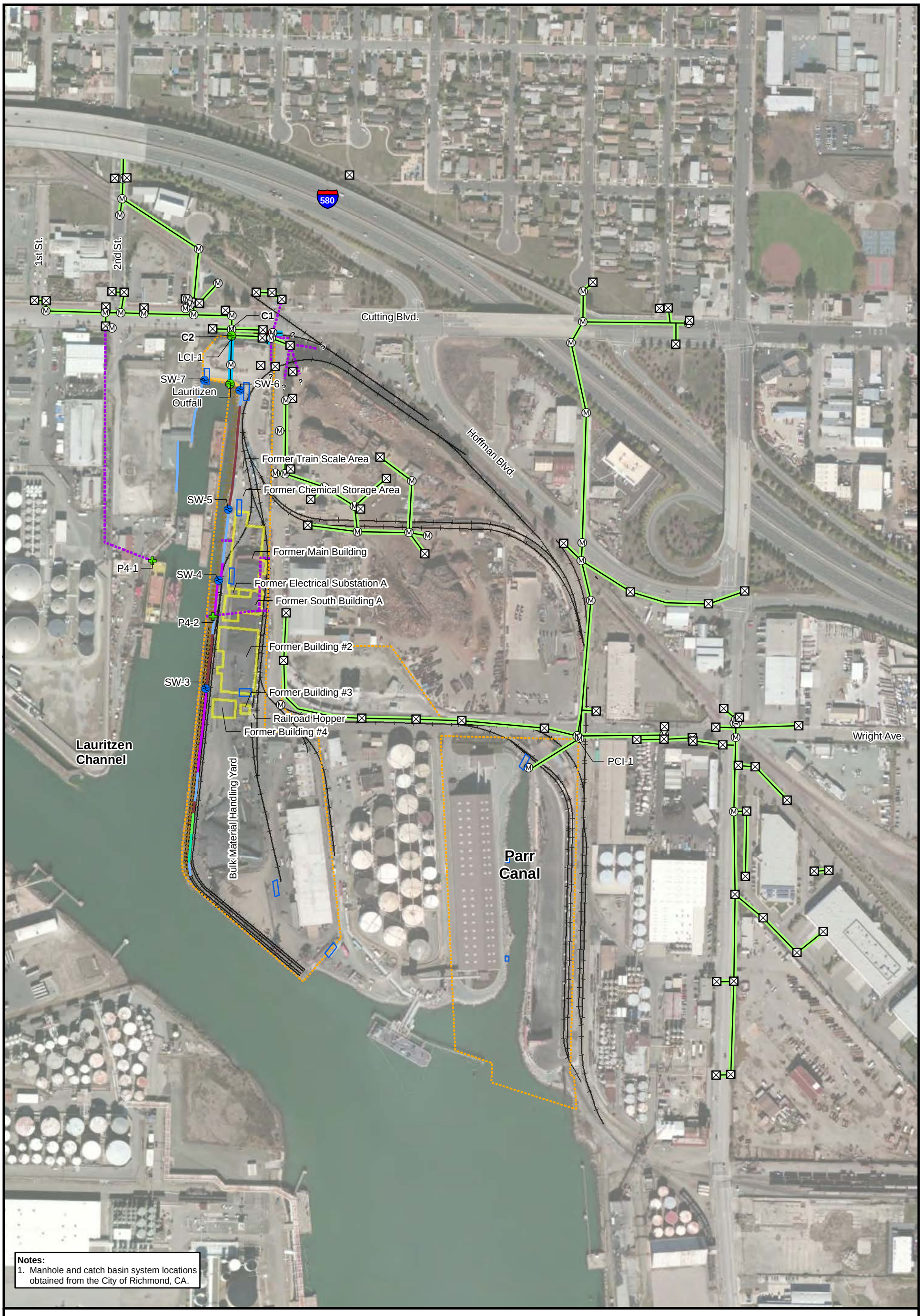
1. NA - Sample not analyzed, field immunoassay results indicated that CR-35 was similar to CR-33.
2. U - parameter not detected above the reporting limit shown
3. Concentrations presented in µg/kg - micrograms per kilogram (part per billion).

0 70 140 280 Feet

**FIGURE 5-1**
**Wood Chip Sample Locations and Results**
United Heckathorn Superfund Site, Richmond, California

CH2MHILL

Document Path: D:\Projects\EPA_UnitedHeckathorn\MapFiles\2013\August\WoodChipSamples.mxd




**LEGEND**

- LRTC Stormwater Outfalls
- Municipal Stormwater Outfall
- Other Pipe or Seep Location
- Railroad
- Pier Pilings
- Former Pier Pilings
- Levin Richmond Terminal Corp Property Line
- Catch Basin
- Manhole
- City of Richmond Stormwater Line
- Hydraulically isolated
- Video Surveyed
- Municipal lines -Unknown status
- Approximate Location of Stormwater Interceptor

**Shoreline Material**

- Concrete
- Rock/Rip Rap
- Rock/Rip Rap and Concrete
- Shotcrete
- Sheet Pile
- Sheet Pile and Concrete

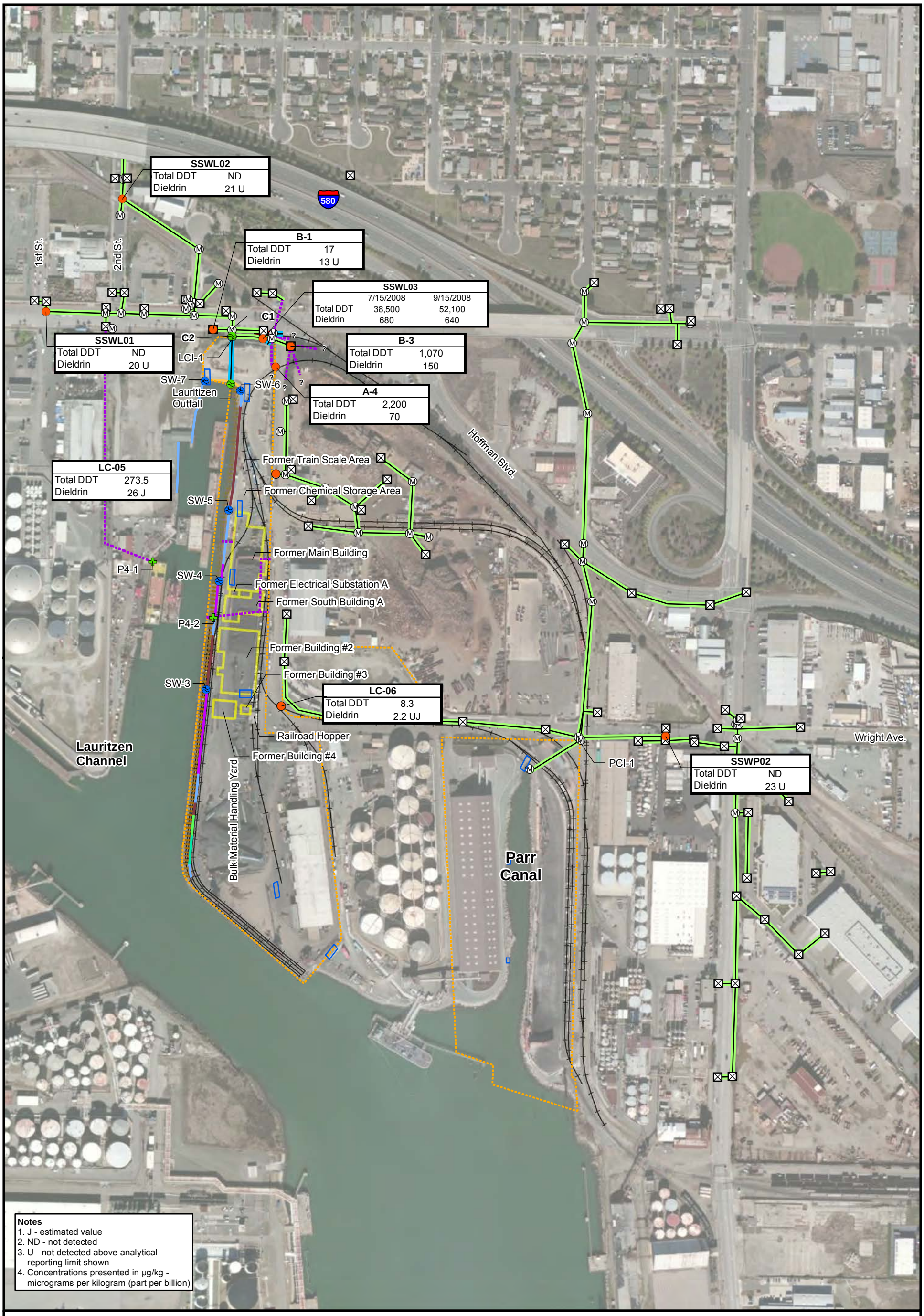
0 125 250 500 Feet

N

**FIGURE 6-1**
**Stormwater System Map**
United Heckathorn Superfund Site,
Richmond, California

CH2MHILL

Document Path: D:\Projects\EPA_UnitedHeckathorn\MapFiles\2013\August\Stormwater_System11X17.mxd Date Saved: 8/8/2013 10:54:03 AM




**Notes**
1. J - estimated value
2. ND - not detected
3. U - not detected above analytical reporting limit shown
4. Concentrations presented in µg/kg - micrograms per kilogram (part per billion)

**LEGEND**

- Stormwater Sample Location
- LRTC Stormwater Outfalls
- Municipal Stormwater Outfall
- Other Pipe or Seep Location
- Railroad
- Pier Pilings
- Former Pier Pilings
- Levin Richmond Terminal Corp Property Line
- Catch Basin
- Manhole
- City of Richmond Stormwater Line
- Hydraulically isolated
- Video Surveyed
- Municipal lines -Unknown status
- Approximate Location of Stormwater Interceptor

**Shoreline Material**

- Concrete
- Rock/Rip Rap
- Rock/Rip Rap and Concrete
- Shotcrete
- Sheet Pile
- Sheet Pile and Concrete

0 125 250 500 Feet

N

**FIGURE 6-2**
**Storm Drain Sediment Analytical Results**
United Heckathorn Superfund Site
Richmond, California

CH2MHILL

SD13-28
SD13-29
SD13-27
SD13-30
SD13-33
SD13-32
SD13-31
SD13-34
SD13-36
SD13-38
SD13-35
SD13-37
SD13-39
SD13-40
SD13-41
RIH-6B-2
RIH-6B-1
RIH-6A-2
RIH-6A-1
Former Building #2
Former Building #3
Railroad Hopper
Former Building #4
Wright Ave
LRTC Office
Maintenance Building
Warehouse
Lauritzen Channel
Santa Fe Channel
Bulk Material Handling Yard
Parr Canal
Inner Richmond Harbor

Data collected for the USACE investigation were used to determine dredge disposal requirements and targeted sample depths were selected relative to mean lower low water (MLLW). The actual as-sampled intervals of the USACE samples are different than those collected as part of the site characterization for Lauritzen Channel. Please see Table 7-1 of the Source ID Report for a listing of USACE sample depths relative to the sediment surface.

Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

**LEGEND**

- LRTC Stormwater Outfalls
- Municipal Stormwater Outfall
- Other Pipe and Seep Locations
- Former Pier Pilings
- Pier Pilings
- Railroad
- Former Buildings
- Dredged Area
- Partially Dredged Area
- Un-Dredged Area
- Concrete
- Rock/Rip Rap
- Rock/Rip Rap and Concrete
- Shotcrete
- Sheet Pile
- Sheet Pile and Concrete
- No YBM Observed

| 2013 Sample Depth | USACE Sample Depths |
|---|---|
| 0 - 0.5 feet | -39.0 to -39.5 MLLW |
| 0.5 - 2 feet | -39.5 to -40.0 MLLW |
| 2 - 4 feet | -40.0 to -40.5 MLLW |
| > 4 feet | |

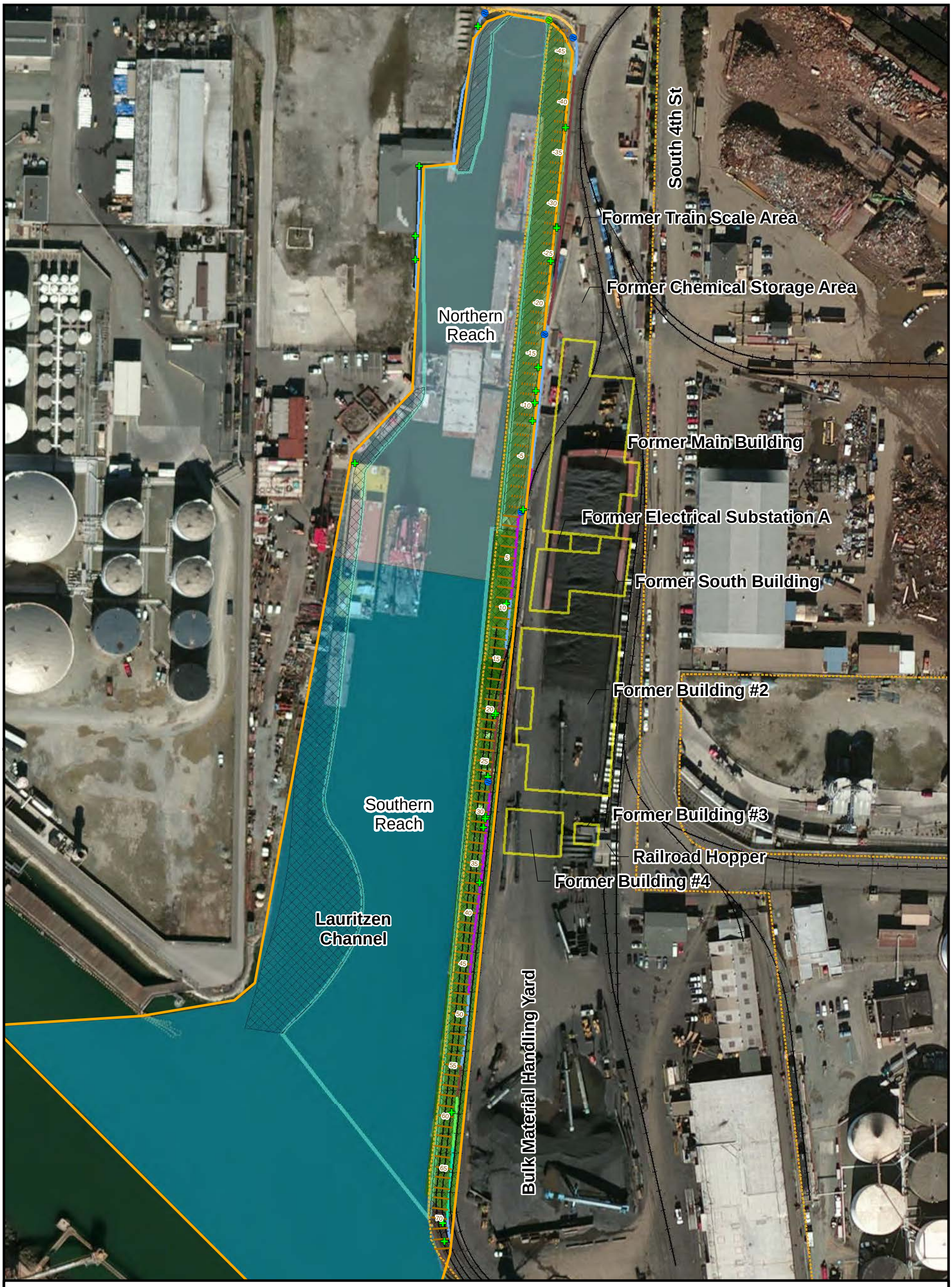
**Sediment Core DDT Results**

| | |
|---|---|
| 0 - 10 µg/kg | 1,001 - 2,000 µg/kg |
| 10.1 - 100 µg/kg | 2,001 - 5,000 µg/kg |
| 101 - 300 µg/kg | 5,001 - 10,000 µg/kg |
| 301 - 500 µg/kg | 10,001 - 20,000 µg/kg |
| 501 - 1,000 µg/kg | >20,000 µg/kg |

**Figure 7-1**
**USACE 2012 Richmond Inner Harbor Samples**
United Heckathorn Superfund Site
Richmond, California

CH2MHILL

BAO \\ZINFANDEL\PROJ\USENVIRONMENTALPROTE\340138UHFS\GIS\EPA_UNITED_HECKATHORN\MAPFILES\2013\AUGUST\USACE2012INNERHARBORSAMPLES.MXD JCARR3 2/26/2014 2:44:27 PM




**LEGEND**

- LRTC Stormwater Outfalls
- Municipal Stormwater Outfall
- Other Pipe and Seep Locations
- Lauritzen Channel Site Boundary
- 10 Pier Pilings (bent number)
- -10 Former Pier Pilings (bent number)
- Former Buildings
- Dredged
- Partially Dredged
- Not Dredged
- Channel Area
- Embankment Area
- Levin Richmond Terminal Corp Property Line
- Railroad

**Shoreline Material**

- Concrete
- Rock/Rip Rap
- Rock/Rip Rap and Concrete
- Shotcrete
- Sheet Pile
- Sheet Pile and Concrete

N

0 62.5 125 250 Feet

# FIGURE 8-1
# Dredged Areas

UNITED HECKATHORN SUPERFUND SITE
RICHMOND, CALIFORNIA

CH2MHILL

D:\Projects\EPA_UnitedHeckathorn\MapFiles\2013\August\DredgeingMap.mxd

South 4th St
Former Train Scale Area
Former Chemical Storage Area
Former Main Building
Former Electrical Substation A
Former South Building
Former Building #2
Former Building #3
Railroad Hopper
Former Building #4
LRTC Office
Maintenance Building
Bulk Material Handling Yard
Warehouse

**LEGEND**

- LRTC Stormwater Outfalls
- Municipal Stormwater Outfall
- Other Pipe and Seep Locations
- Former Buildings
- Levin Richmond Terminal Corp Property Line
- Railroad
- Concrete
- Rock/Rip Rap
- Rock/Rip Rap and Concrete
- Shotcrete
- Sheet Pile
- Sheet Pile and Concrete

**Bathymetry**

- Bathymetric Contour MLLW Feet (5 foot Interval)
- -1 ft
- -44 ft

**Younger Bay Mud Thickness (ft)**

- 0 - 1.00
- 1.01 - 2.00
- 2.01 - 3.00
- 3.01 - 4.00
- 4.01 - 5.00
- >5

- Benthic Sand Layer Present
- Benthic Sand Layer Absent

**Data Notes:**
Young Bay Mud thicknesses have been corrected for less than 100 percent core recovery.

**Bathymetric Data Source:**
Sea Engineering Inc. (SEI)
January 29, 2013.

Data was collected by SEI in 2012 using a Reson 7125 multibeam echosounder operating at 400 kHz.

N

0 100 200 400 Feet

**FIGURE 8-2**
**Younger Bay Mud Thickness and Evidence of Benthic Sand Layer**
United Heckathorn Superfund Site, Richmond, California

CH2MHILL

Document Path: D:\Projects\EPA_UnitedHeckathorn\MapFiles\2013\August\YBM_BenthicSandLayer.mxd

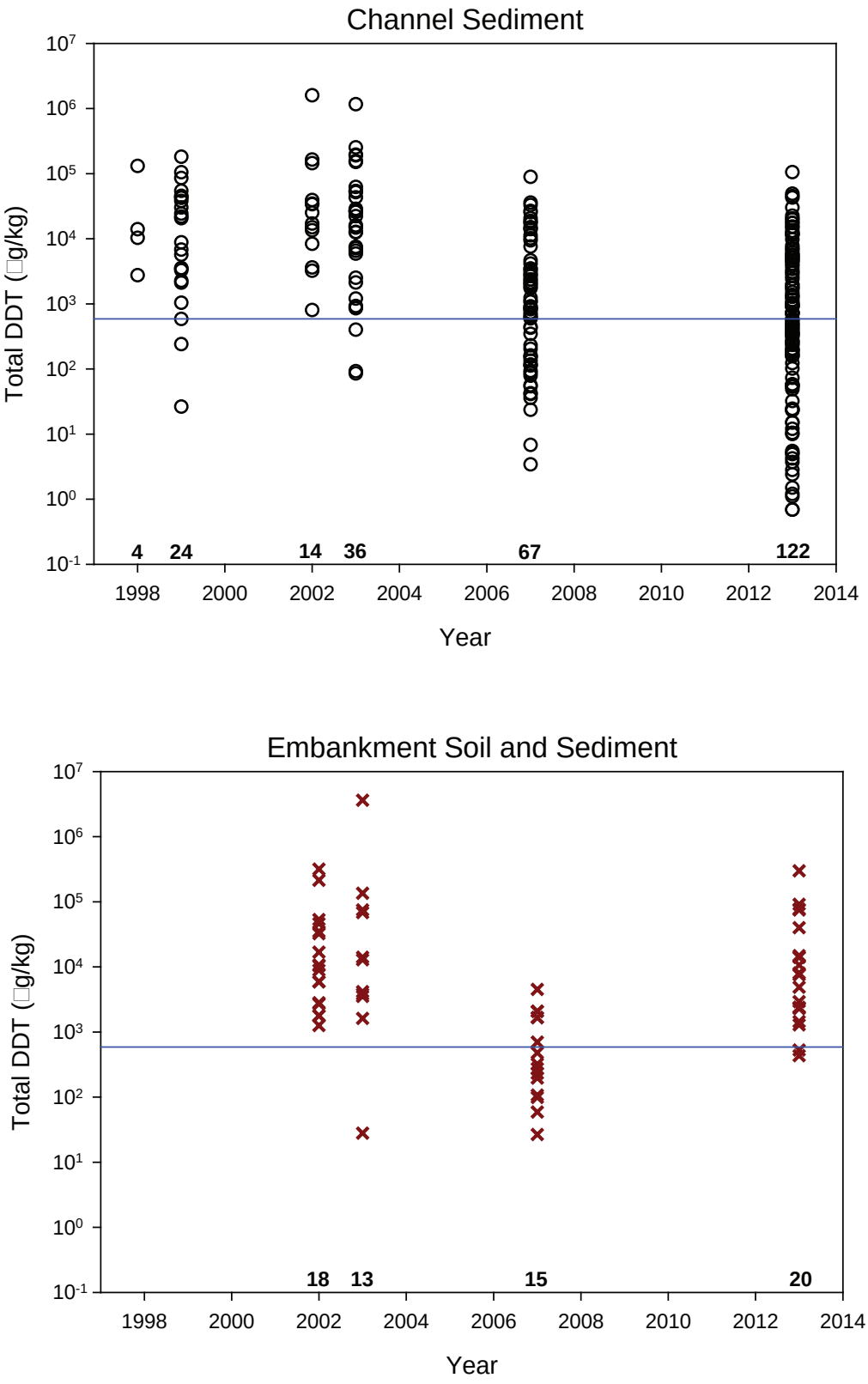
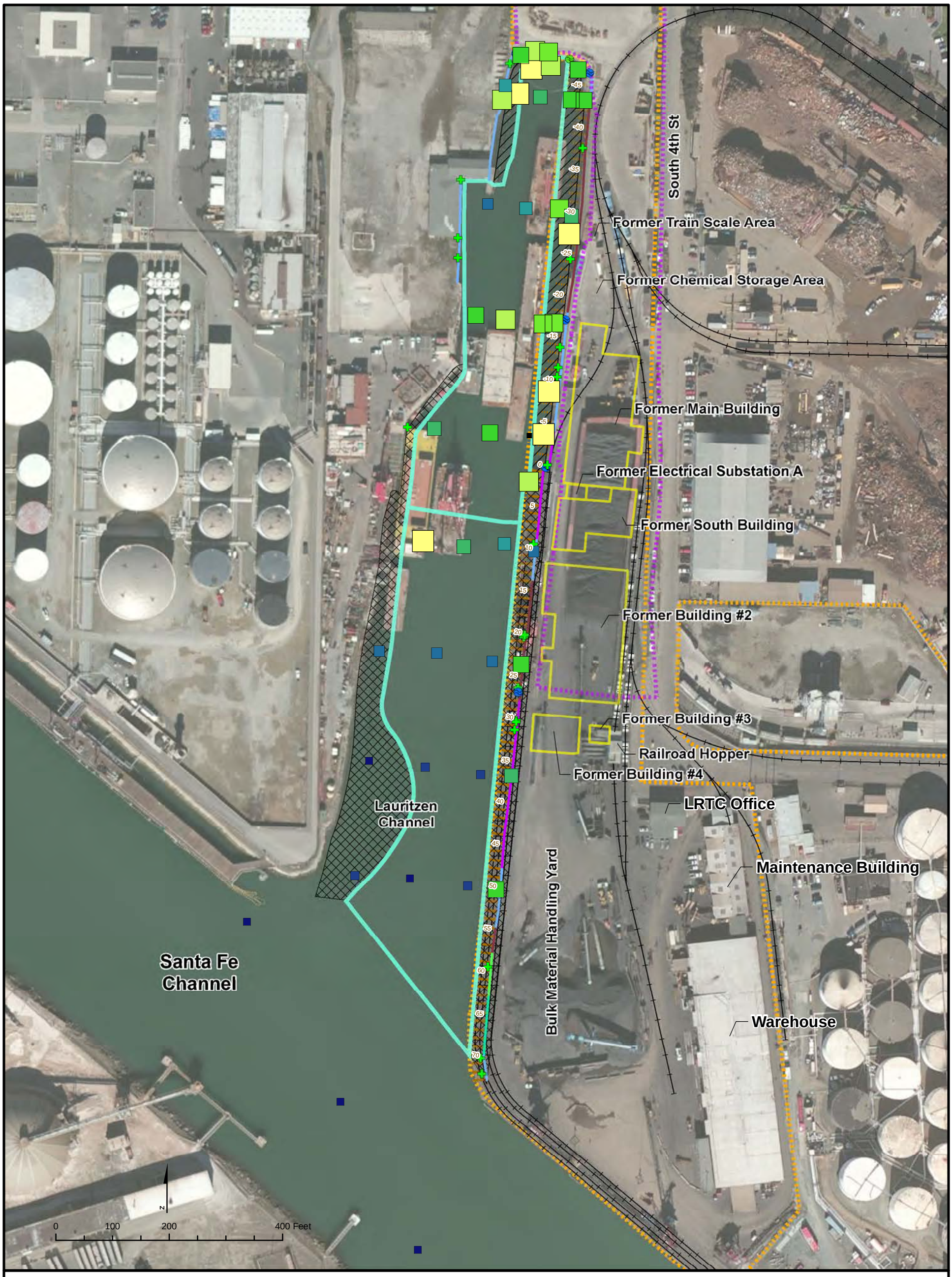



**Figure 8-3**
**Total DDT Concentrations in Channel and Embankment Samples from 1998-2013**
*United Heckathorn Superfund Site, Richmond, California*




**LEGEND**

- LRTC Stormwater Outfalls
- Municipal Stormwater Outfall
- Other Pipe and Seep Locations
- Former Pier Pilings
- Pier Pilings
- Railroad
- Former Buildings
- Dredged Area
- Partially Dredged Area
- Un-Dredged Area
- Concrete
- Rock/Rip Rap
- Rock/Rip Rap and Concrete
- Shotcrete
- Sheet Pile
- Sheet Pile and Concrete

**Sediment Surface Max DDT Results**

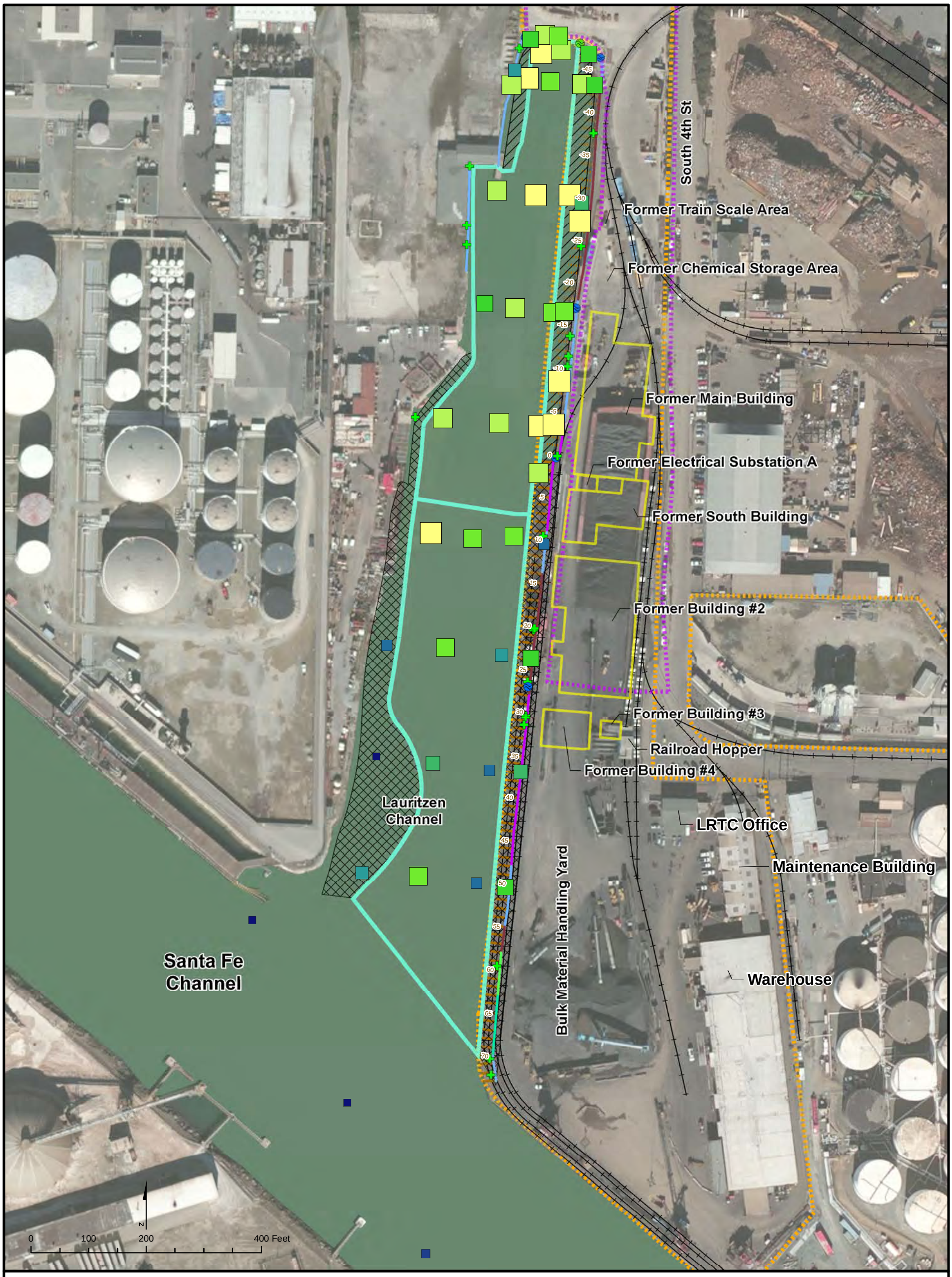
- 0 - 10 µg/kg
- 10.1 - 100 µg/kg
- 101 - 300 µg/kg
- 301 - 500 µg/kg
- 501 - 1,000 µg/kg
- 1,001 - 2,000 µg/kg
- 2,001 - 5,000 µg/kg
- 5,001 - 10,000 µg/kg
- 10,001 - 20,000 µg/kg
- >20,000 µg/kg

**Notes**
bss - below sediment surface
RG - remediation goal
µg/kg - microgram per kilogram

**Figure 8-4**
**Total DDT Concentration in Surface Samples (0 to 0.5 feet bss) from 2013 Sediment Locations**
United Heckathorn Superfund Site, Richmond, California

CH2MHILL

BAO \\ZINFANDEL\PROJ\USENVIRONMENTALPROTE\340138UHFS\GIS\EPA_UNITED_HECKATHORN\MAPFILES\2013\AUGUST\SEDIMENTRESULTS_TOTAL.MXD JCARR3 11/19/2013 2:08:55 PM




**LEGEND**

- LRTC Stormwater Outfalls
- Municipal Stormwater Outfall
- Other Pipe and Seep Locations
- Former Pier Pilings
- Pier Pilings
- Railroad
- Former Buildings
- Dredged Area
- Partially Dredged Area
- Un-Dredged Area
- Concrete
- Rock/Rip Rap
- Rock/Rip Rap and Concrete
- Shotcrete
- Sheet Pile
- Sheet Pile and Concrete

**Sediment Core Max DDT Results**

- 0 - 10 µg/kg
- 10.1 - 100 µg/kg
- 101 - 300 µg/kg
- 301 - 500 µg/kg
- 501 - 1,000 µg/kg
- 1,001 - 2,000 µg/kg
- 2,001 - 5,000 µg/kg
- 5,001 - 10,000 µg/kg
- 10,001 - 20,000 µg/kg
- >20,000 µg/kg

**Notes**
(0) Represents the top depth of the sample interval with the maximum detected DDT concentration at this location

bss - below sediment surface
RG - remediation goal
µg/kg - microgram per kilogram

**Figure 8-5**
**Maximum DDT Concentrations in All Sample Depths (0 to 6 feet bss) from 2013 Sediment Locations**
United Heckathorn Superfund Site
Richmond, California

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# Appendix A
# Hourly Tidal Study Data and Monitoring Well Boring Logs

APPENDIX A

**Hourly Tidal Study Data - March 2013**

*United Heckathorn Superfund Site, Richmond, California*

| | | Elevation - feet NAVD88 | | | |
|---|---|---|---|---|---|
| **Date and Time** | **Lauritzen Channel** | **MW13-01** | **MW13-02** | **MW13-03** | **MW13-04** |
| 3/26/2013 16:00:00 | 1.19 | 3.02 | 3.23 | 2.01 | 3.27 |
| 3/26/2013 17:00:00 | 0.36 | 2.63 | 2.88 | 1.21 | 2.58 |
| 3/26/2013 18:00:00 | -0.13 | 2.38 | 2.62 | 0.72 | 2.11 |
| 3/26/2013 19:00:00 | 0.35 | 2.43 | 2.56 | 1.06 | 2.09 |
| 3/26/2013 20:00:00 | 1.13 | 2.65 | 2.65 | 1.71 | 2.35 |
| 3/26/2013 21:00:00 | 2.64 | 3.20 | 3.05 | 3.00 | 3.13 |
| 3/26/2013 22:00:00 | 3.82 | 3.73 | 3.31 | 4.04 | 3.84 |
| 3/26/2013 23:00:00 | 4.73 | 4.19 | 3.66 | 4.90 | 4.53 |
| 3/27/2013 00:00:00 | 5.29 | 4.52 | 3.93 | 5.45 | 5.02 |
| 3/27/2013 01:00:00 | 5.20 | 4.60 | 4.07 | 5.46 | 5.24 |
| 3/27/2013 02:00:00 | 4.54 | 4.42 | 4.05 | 4.95 | 5.09 |
| 3/27/2013 03:00:00 | 3.15 | 3.93 | 3.80 | 3.80 | 4.49 |
| 3/27/2013 04:00:00 | 1.69 | 3.37 | 3.45 | 2.51 | 3.68 |
| 3/27/2013 05:00:00 | 0.39 | 2.82 | 3.03 | 1.30 | 2.81 |
| 3/27/2013 06:00:00 | -0.17 | 2.49 | 2.73 | 0.73 | 2.22 |
| 3/27/2013 07:00:00 | -0.30 | 2.31 | 2.52 | 0.53 | 1.87 |
| 3/27/2013 08:00:00 | 0.38 | 2.40 | 2.52 | 1.06 | 2.01 |
| 3/27/2013 09:00:00 | 1.45 | 2.71 | 2.71 | 1.96 | 2.49 |
| 3/27/2013 10:00:00 | 2.92 | 3.26 | 3.07 | 3.24 | 3.29 |
| 3/27/2013 11:00:00 | 3.95 | 3.71 | 3.38 | 4.18 | 4.02 |
| 3/27/2013 12:00:00 | 4.71 | 4.11 | 3.69 | 4.91 | 4.62 |
| 3/27/2013 13:00:00 | 4.89 | 4.29 | 3.87 | 5.13 | 4.87 |
| 3/27/2013 14:00:00 | 4.56 | 4.25 | 3.93 | 4.92 | 4.92 |
| 3/27/2013 15:00:00 | 3.58 | 3.95 | 3.81 | 4.12 | 4.55 |
| 3/27/2013 16:00:00 | 2.28 | 3.50 | 3.53 | 3.00 | 3.93 |
| 3/27/2013 17:00:00 | 1.06 | 3.02 | 3.18 | 1.89 | 3.14 |
| 3/27/2013 18:00:00 | 0.44 | 2.72 | 2.89 | 1.28 | 2.59 |
| 3/27/2013 19:00:00 | 0.34 | 2.57 | 2.72 | 1.11 | 2.28 |
| 3/27/2013 20:00:00 | 0.96 | 2.69 | 2.74 | 1.58 | 2.42 |
| 3/27/2013 21:00:00 | 2.14 | 3.07 | 2.96 | 2.57 | 2.93 |
| 3/27/2013 22:00:00 | 3.44 | 3.61 | 3.29 | 3.71 | 3.67 |
| 3/27/2013 23:00:00 | 4.61 | 4.16 | 3.65 | 4.79 | 4.43 |
| 3/28/2013 00:00:00 | 5.33 | 4.56 | 3.95 | 5.48 | 5.04 |
| 3/28/2013 01:00:00 | 5.66 | 4.81 | 4.17 | 5.84 | 5.42 |
| 3/28/2013 02:00:00 | 5.27 | 4.76 | 4.25 | 5.58 | 5.44 |
| 3/28/2013 03:00:00 | 4.15 | 4.39 | 4.10 | 4.67 | 5.04 |
| 3/28/2013 04:00:00 | 2.58 | 3.79 | 3.77 | 3.32 | 4.27 |
| 3/28/2013 05:00:00 | 1.10 | 3.19 | 3.36 | 1.98 | 3.38 |
| 3/28/2013 06:00:00 | -0.07 | 2.68 | 2.94 | 0.88 | 2.53 |
| 3/28/2013 07:00:00 | -0.61 | 2.35 | 2.60 | 0.32 | 1.92 |
| 3/28/2013 08:00:00 | -0.40 | 2.24 | 2.45 | 0.39 | 1.70 |
| 3/28/2013 09:00:00 | 0.32 | 2.36 | 2.50 | 0.97 | 1.91 |
| 3/28/2013 10:00:00 | 1.61 | 2.75 | 2.75 | 2.08 | 2.52 |
| 3/28/2013 11:00:00 | 2.99 | 3.26 | 3.09 | 3.29 | 3.29 |
| 3/28/2013 12:00:00 | 3.99 | 3.71 | 3.43 | 4.22 | 4.00 |
| 3/28/2013 13:00:00 | 4.68 | 4.09 | 3.70 | 4.88 | 4.55 |
| 3/28/2013 14:00:00 | 4.71 | 4.19 | 3.85 | 4.97 | 4.81 |
| 3/28/2013 15:00:00 | 4.33 | 4.16 | 3.88 | 4.70 | 4.78 |
| 3/28/2013 16:00:00 | 3.27 | 3.81 | 3.73 | 3.84 | 4.40 |
| 3/28/2013 17:00:00 | 2.09 | 3.40 | 3.46 | 2.81 | 3.77 |

APPENDIX A

**Hourly Tidal Study Data - March 2013**

*United Heckathorn Superfund Site, Richmond, California*

| | | Elevation - feet NAVD88 | | | |
|---|---|---|---|---|---|
| **Date and Time** | **Lauritzen Channel** | **MW13-01** | **MW13-02** | **MW13-03** | **MW13-04** |
| 3/28/2013 18:00:00 | 1.06 | 3.02 | 3.16 | 1.87 | 3.10 |
| 3/28/2013 19:00:00 | 0.66 | 2.81 | 2.94 | 1.46 | 2.66 |
| 3/28/2013 20:00:00 | 0.86 | 2.79 | 2.86 | 1.55 | 2.55 |
| 3/28/2013 21:00:00 | 1.71 | 3.03 | 2.97 | 2.25 | 2.85 |
| 3/28/2013 22:00:00 | 2.99 | 3.50 | 3.25 | 3.35 | 3.48 |
| 3/28/2013 23:00:00 | 4.27 | 4.05 | 3.59 | 4.50 | 4.34 |
| 3/29/2013 00:00:00 | 5.30 | 4.55 | 3.93 | 5.41 | 4.94 |
| 3/29/2013 01:00:00 | 5.81 | 4.88 | 4.20 | 5.94 | 5.44 |
| 3/29/2013 02:00:00 | 5.85 | 5.01 | 4.37 | 6.05 | 5.69 |
| 3/29/2013 03:00:00 | 5.05 | 4.78 | 4.33 | 5.43 | 5.49 |
| 3/29/2013 04:00:00 | 3.70 | 4.29 | 4.10 | 4.31 | 4.92 |
| 3/29/2013 05:00:00 | 2.11 | 3.66 | 3.73 | 2.91 | 4.07 |
| 3/29/2013 06:00:00 | 0.61 | 3.06 | 3.28 | 1.54 | 3.09 |
| 3/29/2013 07:00:00 | -0.40 | 2.59 | 2.92 | 0.58 | 2.28 |
| 3/29/2013 08:00:00 | -0.86 | 2.25 | 2.51 | 0.07 | 1.71 |
| 3/29/2013 09:00:00 | -0.59 | 2.16 | 2.39 | 0.24 | 1.60 |
| 3/29/2013 10:00:00 | 0.32 | 2.30 | 2.48 | 0.96 | 1.87 |
| 3/29/2013 11:00:00 | 1.64 | 2.69 | 2.74 | 2.10 | 2.52 |
| 3/29/2013 12:00:00 | 2.98 | 3.19 | 3.06 | 3.28 | 3.28 |
| 3/29/2013 13:00:00 | 3.90 | 3.62 | 3.36 | 4.11 | 3.89 |
| 3/29/2013 14:00:00 | 4.43 | 3.94 | 3.63 | 4.66 | 4.44 |
| Minimum | -0.86 | 2.16 | 2.39 | 0.07 | 1.60 |
| Maximum | 5.85 | 5.01 | 4.37 | 6.05 | 5.69 |

**Notes:**

NAVD88 - North American Vertical Datum - 1988

CH2MHILL

| PROJECT NUMBER: | BORING NUMBER: | |
|---|---|---|
| 385441.FI.01 | MW13-01 | SHEET 1 OF 1 |

# SOIL BORING LOG

PROJECT : March 2013 Groundwater Sampling and Hydraulic Evaluation LOCATION : United Heckathorn Superfund Site, Richmond, CA

ELEVATION : -- DRILLING CONTRACTOR : National Exploration, Wells and Pumps, Inc.

DRILLING EQUIPMENT AND METHOD : Geoprobe 7700, Direct Push - Dual Probe

WATER LEVELS : -- START : 3/19/2013 END : 3/19/2013 LOGGER : R. Lucich/J. Salinas

| DEPTH BELOW EXISTING GRADE (ft) | INTERVAL (ft) | RECOVERY (%) | LAB SAMPLE | USCS CODE/ LITHOLOGY | SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | WELL CONSTRUCTION DIAGRAM: WELL DIAMETER: 2" SCREENED INTERVAL: 20' - 30' BGS |
|---|---|---|---|---|---|---|
| | | | | | **Concrete** 0 - 8" | |
| | | | | SW | **Gravelly Sand (SW)** 8" - 7.5' - dark grayish brown, moist, loose, medium to coarse grained, subrounded, gravel is fine to coarse grained | |
| 5 | 5.0 | 50% | | | | |
| | | | | CL | **Clay (CL)** 7.5' - 9.5' - greenish gray, slightly moist, medium plasticity, medium hard | |
| 10 | 10.0 | 95% | | CH | **Clay (CH)** 9.5' - 15' - greenish black, moist, medium plasticity, slightly stiff | |
| 15 | 15.0 | 100% | | CL | **Clay (CL)** 15' - 22' - dark greenish gray, slightly moist, medium plasticity, stiff<br>17" - Color change to olive brown (2.5Y 4/3) | |
| 20 | 20.0 | 95% | | ML | **Clayey Silt (ML)** 22' - 23' - olive brown, moist, stiff | |
| | | | | CL | **Clay (CL)** 23' - 29' - olive brown, moist, very stiff | |
| 25 | 25.0 | 100% | | | 27' - 28' - wet | |
| 30 | 30.0 | | | SM | **Silty Sand (SM)** 29' - 30' - olive brown, moist, very fine grained, slightly dense<br>End Drilling on 3/19/2013<br>Total Borehole Depth: 30.0 ft bgs | |
| 35 | | | | | | |

CH2MHILL

| PROJECT NUMBER: | BORING NUMBER: | |
|---|---|---|
| 385441.FI.01 | MW13-02 | SHEET 1 OF 1 |

# SOIL BORING LOG

PROJECT : March 2013 Groundwater Sampling and Hydraulic Evaluation LOCATION : United Heckathorn Superfund Site, Richmond, CA

ELEVATION : -- DRILLING CONTRACTOR : National Exploration, Wells and Pumps, Inc.

DRILLING EQUIPMENT AND METHOD : Geoprobe 7700, Direct Push - Dual Probe

WATER LEVELS : -- START : 3/19/2013 END : 3/19/2013 LOGGER : R. Lucich/J. Salinas

| DEPTH BELOW EXISTING GRADE (ft) | INTERVAL (ft) | RECOVERY (%) | LAB SAMPLE | USCS CODE/ LITHOLOGY | SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | WELL CONSTRUCTION DIAGRAM: WELL DIAMETER: 2" SCREENED INTERVAL: 14.5' - 24.5' BGS |
|---|---|---|---|---|---|---|
| | | | | | **Concrete**<br>0 - 8" | |
| | | | | GW | **Sandy Gravel (GW)**<br>8" - 5" - yellowish brown, dry, loose, fine to coarse sand and gravel, subangular | |
| 5 | 5.0 | | | | | |
| | | 10% | | | 5' - 10' - No recovery | |
| 10 | 10.0 | | | | | |
| | | 100% | | CL | **Silty Clay (CL)**<br>10' - 14' - gray, moist to very moist, medium stiff | |
| | | | | CH | **Peaty Clay (CH)**<br>14' - 15' - dark grayish brown, very moist, slightly stiff, medium plasticity | |
| 15 | 15.0 | | | CL | 14.5' - Change to very dark gray (10YR 3/1), moist, medium plasticity, slightly stiff | |
| | | 100% | | ML | **Clay (CL)**<br>15' - 17' - dark greenish gray, moist, slightly stiff, medium plasticity | |
| 20 | 20.0 | | | | **Clayey Silt (ML)**<br>17' - 21' - dark greenish gray, very moist, slightly stiff<br>20' - Becomes brown | |
| | | 80% | | SM | **Silty Sand (SM)**<br>21' - 23.5' - grayish brown, wet, slightly dense, fine grained<br>22' - Becomes yellowish brown | |
| 25 | 25.0 | | | SM | **Silty Sand (SM)**<br>23.5' - 25' - brown, wet, slightly dense, fine to coarse grained, subangular to subrounded, with minor fine subangular gravel | |
| | | | | | End Drilling on 3/19/2013<br>Total Borehole Depth: 25.0 ft bgs | |
| 30 | | | | | | |
| 35 | | | | | | |

CH2MHILL

| PROJECT NUMBER: | BORING NUMBER: | |
|---|---|---|
| 385441.FI.01 | MW13-03 | SHEET 1 OF 1 |

# SOIL BORING LOG

PROJECT : March 2013 Groundwater Sampling and Hydraulic Evaluation LOCATION : United Heckathorn Superfund Site, Richmond, CA

ELEVATION : -- DRILLING CONTRACTOR : National Exploration, Wells and Pumps, Inc.

DRILLING EQUIPMENT AND METHOD : Geoprobe 7700, Direct Push - Dual Probe

WATER LEVELS : -- START : 3/20/2013 END : 3/20/2013 LOGGER : J. Salinas

| DEPTH BELOW EXISTING GRADE (ft) | INTERVAL (ft) | RECOVERY (%) | LAB SAMPLE | USCS CODE/ LITHOLOGY | SOIL DESCRIPTION<br>SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | WELL CONSTRUCTION DIAGRAM<br>WELL DIAMETER: 2"<br>SCREENED INTERVAL: 18' - 33' BGS |
|---|---|---|---|---|---|---|
| | | | | | **CONCRETE** | |
| | | | | GW | **Sandy Gravel (GW)**<br>8" - 5' - moist, loose, subangular clasts, fine to coarse sand and gravel | |
| 5 | 5.0 | | | | | |
| | | | | CL | **Clay (CL)**<br>5' - 7' - dark gray, moist, soft, medium plasticity | |
| | | 50% | | GW | **Gravel (GW)**<br>7' - 7.5' - very dark gray, loose, subangular, subangular clasts, some red clasts | |
| | | | | GW | **Sandy Gravel (GW)**<br>7.5' - 11.5' - grayish brown, moist, loose | |
| 10 | 10.0 | | | | | |
| | | 75% | | CL | **Clay (CL)**<br>11.5' - 16' - greenish black, moist, medium stiff, medium plasticity<br>14.5' - some rusting | |
| 15 | 15.0 | | | | | |
| | | 100% | | ML | **Clayey Silt (ML)**<br>16' - 23' - dark greenish gray, moist, medium stiff, medium plasticity<br>18' - subangular, Color change to light olive brown (2.5Y 5/4) | |
| 20 | 20.0 | | | | | |
| | | 100% | | GW | **Sandy Gravel (GW)**<br>23' - 25.5' - light olive brown, wet, loose, fine to coarse grained sand and gravel | |
| 25 | 25.0 | | | | | |
| | | 100% | | CL | **Clay (CL)**<br>25.5' - 27' - dark greenish gray, wet, soft, medium plasticity, subangular, some subangular clasts | |
| | | | | SW | | |
| | | | | GW | **Sand (SW)**<br>27' - 27.5' - olive brown, wet, loose, subangular, fine to coarse grained | |
| 30 | 30.0 | | | | **Gravel (GW)**<br>27.5' - 29.5' - olive brown, wet, loose, subangular | |
| | | | | SW | **Sand (SW)**<br>29.5' - 33' - olive brown, wet, loose, fine to coarse grained | |
| 35 | | | | | End Drilling on 3/20/2013<br>Total Borehole Depth: 33.0 ft bgs | |

CH2MHILL

| PROJECT NUMBER: | BORING NUMBER: | |
|---|---|---|
| 385441.FI.01 | MW13-04 | SHEET 1 OF 1 |

# SOIL BORING LOG

PROJECT : March 2013 Groundwater Sampling and Hydraulic Evaluation LOCATION : United Heckathorn Superfund Site, Richmond, CA

ELEVATION : -- DRILLING CONTRACTOR : National Exploration, Wells and Pumps, Inc.

DRILLING EQUIPMENT AND METHOD : Geoprobe 7700, Direct Push - Dual Probe

WATER LEVELS : -- START : 3/22/2013 END : 3/22/2013 LOGGER : R. Lucich

| DEPTH BELOW EXISTING GRADE (ft) | INTERVAL (ft) / RECOVERY (%) / LAB SAMPLE | USCS CODE/ LITHOLOGY | SOIL DESCRIPTION<br>SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | WELL CONSTRUCTION DIAGRAM<br>WELL DIAMETER: 2"<br>SCREENED INTERVAL: 20' - 30' BGS |
|---|---|---|---|---|
| | | | **Concrete**<br>0-8" | |
| | | SW | **Gravelly Sand (SW)**<br>8" - 6' - reddish brown, dry, loose, medium to coarse grained and subrounded gravel, fine to coarse grained, subrounded sand | |
| 5 | | ML | **Sandy Silt (ML)**<br>6' - 7' - gray, moist, soft | |
| | | SM | **Silty Sand (SM)**<br>7' - 8.5' - gray, wet, loose, very fine grained | |
| | | ML | **Sandy Silt (ML)**<br>8.5' - 9' - gray, moist, soft | |
| 10 | | SM | **Silty Sand (SM)**<br>9' - 12' - gray, wet, loose, very fine grained | |
| | | ML | **Sandy Silt (ML)**<br>12' - 13.5' - gray, moist, soft | |
| | | CH | **Peaty Clay (CH)**<br>13.5' -15' - very dark gray, moist, stiff, low plasticity | |
| 15 | | CL | **Silty Clay (CL)**<br>15' - 17' - greenish gray, moist, slightly stiff, medium plasticity | |
| | | SM | **Silty Sand (SM)**<br>17' - 20' - gray, very moist, slightly dense, very fine grained<br><br>19.5' - Becomes light olive brown (2.5Y 4/3) | |
| 20 | | ML | **Sandy Silt (ML)**<br>20' - 25' - olive brown, very moist, slightly stiff, medium plasticity | |
| 25 | | SM | **Silty Sand (SM)**<br>25' -30' - olive brown, wet, subrounded, slightly dense, very fine grained | |
| 30 | | | End Drilling on 3/22/2013<br>Total Borehole Depth: 30.0 ft bgs | |
| 35 | | | | |

# Appendix C
# 2012 and 2013 Field Summary Technical Memoranda

**Appendix C Table of Contents**

C-1 Summary of Field Activities to Support Phase 4 Source Identification Study United Heckathorn Superfund Site, Richmond, California

C-2 Summary of Field Activities to Support the Source Identification Study, Sediment Grab Sampling and Bent Number 37 Seep Water Sampling United Heckathorn Superfund Site, Richmond, California

C-3 Summary of Field Activities to Support the Source Identification Study United Heckathorn Superfund Site, Richmond, California

C-4 2013 Groundwater Sampling and Hydrogeologic Investigation: Summary of Field Activities to Support Source Identification Study United Heckathorn Superfund Site, Richmond, California

C-5 Summary of Field Activities Tier 1 Sediment Transport Study United Heckathorn Superfund Site, Richmond, California

# Summary of Field Activities to Support Phase 4 Source Identification Study United Heckathorn Superfund Site, Richmond, California

PREPARED FOR: United States Environmental Protection Agency
Region 9

PREPARED BY: CH2M HILL

DATE: January 03, 2012

PROJECT NUMBER: USEPA CONTRACT NO. EP-S9-08-04
USEPA WORK ASSIGNMENT NO. 025-RIFS-09R3
CH2M HILL PROJECT NO. 385441

## Background

Previous Phase I and Phase II source investigations (Kohn and Evans, 2002 and 2004) were performed at the United Heckathorn Superfund Site in Richmond, California to locate potential point sources of contamination along the eastern bank of the Lauritzen Channel. Table 1, which is discussed further below, summarizes the potential point sources associated with outfalls that were identified in the previous studies. The locations of these outfalls and other major structures have been incorporated into the project's geographic information system (GIS); however, field verification of the features was necessary to generate a current site features map in accordance with the *Preliminary Draft Focused Feasibility Study Data Gaps Sampling and Analysis Plan Addendum #2 Source Identification Study* (SAP) (CH2M HILL, 2012). This technical memorandum summarizes the results of the site survey performed in late 2012 to support the Phase 4 source identification study.

## Site Survey Activities

Site survey activities were performed during the spring low tide (approximately -0.6 feet mean lower low water) on November 29 and December 10, 2012. The site survey activities consisted of touring the eastern side of the Lauritzen Channel by boat and foot to locate potential point sources of contamination including outfall pipes, breaks in the sheet pile walls, and other features that could potentially act as preferential pathways for contaminant transport into the channel.

On November 29, 2012, the eastern side of the Lauritzen Channel (between bent numbers -1 and -45) and the head of the channel (between SW-7 and SW-6) were surveyed by foot (Figure 1). On December 10, 2012, the eastern side of the Lauritzen

Channel (underneath the Levin Pier, between bent numbers +1 and +73), the head of the channel (between SW-7 and SW-6), and a portion of the western side of the Lauritzen Channel (west of bent numbers -1 through -19) were surveyed by boat. A representative from the Richmond Levin Terminal escorted CH2M HILL on the Levin boat. A map with the locations of previously documented outfall pipes/structures, as well as a hand-held global positioning system (GPS) unit with pre-loaded GIS information for these features, were used to verify the locations of previously-documented structures. Labels for the previously-documented structures contain a prefix of P1 indicating they were documented during the Phase 1 source investigation. The prefix P4 indicates pipes that were identified on a storm drain figure from the City of Richmond obtained after the Phase 1 source investigation, one structure (P4-3) that was discussed in the Phase 1 source investigation but not located in the field, and all new structures identified during the current field activities on November 29 and December 10, 2012. Locations of new features that were not previously documented were recorded using the GPS unit. Observed features were also photographed and/or videotaped.

# Findings

The key findings of the Phase 4 source identification study are listed below. Table 1 summarizes the potential point sources documented during previous investigations and new information obtained during this Phase 4 source identification study. Figure 1 presents the location of the outfall pipes and other shoreline features. Attachment 1 contains photographs of the observed features.

- All previously documented pipes were located with the exception of PC1-1, P4-1, P4-3, and P1-4. Outfall PC1-1 is located in the Parr Canal, which was not surveyed as part of the Phase 4 source investigation study. Pipe P4-1, located on the western side of the channel, was not accessible by boat due to a barge stationed in the channel. Pipes P1-4 and P4-3 were not located by boat or by foot and are assumed to no longer be present.

- Additional outfall pipes identified in this survey include five storm water interceptor pipes (SW-3 through SW-7) installed during the final remedy for the upland portion of the former United Heckathorn site completed in 1998 (PES, 1998) on the eastern side and head of the channel, four pipes along the western side of the channel (P4-4 through P4-7), and eight new pipes (P4-8 through P4-15) along the eastern side of the channel underneath the Levin Pier. Additionally, two electrical conduits were observed on the eastern side of the channel beneath the Levin Pier.

- The eastern shoreline material consists of sheet pile (steel plates supported by railroad ties), concrete, rip rap, and/or shotcrete, as shown in Figure 1. The majority of the western side of the channel (west of bent numbers -1 through -19) consisted of rock/rip rap.

- Erosion under the sheet pile wall (~1-2 foot voids) was observed at the northern end of the eastern side of the channel, beginning around outfall pipe location P4-3 and extending north to the head of the channel (see Photograph 12 in Attachment 1).

- Sink holes and exposed cap material were observed on the Levin property in the vicinity of P1-4 and P1-3 (see Photographs 25 and 26 in Attachment 1).

In addition to the site surveys described above, observations of the eastern and western shoreline of the Lauritzen Channel were recorded during bathymetric survey activities on December 4, 2012. Noticeable outfall pipes, culverts, and other features that appeared to drain into the channel were photographed from the survey vessel. These photographs will be further evaluated and geo-referenced as part of the Source Identification Study Technical Memorandum to be submitted separately.

# References


CH2M HILL. 2012. *Preliminary Draft. Focused Feasibility Study Data Gaps Sampling and Analysis Plan Addendum #2, Source Identification, Study United Heckathorn Superfund Site, Richmond, California.* November.

Kohn and Evans. 2002. *Phase I Source Investigation at the United Heckathorn Superfund Site, Richmond, California*. PNNL-14088. December.

Kohn and Evans. 2004. *Year 6 Post-Remediation Biomonitoring and Phase II Source Investigation at the United Heckathorn Superfund Site, Richmond, California*. PNNL-14596. March.

PES Environmental, Inc. 1998. *Pre-Final/Final Design and Remedial Action Work Plan Upland Capping Project, Richmond, California*. April.

# Figure 1

SW-7
Lauritizen Outfall (LCI-1)
P4-4
SW-6
P4-3
P4-5
P4-6
P1-1
P1-2
P4-7
P1-3
SW-5
P4-13
P4-14
P4-15
P1-4
Former
Main Building
P4-1
P4-8
SW-4
Electrical Substation "A"
Former South Building
P4-2
P4-9
P1-5
P4-10
SW-3
Conduit-1
Conduit-2
P1-6
Lauritzen
Channel
P1-7
P4-11
P4-12

## LEGEND

- Outfall Locations
- Outfall Locations not verified in field.
- Pier
- 10 Pier Pilings
- -10 Former Pier Pilings
- Bent Number

**Shoreline Material**

- Concrete
- Rock/Rip Rap
- Rock/Rip Rap and Concrete
- Shotcrete
- Sheet Pile
- Sheet Pile and Concrete

- Former United Heckathorn Buildings
- Property Line

N

0 62.5 125 250 Feet

**Note:**
Positive bent numbers are associated with existing rows of pier pilings.
Negative bent numbers are associated with historical pier pilings.

# FIGURE 1
# SUMMARY OF FIELD ACTIVITIES TO SUPPORT PHASE 4 SOURCE IDENTIFICATION STUDY

UNITED HECKATHORN SUPERFUND SITE
RICHMOND, CALIFORNIA

CH2MHILL

Document Path: D:\Projects\EPA_UnitedHeckathorn\MapFiles\2012\Field\SiteFeatures_FieldMapV2.mxd Date Saved: 1/3/2013 5:12:39 PM

# Table 1

TABLE 1
**Potential Point Sources of Contamination to the Lauritzen Channel**
*United Heckathorn Superfund Site Source Identification Technical Memorandum*

| Point Source Identifier[1] | Description [2] | Phase 1 Identifier Transect [3] | Phase 1 Comments | Phase 4 Identifier Bent Number[4] | Phase 4 Comments |
|---|---|---|---|---|---|
| **Pipes Documented Prior to the Phase I Source Investigation** | | | | | |
| LCI-1 | Concrete municipal outfall at north end of Lauritzen Channel<br>Flap gate installed on outfall in October 2012. | -47 | Some water flow observed | Head of channel | Lauritzen Outfall was located and flap gate observed. See Photograph 15 in Attachment 1. |
| PCI-1 | Concrete municipal outfall at north end of Parr Canal.<br>Flap gate installed on outfall prior to site visit on January 25, 2011. | | N/A | | Pipe was not verified because Parr Canal was not inspected as part of the site survey. |
| P1-1 | 8-in. metal outfall through retaining wall about 2 ft above sediment | -27.5 | Some water dripping observed (pipe is submerged at high tide). | | Pipe was located. Tidal drainage was observed dripping from pipe. |
| P1-2 | 5.5-in. metal pipe through retaining wall about 5 ft above present sediment surface, same location as 8-in. pipe above | -27.5 | No sediment in pipe, no water flow, not sampled. | | Pipe was located. |
| P1-3 | L-shaped pipe | -24.5 | Valve closed; not sampled. | | Angled metal pipe was located. Appears to be an abandoned fire main. See Photograph 21 in Attachment 1. |
| P4-3 | Described in Phase I as a screened pipe end in riprap near north end of sheetpile wall | | Not found during Phase I field survey | | Pipe was not located. |

TABLE 1
**Potential Point Sources of Contamination to the Lauritzen Channel**
*United Heckathorn Superfund Site Source Identification Technical Memorandum*

| Point Source Identifier[1] | Description [2] | Phase 1 Identifier Transect [3] | Phase 1 Comments | Phase 4 Identifier Bent Number[4] | Phase 4 Comments |
|---|---|---|---|---|---|
| P4-1 | Pipe discharging to west side of channel, identified on City of Richmond drainage map. | | Not found during Phase I field survey | | Pipe was not verified because this portion of the Lauritzen Channel was inaccessible by boat due to barge stationed in the channel. |
| P4-2 | 21-inch pipe discharging beneath Levin Pier, identified on City of Richmond drainage map. | | Pipe this size not found at expected location during Phase I field survey, but several smaller previously undocumented pipes were found beneath pier. | +9.5 | 2-inch diameter corroded metal pipe was located. See Photograph 3 in Attachment 1. |
| **Pipes identified in Phase I Source Investigation** | | | | | |
| P1-4 | Concrete pipe at bottom of riprap. Described as the "seep" in Phase 2. Grouted on July 18, 2003 by EPA. | -8.5 | Some flow observed. Pipe is difficult to see as it blends in with cobbles and rip rap. | | Pipe was not located. |
| P1-5 | Corroded metal pipe identified during February 6, 2002 deployment, under Levin Pier. | +20 | Appears valved off, end very corroded. | +20.5 | 10-inch diameter corroded metal pipe located. See Photograph 5 in Attachment 1. |
| P1-6 | 6-inch diameter pipe, under Levin Pier. | +31.5 | Appears to discharge occasionally. | +31.5 | Corroded metal pipe was located. See Photograph 8 in Attachment 1. |
| P1-7 | 8-inch diameter pipe, under Levin Pier. | +59.5 | Appears valved off, old, unused; not sampled or photographed. | +59.5 | 12-inch diameter pipe located. Appears to be an abandoned fire main. See Photograph 11 in Attachment 1. |
| **Pipes identified in Phase 4 Source Investigation** | | | | | |
| SW-3 | NA | NA | NA | +27 | 18-inch diameter HDPE storm water interceptor pipe. Filter cloth is loosely hanging from pipe. |

TABLE 1
**Potential Point Sources of Contamination to the Lauritzen Channel**
*United Heckathorn Superfund Site Source Identification Technical Memorandum*

| Point Source Identifier[1] | Description [2] | Phase 1 Identifier Transect [3] | Phase 1 Comments | Phase 4 Identifier Bent Number[4] | Phase 4 Comments |
|---|---|---|---|---|---|
| | | | | | See Photograph 6 in Attachment 1. |
| SW-4 | NA | NA | NA | 0 | 18-inch diameter HDPE storm water interceptor pipe. Contains 8 inch diameter valve and filter cloth intact. Water was flowing from pipe. |
| SW-5 | NA | NA | NA | -17 | 18-inch diameter HDPE storm water interceptor pipe. Contains 8 inch diameter valve and filter cloth intact. See Photograph 20 in Attachment 1. |
| SW-6 | NA | NA | NA | Head of channel, east of LC1-1 | 18-inch diameter HDPE storm water interceptor pipe. Contains 8 inch diameter valve and filter cloth intact. See Photograph 14 in Attachment 1. |
| SW-7 | NA | NA | NA | Head of channel, west of LC1-1 | 15-inch diameter HDPE storm water interceptor pipe. Appears to be valved closed. See Photograph 16 in Attachment 1. |
| P4-4 | NA | NA | NA | Head of channel, west of SW-7 | 10-inch diameter metal pipe. See Photo See Photograph 17 in Attachment 1. |
| P4-5 | NA | NA | NA | western side channel across from -33 | 4-inch diameter metal pipe. See Photograph 18 in Attachment 1. |
| P4-6 | NA | NA | NA | western side channel | 2 to4-inch diameter metal pipe. |

TABLE 1
**Potential Point Sources of Contamination to the Lauritzen Channel**
*United Heckathorn Superfund Site Source Identification Technical Memorandum*

| Point Source Identifier[1] | Description [2] | Phase 1 Identifier Transect [3] | Phase 1 Comments | Phase 4 Identifier Bent Number[4] | Phase 4 Comments |
|---|---|---|---|---|---|
| | | | | across from -26 | |
| P4-7 | NA | NA | NA | western side channel across from -24 | 4-inch diameter metal pipe. |
| P4-8 | NA | NA | NA | 0 | 8-inch diameter corroded metal pipe located at bottom of rip rap. See Photograph 19 in Attachment 1. |
| P4-9 | NA | NA | NA | +20.5 | 9-inch diameter corroded metal U-shaped pipe. Appears to be abandoned fire main. See Photograph 4 in Attachment 1. |
| P4-10 | NA | NA | NA | +26.5 | 4-inch diameter corroded metal pipe. See Photograph 7 in Attachment 1. |
| P4-11 | NA | NA | NA | +70.5 | 18-inch diameter metal pipe cemented shut. |
| P4-12 | NA | NA | NA | +72 | 6-inch diameter metal pipe. |
| P4-13 | NA | NA | NA | -14 | 2-inch diameter corroded metal pipe. See Photograph 22 in Attachment 1. |
| P4-14 | NA | NA | NA | -11.5 | 2-inch diameter corroded metal pipe. See Photograph 23 in Attachment 1. |
| P4-15 | NA | NA | NA | -10.5 | 2-inch diameter long metal pipe. See Photograph 24 in Attachment 1. |
| Conduits 1 and 2 | NA | NA | NA | +30.5 | 2 metal conduits. See Photograph 9 in Attachment 1. |

**NOTES:**

NA=Not applicable

[1] Point source identifiers have been assigned for this study. Labels containing a prefix of P1 refer to pipes that were identified in the field during the Phase I Source Investigation (Kohn and Evans, 2002). The prefix P4 refers to pipes that were identified on a storm drain figure from the City of Richmond obtained after the Phase I Source Investigation, one structure P4-3 that was discussed in the Phase I Source Investigation but was not located in the field, and all new structures identified during field activities on 11/29/12 and 12/10/12.

[2] Descriptions from Table 3.1 of the Phase I Source Investigation (Kohn and Evans, 2002).

[3] A transect naming system and navigational baseline were established using the numbers assigned to rows of pier pilings (also known as bent numbers) supporting the Levin pier. Each row of pilings was assigned a whole number starting with +1 at the north end of the pier. The transect numbering system for the rows of pier pilings is presented as Attachment B of the SAP (CH2M HILL, 2012). Transect numbers fall between whole number pier pilings (e.g., +17.5 falls between +17 and +18).

[4] Positive bent numbers are associated with existing rows of pier pilings. Negative bent numbers are associated with historical pier pilings. Bent numbers are spaced approximately 15 feet apart.

# Attachment 1
# Photograph Log

Photograph 1: View of rock/rip rap under Levin Pier.

Photograph 2: View of sheet pile (steel plates supported by railroad ties) and rock/rip rap under Levin pier

Photograph 3: View of 2-inch diameter corroded metal pipe at Bent +9.5. Apppears to be pipe P4-2.

Photograph 4: View of 9-inch diameter corroded metal U-shaped pipe at Bent +20.5 (pipe P4-9). Appears to be abandoned fire main.

Photograph 5: View of 10-inch diameter corroded metal pipe at Bent +20.5. Appears to be pipe P1-5.

Photograph 6: View of 18-inch diameter HDPE pipe SW-3 at Bent +27. Filter cloth loosely hanging.

Photograph 7: 4-inch diameter corroded metal pipe at Bent +26.5 (Pipe P4-10).

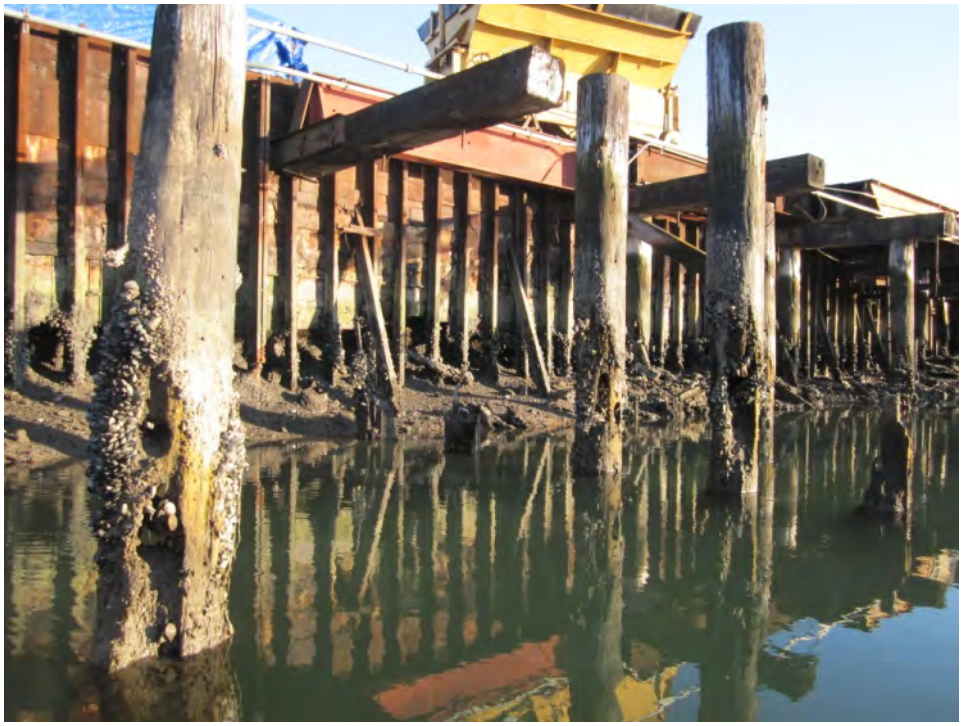
Photograph 8: 6-inch diameter corroded metal pipe (P1-6) and Shotcrete at Bent +31.5.

Photograph 9: Two 2-inch diameter metal conduits at Bent +30.5.

Photograph 10: Shotcrete between Bents +28 and +48.

Photograph 11: 12-inch diameter pipe (P1-7) at Bent +59.5. Appears to be an abandoned fire main.

Photograph 12: Erosion under sheet pile at abandoned pier near Bent -40 (~1-2 foot voids).



Photograph 13: Abandoned pier northern end/eastern side of Lauritzen Channel

Photograph 14: 18-inch diameter storm water interceptor pipe SW-6 with 8-inch valve and filter cloth at head/eastern side of Lauritzen Channel.

Photograph 15: Lauritzen Channel Outfall (LCI-1) at head of Lauritzen Channel.

Photograph 16: 15-inch diameter storm water interceptor pipe SW-7 at head/western side of Lauritzen Channel.

Photograph 17: 10-inch diameter metal pipe (P4-4) at head/western side of Lauritzen Channel.

Photograph 18: 2 to 4-inch diameter metal pipe (P4-5), western side of Lauritzen Channel across from Bent -33.

Photograph 19: 8-inch diameter corroded metal pipe (P4-8) beneath storm water interceptor pipe SW-4 at Bent 0.

Photograph 20: 18-inch diameter storm water interceptor pipe (SW-5) with 8-inch diameter valve and filter cloth at Bent -17.

Photograph 21: Angled metal pipe located at Bent -24.5. Appears to be pipe P1-3, an abandoned fire main.

Photograph 22: 2-inch diameter corroded metal pipe (P4-13) located at Bent -14.

Photograph 23: 2-inch diameter corroded metal pipe (P4-14) located at Bent -11.5.

Photograph 24: 2-inch diameter corroded metal pipe (P4-15) located at Bent -10.5

Photograph 25: Sink hole showing exposed cap material.

Photograph 26: Exposed cap material.

# Summary of Field Activities to Support the Source Identification Study, Sediment Grab Sampling and Bent Number 37 Seep Water Sampling United Heckathorn Superfund Site, Richmond, California

| | |
|---|---|
| PREPARED FOR: | United States Environmental Protection Agency<br>Region 9 |
| PREPARED BY: | CH2M HILL |
| DATE: | August 14, 2013 |
| PROJECT NUMBER: | USEPA CONTRACT NO. EP-S9-08-04<br>USEPA WORK ASSIGNMENT NO. 025-RIFS-09R3<br>CH2M HILL PROJECT NO. 385441 |

## Background

Surface sediment grab samples were collected as part of the sediment sampling activities described in the Final Focused Feasibility Study Data Gaps Sampling and Analysis Plan Addendum #2, Source Identification Study, United Heckathorn Superfund Site (SAP) (CH2M HILL, 2013). Sediment sampling activities included collection of sediment grab samples from 14 locations (discussed in this technical memorandum) and core samples from 27 locations (discussed in the vibracoring field summary technical memorandum). Sediment samples were analyzed to identify the source(s) of dichlorodiphenyl-trichloroethane (DDT)[1] This technical memorandum summarizes the grab sediment sampling activities performed on March 13 and April 29, 2013. Additionally, a new seep at bent number 37[2] was identified during surface sediment sampling. The collection of one water sample from this location is summarized at the end of this technical memorandum. The analytical results for the sediment grab samples and seep water sample will be presented and evaluated in the Source Identification Study report.

Nine unbiased sediment grab samples (with locations identified using a modified grid system) were collected along the northern and eastern sides of the Lauritzen Channel (Figure 1). Three biased grab samples were collected near the 8-inch pipe at bent number -27.5, the former seep pipe at bent number -8.5, and the hot spot identified under the north end of the Levin pier in the Phase I Source Identification Study (Kohn and Evans, 2002).

[1] DDT is defined as the sum of 2,4'- and 4,4'-dichlorodiphenyltrichloroethane (DDT); 2,4'- and 4,4'-dichlorodiphenyldichloroethane (DDD); and 2,4'- and 4,4'-dichlorodiphenyldichloroethene (DDE)

[2] Bent numbers are the numbers assigned to rows of pier pilings supporting the Levin pier. Each row of pilings was assigned a whole number starting with +1 at the north end of the pier. Positive bent numbers are associated with existing rows of pier pilings. Negative bent numbers are associated with historical pier pilings.

The locations chosen for sediment grab samples were in water that was too shallow for or otherwise inaccessible (between pilings and under the piers) to the larger vessel used during the sediment vibracore sampling activities in April 2013. A small vessel and a hand-deployed Ekman sampler were used to collect sediment grab samples at many of these locations; however, a few locations were accessed by foot.

## Sediment Grab Sample Collection Activities

On March 13, 2013, sediment grab samples were collected at locations SD13-01, SD13-02, SD13-03, SD13-06, SD13-07, SD13-11, SD13-16, SD13-17, and SD13-21 (nine of the fourteen proposed grab sediment sample locations) along the northern and eastern side of the Lauritzen Channel. A small vessel (13-foot Boston Whaler), an Ekman sampler, and boat operator were provided by the United States Environmental Protection Agency (EPA) Region 9 Laboratory. The tides ranged from 1.03 feet Mean Lower Low Water (MLLW) at 0900 hours, to a high tide of 5.67 feet MLLW at 1400 hours, and 4.48 feet MLLW at 1600 hours on March 13, 2013.

On April 29, 2013, during an exceptionally low tide, grab samples were collected from the remaining four locations (SD13-22, SD13-26, SD-30, and SD13-34), which were located under the pier and at the previously identified hotspot near the north end of the pier. Grab samples were collected by hand from locations under the pier in the morning. The final grab sample was collected at the hot spot using the Ekman dredge. A small vessel (16-foot flat-bottomed work boat), and operator were provided by the Levin Richmond Terminal. The tides ranged from 0.03 feet MLLW at 0800 hours, to a low tide of -1.09 feet MLLW at 0948 hours, and 0.38 feet MLLW at 1145 hours on April 29, 2013.

The sediment grab sample locations were determined in the field using a handheld global positioning system (GPS) unit (Trimble) that was preloaded with the proposed sample location coordinates. The vessel was anchored at each location using either bow or stern anchors, or by tying the vessel to a pier, piling or other fixed point. On March 13, 2013, the geographic information system (GIS) coordinates were collected at six of the nine sediment grab sample locations (SD13-01, SD13-02, SD13-03, SD13-06, SD13-07, and SD13-11). The GPS battery failed at approximately 1330 hours; therefore, the GIS coordinates for the remaining three sediment grab sample locations (SD13-16, SD13-17, and SD13-21) were downloaded from an onsite mobile phone and the location was identified based on site features and landmarks such as the pier bent numbers. The sediment grab samples collected on April 29, 2013 were located under the pier where there is no GPS coverage; therefore, these locations were also identified using landmarks including the associated pier bent numbers. Figure 1 presents the locations of the sediment grab samples collected in March and April 2013. The sample collection forms are presented in Attachment 1 and the laboratory chains of custody are presented in Attachment 2. Attachment 3 presents a photographic log of the sediment grab sampling activities.

# Sediment Grab Sample Processing Activities

## March 13, 2013

At each sediment grab sample location, the water depth was measured using a hand-held sonar device and recorded on the sample collection form (Attachment 1). The channel water was very clear at most locations, which allowed the operator to see the Ekman sampler on the channel bottom. The majority of the sediment grab sample locations were very rocky and contained debris (e.g., shell fragments, rocks, leaf litter) which interfered with sediment sample recovery. For this reason, multiple drops of the Eckman sampler were necessary at the same location to collect the volume of sediment required for laboratory analyses. Materials collected from multiple drops of the Eckman sampler were placed into disposable commercial food-grade aluminum pans. Rocks and other debris were discarded. The sediment sample color, contents, and lithology were recorded (Attachment 1) and photos of the samples were taken (Attachment 3).

The sediment was homogenized using prepackaged disposable scoops and transferred to pre-labeled sample containers. The time and date of sample collection were recorded (Attachment 1). Samples were collected at each location for pesticide analysis (EPA Method 8081A), total organic carbon (TOC; Walkley-Black method), and grain size (American Society for Testing and Materials [ASTM] Method D4464). Samples were stored on ice inside a cooler during the sampling activities. Samples collected for pesticide analysis were submitted to the Contract Laboratory Program (CLP) lab (one 4 ounce (oz) jar for KAP) and split samples were submitted to the EPA Region 9 Laboratory (one 4 oz jar). Samples for analysis of physical parameters (grain size and TOC) were submitted to PTS Laboratories (one gallon zip lock bag). One field duplicate was collected for pesticide analysis. Laboratory chains of custody are presented in Attachment 2. The Eckman sampler was cleaned of sediment between each station by scrubbing with an Alconox solution and rinsing with site water.

## April 29, 2013

At each sediment grab sample location, the location was carefully documented by noting the adjacent pier bent numbers because the GPS could not be used under the pier. The only location underwater at the time of sampling was SD13-22. The water depth at location SD13-22 was determined by measuring the length of line for the Ekman Dredge, which was recorded on the sample collection form (Attachment 1). The embankment under the pier is covered in either rip-rap or concrete, although enough sediment was available at each location to collect sufficient sample volume for analysis. The sediment was generally silty sand with gravel, although some clay balls were observed. Sediment was removed from the embankment using disposable scoops and mixed thoroughly in commercial food-grade aluminum pans. Rocks and other debris were discarded. Location SD13-22 was very rocky, which interfered with sediment sample recovery. Ten drops of the Eckman sampler were necessary at this location to collect the volume of sediment required for laboratory analyses. Materials collected from multiple drops of the Eckman sampler were placed into a disposable plastic bag and thoroughly mixed. Rocks and other debris were discarded. The sediment sample color, contents, and lithology were recorded (Attachment 1) and photos of the samples were taken (Attachment 3).

The sediment was homogenized using prepackaged disposable scoops and transferred to pre-labeled sample containers. The time and date of sample collection was recorded (Attachment 1). Samples were collected at each location for pesticide analysis (EPA Method 8081A), TOC (Walkley-Black method), and grain size (ASTM Method D4464). Samples were stored on ice inside a cooler during the sampling activities. Samples collected for pesticides analysis were submitted to the CLP lab (one 4 oz jar for KAP) and split samples were submitted to the EPA Region 9 Laboratory (one 4 oz jar). Sample for the analysis of physical parameters (grain size and TOC) were submitted to PTS Laboratories (one gallon zip lock bag). Laboratory chains of custody are presented in Attachment 2. The Ekman sampler was cleaned of any sediment by scrubbing with an Alconox solution and rinsing with site water before it was returned.

Water was observed seeping out of the lower embankment between bent numbers 24 and 25; however, the flow was diffuse and occurred below the riprap in unarmored sediment below the tide line. A seep was observed flowing out of the embankment at bent number 37 as shown on Photographs 22 and 23 of Attachment 3. This seep was sampled as described later in this memorandum.

# Sediment Grab Sample Descriptions

The sample collection forms (Attachment 1) present the information recorded for each sediment sample collected. The information recorded includes the date, time, and type of sample collected, the water depth at each location, the surface sediment sample collection depth (0 to 0.5 feet below sediment surface), tide height, GIS coordinates for each location, and description of sediment encountered (color, contents, and lithology). A summary of the sediment sample descriptions is presented below.

## SD13-01

The unbiased sediment sample (SD13-01-0005) is located at the head of the Lauritzen Channel. The Eckman sampler was deployed multiple times (approximately 12). The deployments failed due to debris caught in the jaws of the Eckman sampler, shells and/or gravel caught in the spring mechanism, or the sampler not tripping due to the shallow depth. The clear visibility of the channel bottom allowed the operator to see a steep slope of the near shore location and the rocks and debris on the bottom of the channel. The vessel was relocated approximately 20 feet southeast of the original proposed location, to a slightly deeper, flatter location with less debris. The water depth was measured at 7.8 feet deep at this location. Two partially filled grab samples were homogenized for sample processing. Sediment was dark grey-green with a dark brown and black layer at the surface. The material was silty clay with gravel, sand, shells, and debris (wood, plastic, and leaves). Photographs 1 and 2 in Attachment 3 show the sediment.

## SD13-02

The unbiased sediment sample (SD13-02-0005) is located at the head of the Lauritzen Channel. The first drop of the Ekman sampler was successful at this location. The channel bottom was visible and appeared rocky. The water depth was measured at 11 feet. The material was black silty clay with sand, shells, plastic, and woody debris. Large sticks and

shells were removed prior to homogenization and sample processing. Photograph 3 in Attachment 3 shows the sediment.

## SD13-03

The unbiased sediment sample (SD13-03-0005) is located at the head of the Lauritzen Channel and south of the municipal storm drain outfall. Multiple attempts were made until a successful sample was collected. The failed attempts were due to the presence of debris on the bottom of the channel. The water depth was measured at 6.5 feet. An oily sheen was observed on the water in the Ekman sampler. A large fraction of the sample consisted of leaf litter, branches, and shells. Sediment was black with green and brown layers. The material was silty clay with sand, gravel, woody debris, and shells. There was a slight organic odor observed. Multiple worms and amphipods were also observed in the material. Photographs 4 and 5 in Attachment 3 show the sediment.

## SD13-07

The unbiased sediment sample (SD13-07-0005) is located along the eastern side of the Lauritzen Channel. The sample vessel was tied up to the "Do not eat fish" sign located at bent number -5. The water depth was measured at 10.8 feet. Five deployments of the Eckman sampler were made and rocks were obtained. The sixth deployment of the Ekman sampler was successful. The sediment was black with a surface layer of brown and green organic material and it had a slight organic odor. The material was silty clay with sand, rocks, shells, sticks and leaves. Photographs 6 and 7 in Attachment 3 show the sediment.

## SD13-11

The unbiased sediment sample (SD13-11-0005) is located along the eastern side of the Lauritzen Channel near bent number -30. The water depth was measured at 15 feet. One attempt yielded a successful Ekman grab sample. Sediment was brown and black with a green layer. Uniform black specks were observed throughout the material. Worms and amphipods were also observed in the sediment. The sediment was silty clay with sand, shell debris, leaves, and rocks. Photographs 8 through 10 in Attachment 3 show the sediment.

## SD13-12

The biased sediment sample (SD13-12-0005) is located along the eastern side of the Lauritzen Channel at bent number -27.5, adjacent to the 8-inch pipe documented in the Phase I Source Investigation (Kohn and Evans, 2002). The water depth was measured at 10.6 feet. Rocks were obtained in two unsuccessful deployments of the Ekman. Sediments obtained from 3 deployments of the Eckman (Attempts 3 through 5) were combined into one sample. Sediment was black with brown layers. Uniform black specks were observed throughout the material. Worms and amphipods were also observed in the sediment. The sediment was silty clay with sand, shell debris, leaves, and rocks. Photograph 11 in Attachment 3 shows the sediment.

## SD13-16

The unbiased sediment sample (SD13-16-0005) is located along the eastern side of the Lauritzen Channel, south of the stormwater interceptor SW-5 outfall near bent number -16.5. The GPS unit's battery failed so the location coordinates were downloaded from an

onsite mobile phone (Attachment 1). The water depth was measured at 9 feet. The channel bottom was very rocky. Multiple attempts were conducted and the sample was collected from a combination of partially filled Ekman samples. An oily sheen was observed on the water in the pan. Sediment was black with yellow-brown clay clumps (appears to be Older Bay Mud [OBM] material). The sediment was silty clay with clay clumps, gravel, shells and rocks. Material resembling bauxite (reddish nodules) was observed in the sample (bauxite is typically transported from the terminal). Photograph 12 in Attachment 3 shows the sediment.

## SD13-17

The biased sediment sample (SD13-17-0005) is located along the eastern side of the Lauritzen Channel, at bent number -8.5, adjacent to the former seep pipe (P1-4) that was identified in the Phase I Source Investigation (Kohn and Evans, 2002) and sealed in 2003. The GPS unit was not operational. The location coordinates were downloaded from an onsite mobile phone (Attachment 1). The water depth was measured at 9 feet. Sediment was greyish-brown with small black specs uniformly distributed throughout the material. The sediment was silty clay with some rocks and sand. Algae was observed on the surface sediment. An oily sheen was observed on the water surface in the pan. Photograph 13 in Attachment 3 shows the sediment.

## SD13-21

The unbiased sediment sample (SD13-21-0005) is located along the eastern side of the Lauritzen Channel, on the north side of the floating dock at bent number -3.5. The GPS unit was not operational. The location coordinates were downloaded from an onsite mobile phone (Attachment 1). The water depth was measured at 11 feet. Two partially filled Ekman samples were combined to collect sufficient sample volume to submit field duplicates. The first Ekman sample contained silty clay with sand, rocks and clay clump. The second drop contained a large clay clump containing roots (appears to be OBM). Because the Ekman sampler will not penetrate OBM, it appears that the clump of OBM obtained in the Ekman sampler was disturbed during an earlier event. The material was homogenized for primary, split, and field duplicate samples. Photograph 14 in Attachment 3 shows the sediment material and Photograph 15 shows a clump of clay that is presumed to be OBM.

## SD13-22

The biased sediment sample (SD13-22-0005) is located along the eastern side of the Lauritzen Channel, on the south side of the floating dock between bent numbers 2 and 3. The GPS unit was not useful due to the overhanging pier structure. The location coordinates were estimated on the figure based on landmarks recorded in field notes. The water depth was measured at 30 feet. Ten Ekman samples were attempted but only one drop provided sufficient sediment to submit for analysis. The first Ekman sample contained silty sand with gravel, clay and shell hash. The next nine Ekman drops were retrieved either with rocks in the jaws or hinges, empty, or untripped. The material was homogenized for primary samples. Photograph 16 in Attachment 3 shows the sediment.

## SD13-26

The unbiased sediment sample (SD13-26-0005) is located along the eastern side of the Lauritzen Channel, on the south side of the floating dock between bent numbers 10 and 11. The GPS unit was not useful due to the overhanging pier structure. The location coordinates were estimated on the figure based on landmarks recorded in field notes. The embankment at this location consists of approximately 3 feet of conglomerate concrete along the top of the embankment, above approximately 6-7 feet of angular rock (from 6-inch in diameter to riprap). The lower 1-2 feet of embankment at this tide level consists of OBM with a very thin veneer of soft sediment. Pockets of an orange, organic material (possibly algae) was observed on rocks in the area. The sample was collected at 0930 at a tide of -1.02 feet MLLW just below the riprap, from the clay sediment. The material was homogenized for primary samples. Photographs 17 and 18 in Attachment 3 show the embankment and sediment.

## SD13-30

The unbiased sediment sample (SD13-30-0005) is located along the eastern side of the Lauritzen Channel, on the south side of the floating dock between bent numbers 23 and 24. The GPS unit was not useful due to the overhanging pier structure. The location coordinates were estimated on the figure based on landmarks recorded in field notes. The embankment at this location consists of a partial sheet pile wall along the top of the embankment, above approximately 4 to 5 feet of angular rock (from 6-inch in diameter to riprap). The sample was collected at 0905 at a tide of -0.84 feet MLLW approximately 1 foot above the water. Riprap was removed to expose the silty clay with sand and gravel. The sediment was grayish black and had a slight sulfurous odor. The material was homogenized for primary samples. Photographs 19 and 20 in Attachment 3 show the embankment and sediment.

## SD13-34

The unbiased sediment sample (SD13-34-0005) is located along the eastern side of the Lauritzen Channel, on the south side of the floating dock between bent numbers 36 and 37, approximately 1 foot north of the bent number 37 piling. The GPS unit was not useful due to the overhanging pier structure. The location coordinates were estimated on the figure based on landmarks recorded in field notes. The embankment at this location consists of shotcrete concrete along the top of the embankment, above approximately 4-5 feet of angular rock (from 6-inch diameter to riprap). The sample was collected at 0840 at a tide of -0.58 feet MLLW approximately 1 foot above the water. Riprap was removed to expose the greyish brown, silty sand with gravel and shells. The material was homogenized for primary samples. Photographs 21, 22, and 24 in Attachment 3 show the embankment and sediment. Photograph 23 shows the seep at bent number 37 just a few feet to the south of this location.

## SD13-38

The unbiased sediment sample (SD13-38-0005) is located along the eastern side of the Lauritzen Channel, on the south side of the floating dock between bent numbers 50 and 51. The GPS unit was not useful due to the overhanging pier structure. The location coordinates were estimated on the figure based on landmarks recorded in field notes. The embankment at this location consists of steel rails driven into the sediment to support the embankment which consists of ballast and riprap along top of the embankment, above approximately 4-5 feet of angular rock (from 6-inch diameter to riprap) and debris (including a plastic

gasoline jug). The sample was collected at 0800 at a tide of 0.03 feet MLLW approximately 3 foot above the water. Riprap was removed to expose the dark brown, silty sand with gravel and shells. A small amount of clay was observed. The material was homogenized for primary samples. Photographs 25 in Attachment 3 show the embankment and sediment.

## Bent Number 37 Seep Water Sampling Activities

A seep was located at bent number 37 during the sediment grab sampling activities on April 29, 2013 (Photographs 22 and 23 in Attachment 3). The seep was found in an area that was shotcreted by Levin Richmond Terminal Corporation (LRTC) during a low tide in June 2012. The seep water was flowing out of a circular void in the shotcrete approximately 2 feet above the water line at 0840 (tide at -0.58 feet MLLW), which suggests that the seep would be below the water line most of the time. No sediment was exposed below this seep, but sediment sample SD13-34 was taken approximately 3 feet north of the seep where sediment was present.

A sample of the flowing water was collected from the seep to determine conductivity of the water. Rich Bauer (Region 9 Environmental Protection Agency Laboratory Chemistry Lead) determined the water was approximately 2,400 ppm total dissolved solids (TDS), which is slightly brackish (typical seawater is 35,000 ppm TDS), and suggests a possible groundwater source. The location of the seep was documented and added to the GIS database for the United Heckathorn Project as point source P4-16 to conform with the naming convention used for the site survey conducted in 2012 to locate any point sources along the embankment. The project team recommended a water sample be collected from the seep location at bent number 37 during an extreme low tide when the area could be accessed safely.

On July 24, 2013, the low tide for the Inner Richmond Harbor was -1.0 feet MLLW at 0743 hours. The width of the seep was estimated to be about 2 inches the flow was estimated to be about 20 gallons per minute. Field parameters including pH (7.01), temperature (20.3 degrees Celsius), electrical conductivity (5.534 milliseimens per centimeter), and total dissolved solids (0.0034 kilograms per Liter) were measured and recorded in the field notes (Attachment 4). The amount of time it took to fill each 1 Liter glass amber bottle was also recorded (ranged from 12 to 14 seconds with only 30 to 50 percent of the flow being captured).

The water sample was collected from the seep during the extreme low tide using a new flexible food-grade cutting board to channel the water into the sample containers. Prior to using this method, the Project Manager contacted a Senior Chemist with Vista Analytical Laboratories (Vista), to ensure that chemicals in the cutting board such as phthalates or other plasticizers would not cause interference with the pesticide analyses. Vista's Senior Chemist confirmed that their high-resolution analytical method would not be affected by any plastics that might leach from the cutting board; however, he noted that standard analytical methods may be affected. The sample was sent to Vista for analysis of total and dissolved dichlorodiphenyl-trichloroethanes (DDTs[3]) and Dieldrin (four 1-Liter amber glass

[3] 2,4'- and 4,4'-dichlorodiphenyltrichloroethane (DDT); 2,4'- and 4,4'-dichlorodiphenyldichloroethane (DDD); and 2,4'- and 4,4'-dichlorodiphenyldichloroethene (DDE)

bottles) and a sample was also provided to EPA Region 9 laboratory for analysis of total suspended solids (three 250-milliliter poly bottles). The field observations and chains of custody for the water sample are provided in Attachment 4.

# References

CH2M HILL. 2013. Final *Focused Feasibility Study Data Gaps Sampling and Analysis Plan Addendum #2 Source Identification Study United Heckathorn Superfund Site*. February.

Kohn, N. and N. Evans. 2002. *Phase I Source Investigation at the United Heckathorn Superfund Site, Richmond, California*. PNNL-14088. December.

Kohn, N. and N. Evans. 2004. *Year 6 Post-Remediation Biomonitoring and Phase II Source Investigation at the United Heckathorn Superfund Site, Richmond, California*. PNNL-14596. March.

# Figure 1
# Grab Sediment Sampling Locations

## LEGEND

- Sediment Grab Sample Location
- Vibracore Sample Location

**Bathymetry**

- 1 ft
- 44 ft
- Bathymetric Contour (5 foot Interval)

- Outfall Location
- Former Pier Pilings
- Pier Pilings
- Railroad
- Former Buildings
- Dredged Area
- Partially Dredged Area
- Un-Dredged Area
- Concrete
- Rock/Rip Rap
- Rock/Rip Rap and Concrete
- Shotcrete
- Sheet Pile
- Sheet Pile and Concrete

**FIGURE 1**
**2013 Sediment Sampling Locations**
*United Heckathorn Superfund Site*
*Richmond, California*

CH2MHILL

Document Path: D:\Projects\EPA_UnitedHeckathorn\MapFiles\2013\July\SedimentSampleLocations.mxd

# Attachment 1
# Sample Collection Forms

Sample ID on chain of custody: SD13-01-0005

# SAMPLE COLLECTION FORM

(complete one form per sample)

**Event Name: United Heckathorn Source ID**

## Sample Collection Information

Date: 3/13/13 Time: 1040

Sample Type: ☑ Primary ☐ Field Duplicate ☐ Rinse blank ☐ Trip Blank ☐ Field/Ambient Blank

If FD, please list Primary sample _____

Matrix: Sediment

Depth (ft bgs): 0 (beginning depth) - 0.5' (ending depth) Water Depth 7.8'

Sample Method: Ponar Grab (dedicated equipment being used?) Y

Weather: Clear/Sunny Temperature: 55.9°F

Sample Location ID: SD13-01 GPS (Northing/Easting): 6023257.96435 / 2164985.343

CLP ID: SD13-01-0005 GPS Datum: NAD 1983 CA State Plane Zone 3 feet

EPA split sample ID: Y8RL5 Tide cycle/Datum: ~2.5 ft/MLLW

## Sediment Descriptions

**Color:** Dark grey-greenish with dark brown + black

**Moisture:** Dry Sl. Moist Moist V.Moist (Wet)

**Major Description:** Clay (Silty Clay) Silt Clayey Sand Sandy Clay Sand Gravelly Sand Gravel Grvly Clay

**Minor Description:** (Organic) Mottled Plastic M.Plastic Nodules vf f coarse-grained Ang / SA / SR / Rounded Well / (poorly) mod - sorted well / (poorly) / mod - cemented (loose)

**Other Descriptors:**

Sticks, vegetative debris, shell fragments, plastic, piece of wood piling, glass shards, Sediment is silty clay with gravel, sand, and debris. Sediment is loose, no plasticity.

**Photographic Log:**

| Photo file name | Date | Initials | Subject of Photo |
|---|---|---|---|
| SD13-01-0005-1 | 3/13/13 | Tamara's iphone | Sediment in Ponar |
| SD13-01-0005-2 | 3/13/13 | " | " " |
| SD13-01-0005-3 | 3/13/13 | " | Sediment in pan |
| SD13-01-0005-4 | 3/13/13 | " | " " |

## Sample Parameters

| Parameters | Sample Containers |
|---|---|
| ☑ Pesticides (EPA Method 8081A) | 2 x 4oz jars |
| ☑ TOC (Walkley-Black) | } 1/2 gal ziplock |
| ☐ Percent solids (ASTM Method D2216) | |
| ☐ percent moisture (ASTM Method D2216) | |
| ☑ grain size ((ASTM Method D4464)) | |
| ☐ specific gravity (ASTM Method D854) | |
| ☐ Atterberg limits ((ASTM Method D4318) | |

Sampling Notes: Channel bottom visible through clear water. Mooring lines, tire, & debris observed. Very rocky bottom. Took 12 attempts w/ 1 ponar grab. Sample was homogenized from 2 successful ponar grabs. Due to very rocky bottom, had to move the location west from original.

Sampler Name: Tamara Frank

## SAMPLE COLLECTION FORM
(complete one form per sample)

Sample ID on chain of custody: SD13-02-0005

**Event Name: United Heckathorn Source ID**

### Sample Collection Information

Date: 3/13/13 Time: 11:10am

Sample Type: [x] Primary [ ] Field Duplicate [ ] Rinse blank [ ] Trip Blank [ ] Field/Ambient Blank

If FD, please list Primary sample _____

Matrix: Sediment

Depth (ft bgs): 0 - 0.5 (beginning depth / ending depth) Water Depth 11 ft

Sample Method: Ponar Grab (dedicated equipment being used?) Y

Weather: Sunny, clear Temperature: 71.6°F

Sample Location ID: SD13-02 GPS (Northing/Easting): 6023292.8112 / 2164488.6969

CLP ID: SD13-02-0005 GPS Datum: NAD 1983 CA Plane Zone 3 feet

EPA split sample ID: Y8RL6 Tide ~~cycle~~ hat / datum: ~3.0 ft / MLLW

### Sediment Descriptions

**Color:** Black

**Moisture:** Dry Sl. Moist Moist V.Moist Wet

**Major Description:** Clay Silty Clay Silt Clayey Sand Sandy Clay Sand Gravelly Sand Gravel Grvly Clay

**Minor Description:** Organic Mottled Plastic M.Plastic Nodules vf f coarse-grained Ang / SA / SR / Rounded Well / poorly / mod - sorted well / poorly / mod - cemented Loose

**Other Descriptors:**

Shells, sticks, plastic debris, woody material.

silty/clay, somewhat consolidated, no plasticity. organic material with sticks and shells

**Photographic Log:**

| Photo file name | Date | Initials | Subject of Photo |
|---|---|---|---|
| SD13-02-0005-1 | 3/13/13 | Tamara's | Sediment in ponar |
| SD13-02-0005-2 | 3/13/13 | Iphone | " " |

### Sample Parameters

| Parameters | Sample Containers |
|---|---|
| [x] Pesticides (EPA Method 8081A) | 2x 4oz jar |
| [x] TOC (Walkley-Black) | 1x 1/2 gal Ziplock |
| [ ] Percent solids (ASTM Method D2216) | |
| [ ] percent moisture (ASTM Method D2216) | |
| [x] grain size ((ASTM Method D4464)) | 1x 1/2 gal Ziplock |
| [ ] specific gravity (ASTM Method D854) | |
| [ ] Atterberg limits ((ASTM Method D4318) | |

Sampling Notes: Channel bottom visible. Rocky bottom.

Sampler Name: Tamara Frank

# SAMPLE COLLECTION FORM

(complete one form per sample)

Sample ID on chain of custody: SD13-03-0005

**Event Name: United Heckathorn Source ID**

## Sample Collection Information

Date: 3/13/13 Time: 1140

Sample Type: ☑ Primary ☐ Field Duplicate ☐ Rinse blank ☐ Trip Blank ☐ Field/Ambient Blank

If FD, please list Primary sample _____

Matrix: Sediment

Depth (ft bgs): 0 (beginning depth) - 0.5' (ending depth) Water Depth 6.5'

Sample Method: Ponar grab (dedicated equipment being used?) Y

Weather: Sunny/Clear Temperature: 76°F

Sample Location ID: SD13-03 GPS (Northing/Easting): 6023340.9885 / 2164483.0340

CLP ID: SD13-03-0005 GPS Datum: NAD 1983 CA State Plane Zone 3 feet

EPA split sample ID: V8LL7 Tide Cycle LL / Datum: ~3.8 ft/MLLW

## Sediment Descriptions

**Color:** Black w/ green + brown

**Moisture:** Dry Sl. Moist Moist V.Moist (Wet)

**Major Description:** Clay (Silty Clay) Silt Clayey Sand Sandy Clay Sand Gravelly Sand Gravel Grvly Clay

**Minor Description:** (Organic) Mottled Plastic M.Plastic Nodules vf f coarse-grained Ang / SA / SR / Rounded Well / (poorly) / mod - sorted well / (poorly) / mod - cemented (Loose)

**Other Descriptors:**

Organic odor. Oily sheen on water inside ponar.
Silty clay w/ sand and gravel, woody debris, beer caps, leaf litter, shell debris, gravel, sticks, and moderate amount of worms, tunicates, copepods. Large fraction of volume is leaves, branches, and shells.

**Photographic Log:**

| Photo file name | Date | Initials | Subject of Photo |
|---|---|---|---|
| SD13-03-0005-1 | 3/13/13 | Tamara's | Sediment in ponar |
| " " -2 | " | | Sediment in pan |
| " " -3 | " | Iphone | " " |

## Sample Parameters

| Parameters | Sample Containers |
|---|---|
| ☑ Pesticides (EPA Method 8081A) | 2 x 4oz jar |
| ☑ TOC (Walkley-Black) | > 1/2 gal ziplock |
| ☐ Percent solids (ASTM Method D2216) | |
| ☐ percent moisture (ASTM Method D2216) | |
| ☑ grain size ((ASTM Method D4464)) | |
| ☐ specific gravity (ASTM Method D854) | |
| ☐ Atterberg limits ((ASTM Method D4318) | |

Sampling Notes: grab material appears to be composed of some storm drain material based on the amount of leaves and branches observed at this location.

Sampler Name: Tamara Frank

## SAMPLE COLLECTION FORM

(complete one form per sample)

Sample ID on chain of custody: SD13-07-0005

**Event Name: United Heckathorn Source ID**

### Sample Collection Information

Date: 3/13/13 Time: 1220

Sample Type: [x] Primary [ ] Field Duplicate [ ] Rinse blank [ ] Trip Blank [ ] Field/Ambient Blank

If FD, please list Primary sample _____

Matrix: Sediment

Depth (ft bgs): 0 (beginning depth) - 0.5' (ending depth) Water Depth 10.8'

Sample Method: Ponar grab (dedicated equipment being used?) Y

Weather: Sunny/Clear Temperature: 81°F

Sample Location ID: SD13-07 GPS (Northing/Easting): 6023551.2709/2116424.3453

CLP ID: SD13-07-0005 GPS Datum: NAD 1983 CA State Plane Zone 3 ft

EPA split sample ID: YORLB Tide table/Datum: -4.3 ft/MLLW

### Sediment Descriptions

**Color:** Black w/ brown and green

**Moisture:** Dry Sl. Moist Moist V.Moist (Wet)

**Major Description:** Clay Silty Clay Silt Clayey Sand Sandy Clay Sand Gravelly Sand Gravel Grvly Clay

**Minor Description:** (Organic) Mottled Plastic M.Plastic Nodules vf f coarse-grained Ang / SA / SR / Rounded

Well / (poorly) / mod - sorted well / (poorly) / mod - cemented (Loose)

**Other Descriptors:**

Slight organic odor.

Silty clay w/ sand + rocks, shell debris, sticks, and leaves.

**Photographic Log:**

| Photo file name | Date | Initials | Subject of Photo |
|---|---|---|---|
| SD13-07-0005-1 | 3/13/13 | Tamara's Iphone | Pier piling location |
| " " -2 | " | | " " " |
| " " -3 | " | | Rocky/riprap bottom |
| " " -4 | " | | " " |
| " " -5 | " | | Sediment in pan |
| " " -6 | " | | " |

### Sample Parameters

| Parameters | Sample Containers |
|---|---|
| [x] Pesticides (EPA Method 8081A) | 2x 4oz jars |
| [x] TOC (Walkley-Black) | |
| [ ] Percent solids (ASTM Method D2216) | > ½ gal Ziplock |
| [ ] percent moisture (ASTM Method D2216) | |
| [x] grain size ((ASTM Method D4464)) | |
| [ ] specific gravity (ASTM Method D854) | |
| [ ] Atterberg limits ((ASTM Method D4318) | |

Sampling Notes: Rocky riprap bottom. Sample collected 6th attempt. Sample location next to Fish prohibition sign at Bent - 5.

Sampler Name: Tamara Frank

## SAMPLE COLLECTION FORM

(complete one form per sample)

Sample ID on chain of custody: SD13-11-0005

**Event Name: United Heckathorn Source ID**

### Sample Collection Information

Date: 3/13/13 Time: 1250

Sample Type: [x] Primary [ ] Field Duplicate [ ] Rinse blank [ ] Trip Blank [ ] Field/Ambient Blank

If FD, please list Primary sample _____

Matrix: Sediment

Depth (ft bgs): 0 (beginning depth) - 0.5' (ending depth) Water Depth 15'

Sample Method: Ponar Grab (dedicated equipment being used?) Y

Weather: Sunny/Clear Temperature: 79.9°F

Sample Location ID: SD13-11 GPS (Northing/Easting): 6023329.2936 / 2164224.6048

CLP ID: SD13-11-0005 GPS Datum: NAD 1983, CA State Plane Zone 3 feet

EPA split sample ID: Y8RL9 Tide ~~Guide~~/Datum: ~5ft MLLW

### Sediment Descriptions

Color: Brown w/ green and some black. Uniform black specs in material.

Moisture: Dry Sl. Moist Moist V.Moist (Wet)

Major Description: Clay (Silty Clay) Silt Clayey Sand Sandy Clay Sand Gravelly Sand Gravel Grvly Clay

Minor Description: (Organic) Mottled Plastic M.Plastic Nodules vf f coarse-grained Ang / SA / SR / Rounded

Well / (poorly) / mod - sorted well / (poorly) / mod - cemented (Loose)

Other Descriptors:

Black specs uniformally distributed throughout material.

Silty clay with sand, shell debris, leaves, rocks, and worms.

**Photographic Log:**

| Photo file name | Date | Initials | Subject of Photo |
|---|---|---|---|
| SD13-11-0005-1 | 3/13/13 | Tamara's | Sediment in Ponar |
| " -2 | " | Iphone | " |
| " -3 | " | | " |
| " -4 | " | | " |
| " -5 | " | | Sediment in pan |
| " -6 | " | | " |

### Sample Parameters

| Parameters | Sample Containers |
|---|---|
| [x] Pesticides (EPA Method 8081A) | 2 x 4oz jar |
| [x] TOC (Walkley-Black) | > ½ gal Ziplock |
| [ ] Percent solids (ASTM Method D2216) | |
| [ ] percent moisture (ASTM Method D2216) | |
| [x] grain size ((ASTM Method D4464)) | |
| [ ] specific gravity (ASTM Method D854) | |
| [ ] Atterberg limits ((ASTM Method D4318) | |

Sampling Notes: _____

Sampler Name: Tamara Frank

## SAMPLE COLLECTION FORM

(complete one form per sample)

Sample ID on chain of custody: SD13-12-0005

**Event Name: United Heckathorn Source ID**

**Sample Collection Information**

Date: 3/13/13 Time: 1320

Sample Type: [x] Primary [ ] Field Duplicate [ ] Rinse blank [ ] Trip Blank [ ] Field/Ambient Blank

If FD, please list Primary sample _____

Matrix: Sediment

Depth (ft bgs): 0 (beginning depth) - 0.5' (ending depth) Water Depth 10.56'

Sample Method: Ponar Grab (dedicated equipment being used?) y

Weather: Sunny/Clear Temperature: 72.5°F

Sample Location ID: SD13-12 GPS (Northing/Easting): lat 37.33325, -0.080 / 2164192.9685

CLP ID: SD13-12-0005 GPS Datum: NAD 1983, CA State Plane Zone 3 feet

EPA split sample ID: Y8RH0 Tide cycle/Datum: ~5.1 ft MLLW

**Sediment Descriptions**

Color: Black w/ brown layers. Small black specs uniformally distributed throughout material

Moisture: Dry Sl. Moist Moist V.Moist (Wet)

Major Description: Clay (Silty Clay) Silt Clayey Sand Sandy Clay Sand Gravelly Sand Gravel Grvly Clay

Minor Description: (Organic) Mottled Plastic M.Plastic Nodules vf f coarse-grained Ang / SA / SR / Rounded

Well / (poorly) / mod - sorted well / (poorly) / mod - cemented (Loose)

Other Descriptors:

Silty clay w/ sand, rocks, shells, leaf litter, and worms. A lot of biological activity observed (worms, copepods, tunicates, sand fleas). Small black specks uniformally distributed throughout material.

**Photographic Log:**

| Photo file name | Date | Initials | Subject of Photo |
|---|---|---|---|
| SD13-12-0005-1 | 3/13/13 | Tamara's Iphone | Sediment in pan |
| -2 | " | | " |
| -3 | " | | " |
| -4 | " | | " |
| -5 | " | | " |
| -6 | " | | " |

**Sample Parameters**

| Parameters | Sample Containers |
|---|---|
| [x] Pesticides (EPA Method 8081A) | 2 x 40z jar |
| [x] TOC (Walkley-Black) | > ½ gal ziplock |
| [ ] Percent solids (ASTM Method D2216) | |
| [ ] percent moisture (ASTM Method D2216) | |
| [x] grain size ((ASTM Method D4464)) | |
| [ ] specific gravity (ASTM Method D854) | |
| [ ] Atterberg limits ((ASTM Method D4318) | |

Sampling Notes: Very rocky bottom. Multiple attempts to collect sample. Sample was homogenized from 3 partially filled ponar grabs.

Location @ bent -27.5 (8" pipe from PH I)

Sampler Name: Tamara Frank

## SAMPLE COLLECTION FORM

(complete one form per sample)

Sample ID on chain of custody: SD13-16-0005

**Event Name: United Heckathorn Source ID**

**Sample Collection Information**

Date: 3/13/13 Time: 1400

Sample Type: [x] Primary [ ] Field Duplicate [ ] Rinse blank [ ] Trip Blank [ ] Field/Ambient Blank

If FD, please list Primary sample _____

Matrix: Sediment

Depth (ft bgs): 0 (beginning depth) - 0.5' (ending depth) Water Depth 9'

Sample Method: Ponar Grab (dedicated equipment being used?) Y

Weather: Sunny / Clear Temperature: 85°F

Sample Location ID: SD13-16 GPS (Northing/Easting): GPS unit died (battery)

CLP ID: SD13-16-0005 GPS Datum: _____

EPA split sample ID: Y8RH1 Tide/Datum: -5.4 ft / MLLW

**Sediment Descriptions**

**Color:** Black w/ yellow-brown clumps

**Moisture:** Dry Sl. Moist Moist V.Moist (Wet)

**Major Description:** Clay (Silty Clay) Silt Clayey Sand Sandy Clay Sand Gravelly Sand Gravel Grvly Clay

**Minor Description:** (Organic) Mottled Plastic M.Plastic Nodules vf f coarse-grained Ang / SA / SR / Rounded

Well / (poorly) / mod - sorted well / (poorly) / mod - cemented (Loose)

**Other Descriptors:**

Oily sheen observed on water in pan.

Silty clay w/ yellow brown clay clumps. Small fraction of shells, rocks, and gravel.

**Photographic Log:**

| Photo file name | Date | Initials | Subject of Photo |
|---|---|---|---|
| SD13-16-0005-1 | 3/13/13 | Tamara's | Sediment in pan w/ clay clumps |
| " " -2 | " | Iphone | " " |
| " " -3 | " | | " " |

**Sample Parameters**

| Parameters | Sample Containers |
|---|---|
| [x] Pesticides (EPA Method 8081A) | 2x 4oz jar |
| [x] TOC (Walkley-Black) | > ½ gal ziplock |
| [ ] Percent solids (ASTM Method D2216) | |
| [ ] percent moisture (ASTM Method D2216) | |
| [x] grain size ((ASTM Method D4464)) | |
| [ ] specific gravity (ASTM Method D854) | |
| [ ] Atterberg limits ((ASTM Method D4318) | |

Sampling Notes: Sample location e Bent -16.5 near SW-5 pipe (South of SW-5).

Iphone GIS coordinates 37.923 N / 22.367 W

Sampler Name: Tamara Frank

## SAMPLE COLLECTION FORM

(complete one form per sample)

Sample ID on chain of custody: SDB-17-0005

**Event Name:** United Heckathorn Source ID

### Sample Collection Information

Date: 3/13/13 Time: 1430

Sample Type: ☑ Primary ☐ Field Duplicate ☐ Rinse blank ☐ Trip Blank ☐ Field/Ambient Blank

If FD, please list Primary sample _____

Matrix: Sediment

Depth (ft bgs): 0 (beginning depth) - 0.5' (ending depth) Water Depth: 9 ft

Sample Method: Ponar Grab (dedicated equipment being used?) y

Weather: Sunny/Clear Temperature: 84.5°F

Sample Location ID: SDB-17 GPS (Northing/Easting): GPS unit died (battery)

CLP ID: SDB-17-0005 GPS Datum: " "

EPA split sample ID: Y82H2 Tide cycle/Datum: ~5.3 ft / MLLW

### Sediment Descriptions

Color: Greyish/Brown w/small black speck uniformity distributed throughout material

Moisture: Dry Sl. Moist Moist V.Moist (Wet)

Major Description: Clay (Silty Clay) Silt Clayey Sand Sandy Clay Sand Gravelly Sand Gravel Grvly Clay

Minor Description: (Organic) Mottled Plastic M.Plastic Nodules vf f coarse-grained Ang / SA / SR / Rounded

Well / (poorly) / mod - sorted well / (poorly) / mod - cemented (Loose)

Other Descriptors:

Algae observed on surface sediment.

Silty clay w/some rocks and sand. Black speck uniformity distributed throughout material.

**Photographic Log:**

| Photo file name | Date | Initials | Subject of Photo |
|---|---|---|---|
| SDB-17-0005-1 | 3/13/13 | Tamara's | Sediment in Ponar |
| " -2 | " | " | " " |
| " -3 | " | Iphone | " " |
| " -4 | " | | Sediment in PHN Piling location |
| " -5 | " | | |
| " -6 | " | | |
| " -7 | " | | |

### Sample Parameters

| Parameters | Sample Containers |
|---|---|
| ☑ Pesticides (EPA Method 8081A) | 2x 40z jar |
| ☑ TOC (Walkley-Black) | |
| ☐ Percent solids (ASTM Method D2216) | |
| ☐ percent moisture (ASTM Method D2216) | > 1/2 gal ziplock |
| ☑ grain size ((ASTM Method D4464)) | |
| ☐ specific gravity (ASTM Method D854) | |
| ☐ Atterberg limits ((ASTM Method D4318) | |

Sampling Notes: Oily sheen observed on $H_2O$ in pan. Sample location at Brt - 8.5, Pipe P1-4 (from PHT) was not observed/located.

Iphone GIS coordinates 37.903 N / 22.367 W

Sampler Name: Tamara Frank

## SAMPLE COLLECTION FORM

(complete one form per sample)

Sample ID on chain of custody: SD13-21-0005

**Event Name:** United Heckathorn Source ID

### Sample Collection Information

Date: 3/13/13 Time: 1500

Sample Type: [x] Primary [x] Field Duplicate [ ] Rinse blank [ ] Trip Blank [ ] Field/Ambient Blank

If FD, please list Primary sample: SD13-21-0005 (primary); SD13-79-0005 (FD)

Matrix: Sediment

Depth (ft bgs): 0 (beginning depth) - 0.5' (ending depth) Water Depth: 11ft

Sample Method: Ponar grab (dedicated equipment being used?)

Weather: Sunny/clear Temperature: 79°F

Sample Location ID: SD13-21 GPS (Northing/Easting): GPS unit died (battery)

CLP ID: SDB-21-0005/SD13-79-0005 GPS Datum: "

EPA split sample ID: Y8RH3 (primary) Tide cycle/datum: ~5.1ft lmllw

Y8RH5 (FD)

### Sediment Descriptions

Color: Grey w/ dark grey/black clumps

Moisture: Dry Sl. Moist Moist V.Moist (Wet)

Major Description: Clay (Silty Clay) Silt Clayey Sand Sandy Clay Sand Gravelly Sand Gravel Grvly Clay

Minor Description: (Organic) Mottled Plastic M.Plastic Nodules vf f coarse-grained Ang / SA / SR / Rounded

Well / poorly / mod - sorted well / poorly / mod - cemented (Loose)

Other Descriptors:

Silty clay w/ rocks, Sand & Clay clumps, Clay clumps contain roots.

~~Not much vegetation or~~ L.L. No vegetation or bio activity observed.

### Photographic Log:

| Photo file name | Date | Initials | Subject of Photo |
|---|---|---|---|
| SD13-21-0005-1 | 3/13/13 | Tamara's | Sediment in ponar |
| " -2 | " | " | Sediment in Pan |
| " -3 | " | Iphone | " w/ clay clumps |
| " -4 | " | " | " " |

### Sample Parameters

| Parameters | Sample Containers |
|---|---|
| [x] Pesticides (EPA Method 8081A) | 2 x 4oz jar |
| [x] TOC (Walkley-Black) | |
| [ ] Percent solids (ASTM Method D2216) | |
| [ ] percent moisture (ASTM Method D2216) | > ½ gal Ziplock |
| [x] grain size ((ASTM Method D4464)) | |
| [ ] specific gravity (ASTM Method D854) | |
| [ ] Atterberg limits ((ASTM Method D4318) | |

Sampling Notes: Sample located @ Bent-3.5. Sample homogenized from 2 ponar grabs. N Sample (CLP) SD13-21-0005; FD - SD13-79-0005

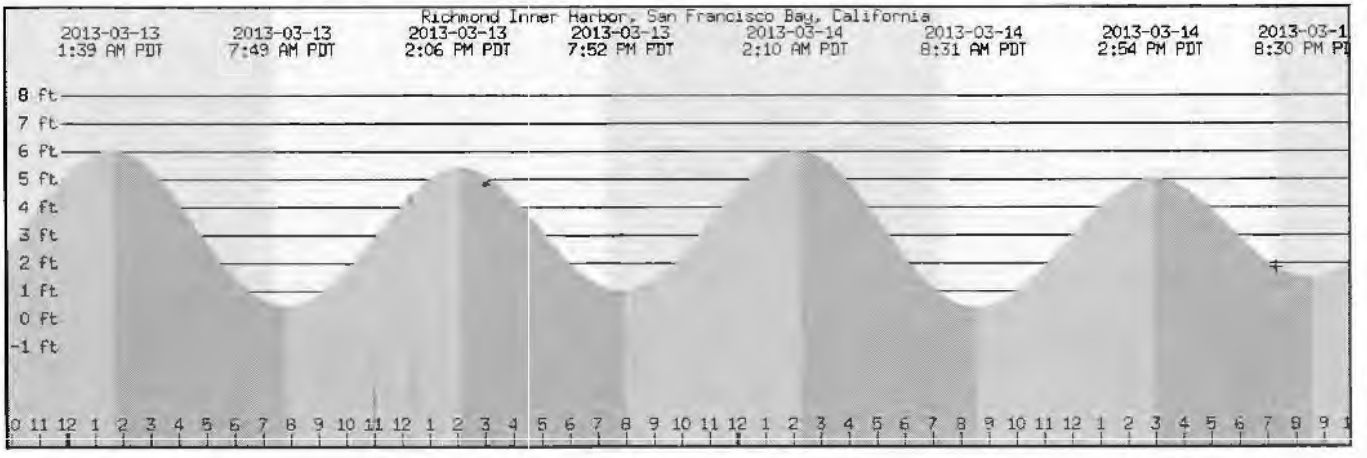
N Sample (EPA) Y8RH3; FD - Y8RH5

Iphone GIS Coordinates 37.923 N 122.367 W

Sampler Name: Tamara Frank

Mobile Geographics Tides for iPhone

# Richmond Inner Harbor, San Francisco Bay, California
# Requested time: 2013-03-13 12:00 AM PDT

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Richmond Inner Harbor, San Francisco Bay, California
37.9100° N, 122.3583° W

| | | | |
|---|---|---|---|
| 2013-03-13 | 1:39 AM PDT | 6.06 feet | High Tide |
| 2013-03-13 | 7:23 AM PDT | Sunrise | |
| 2013-03-13 | 7:49 AM PDT | 0.48 feet | Low Tide |
| 2013-03-13 | 2:06 PM PDT | 5.43 feet | High Tide |
| 2013-03-13 | 7:15 PM PDT | Sunset | |
| 2013-03-13 | 7:52 PM PDT | 1.00 feet | Low Tide |
| 2013-03-14 | 2:10 AM PDT | 6.01 feet | High Tide |
| 2013-03-14 | 7:21 AM PDT | Sunrise | |
| 2013-03-14 | 8:31 AM PDT | 0.42 feet | Low Tide |
| 2013-03-14 | 2:54 PM PDT | 5.03 feet | High Tide |
| 2013-03-14 | 7:16 PM PDT | Sunset | |
| 2013-03-14 | 8:30 PM PDT | 1.46 feet | Low Tide |
| 2013-03-15 | 2:42 AM PDT | 5.89 feet | High Tide |
| 2013-03-15 | 7:20 AM PDT | Sunrise | |
| 2013-03-15 | 9:15 AM PDT | 0.46 feet | Low Tide |
| 2013-03-15 | 3:45 PM PDT | 4.64 feet | High Tide |
| 2013-03-15 | 7:16 PM PDT | Sunset | |
| 2013-03-15 | 9:10 PM PDT | 1.91 feet | Low Tide |
| 2013-03-16 | 3:16 AM PDT | 5.71 feet | High Tide |
| 2013-03-16 | 7:18 AM PDT | Sunrise | |
| 2013-03-16 | 10:02 AM PDT | 0.57 feet | Low Tide |
| 2013-03-16 | 4:43 PM PDT | 4.29 feet | High Tide |
| 2013-03-16 | 7:17 PM PDT | Sunset | |
| 2013-03-16 | 9:54 PM PDT | 2.33 feet | Low Tide |
| 2013-03-17 | 3:55 AM PDT | 5.51 feet | High Tide |

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## Time Control

Year: 2013 • Month: 3 • Day: 13 • Go

Note: predictions for some locations do not cover the full span of years. If your browser returns a blank page or a "no data" error, then the predictions

# SAMPLE COLLECTION FORM

(complete one form per sample)

Sample ID on chain of custody: SD13-22-0005

**Event Name: United Heckathorn Source ID**

## Sample Collection Information

Date: 4/29/13 Time: 1145

Sample Type: ☑ Primary ☐ Field Duplicate ☐ Rinse blank ☐ Trip Blank ☐ Field/Ambient Blank

If FD, please list Primary sample _____

Matrix: Sediment

Depth (ft bgs): 0 (beginning depth) - 0.5' (ending depth) Water Depth 30 ft

Sample Method: Ponar Grab Sediment Sample (dedicated equipment being used?) Y

Weather: Sunny Temperature: ~75°F

Sample Location ID: SD13-22 GPS (Northing/Easting): No signal under pier

CLP ID: V8LN4 GPS Datum: Pilunga. Sample placed between

EPA split sample ID: NA Bents +2 and +3.

## Sediment Descriptions

**Color:** Gray

**Moisture:** Dry Sl. Moist Moist V.Moist (Wet)

**Major Description:** Clay Silty Clay (Silt) Clayey Sand Sandy Clay (Sand) Gravelly Sand (Gravel) Grvly Clay

**Minor Description:** Organic Mottled Plastic M.Plastic Nodules vf f coarse-grained Ang / SA / SR / Rounded Well / poorly / mod - sorted well / poorly / mod - cemented (Loose)

**Other Descriptors:**

Silty sand with some gravel and clay. Some shell hash.

**Photographic Log:**

| Photo file name | Date | Initials | Subject of Photo |
|---|---|---|---|
| SD13-22-1 | 4/29/13 | T.F. | T.F. collecting sample w/ Ponar |
| SD13-22-2 | 4/29/13 | T.F. | Sediment sample from ponar |

## Sample Parameters

| Parameters | Sample Containers |
|---|---|
| ☑ Pesticides (EPA Method 8081A) | 1 x 40z jar |
| ☑ TOC (Walkley-Black) | 3 1gal Ziplock bags |
| ☐ Percent solids (ASTM Method D2216) | |
| ☐ percent moisture (ASTM Method D2216) | |
| ☑ grain size ((ASTM Method D4464)) | |
| ☐ specific gravity (ASTM Method D854) | |
| ☐ Atterberg limits ((ASTM Method D4318) | |

Sampling Notes: 16 Ponar attempts at this location due to very rocky bottom. Sample was collected from 1st attempt. ~~Sample collected~~ Sample collected between Bents +2 and +3 in Hotspot Area.

Sampler Name: Tamara Frank

Sample ID on chain of custody: SD13-26-0005

# SAMPLE COLLECTION FORM

(complete one form per sample)

**Event Name: United Heckathorn Source ID**

## Sample Collection Information

Date: 4/29/13 Time: 0930

Sample Type: [x] Primary [ ] Field Duplicate [ ] Rinse blank [ ] Trip Blank [ ] Field/Ambient Blank

If FD, please list Primary sample _____

Matrix: Sediment

Depth (ft bgs): 0 (beginning depth) - 0.5' (ending depth) Water Depth NA / embankment sample

Sample Method: Grab w/disposable scoops (dedicated equipment being used?) y

Weather: Sunny Temperature: ~65

Sample Location ID: SD13-26 GPS (Northing/Easting): NA / no signal under pier.

CLP ID: YBRM6 GPS Datum: Sample collected Between Bents +10 and +11

EPA split sample ID: NA

## Sediment Descriptions

**Color:** grayish black

**Moisture:** Dry Sl. Moist Moist V.Moist (Wet)

**Major Description:** (Clay) Silty Clay (Silt) Clayey Sand Sandy Clay Sand Gravelly Sand (Gravel) Grvly Clay

**Minor Description:** Organic Mottled Plastic M.Plastic Nodules vf f coarse-grained Ang / SA / SR / Rounded Well / poorly / mod - sorted well / poorly / mod - cemented (Loose)

**Other Descriptors:**

Clay clumps with some rocks. Presumed OBM. Roots are visible.

## Photographic Log:

| Photo file name | Date | Initials | Subject of Photo |
|---|---|---|---|
| SD13-26-1 | 4/29/13 | L.L. | T.F. collecting sample @ embankment |
| SD13-26-2 | 4/29/13 | L.L. | location of embankment Shotcrete |
| SD13-26-3 | 4/29/13 | L.L. | L.L. homogenizing sediment sample in pan |
| SD13-26-4 | 4/29/13 | L.L. | Close up presumed OBM w/ roots |

## Sample Parameters

| Parameters | Sample Containers |
|---|---|
| [x] Pesticides (EPA Method 8081A) | 1 x 4oz jar |
| [x] TOC (Walkley-Black) | > 1 gal Ziplock |
| [ ] Percent solids (ASTM Method D2216) | |
| [ ] percent moisture (ASTM Method D2216) | |
| [x] grain size ((ASTM Method D4464)) | |
| [ ] specific gravity (ASTM Method D854) | |
| [ ] Atterberg limits ((ASTM Method D4318) | |

Sampling Notes: _____

Sampler Name: Tamara Frank

Sample ID on chain of custody: SD13-30-0005

# SAMPLE COLLECTION FORM

(complete one form per sample)

**Event Name: United Heckathorn Source ID**

## Sample Collection Information

Date: 4/29/13 Time: 0905

Sample Type: [x] Primary [ ] Field Duplicate [ ] Rinse blank [ ] Trip Blank [ ] Field/Ambient Blank

If FD, please list Primary sample _____

Matrix: Sediment

Depth (ft bgs): 0 (beginning depth) - 0.5' (ending depth) Water Depth NA / embankment

Sample Method: Grab w/disposable scoops (dedicated equipment being used?) Y

Weather: Sunny Temperature: ~65

Sample Location ID: SD13-30 GPS (Northing/Easting): NA / No signal under pier.

CLP ID: VBRM7 GPS Datum: Sample between Bents +23 and +24

EPA split sample ID: SD13-30-0005

## Sediment Descriptions

**Color:** grayish-black

**Moisture:** Dry Sl. Moist Moist V.Moist (Wet)

**Major Description:** Clay (Silty Clay) Silt Clayey Sand Sandy Clay (Sand) Gravelly Sand (Gravel) Grvly Clay

**Minor Description:** Organic Mottled Plastic M.Plastic Nodules vf f coarse-grained Ang / SA / SR / Rounded Well / poorly / mod - sorted well / poorly / mod - cemented (Loose)

**Other Descriptors:**

Silty clay with sand and gravel and clumps of clay. Some shell hash. Slight sulfurous odor.

**Photographic Log:**

| Photo file name | Date | Initials | Subject of Photo |
|---|---|---|---|
| SD13-30-1 | 4/29/13 | L.L. | T.F. collecting sample |
| SD13-30-2 | 4/29/13 | L.L. | Sample in pan |

## Sample Parameters

| Parameters | Sample Containers |
|---|---|
| [x] Pesticides (EPA Method 8081A) | 1 x 40z jar |
| [x] TOC (Walkley-Black) | 1 gal ziplock |
| [ ] Percent solids (ASTM Method D2216) | |
| [ ] percent moisture (ASTM Method D2216) | |
| [x] grain size ((ASTM Method D4464)) | |
| [ ] specific gravity (ASTM Method D854) | |
| [ ] Atterberg limits ((ASTM Method D4318) | |

Sampling Notes: _____

Sampler Name: Tamara Frank

Sample ID on chain of custody: SD13-34-0005

# SAMPLE COLLECTION FORM

(complete one form per sample)

**Event Name: United Heckathorn Source ID**

## Sample Collection Information

Date: 4/29/13 Time: 0840

Sample Type: [X] Primary [ ] Field Duplicate [ ] Rinse blank [ ] Trip Blank [ ] Field/Ambient Blank

If FD, please list Primary sample _____

Matrix: Sediment

Depth (ft bgs): 0 (beginning depth) - 0.5 (ending depth) Water Depth NA / ambient

Sample Method: Grab with disposable scoops (dedicated equipment being used?) Y

Weather: Clear Temperature: ~ 60 °F

Sample Location ID: SD13-34 GPS (Northing/Easting): No signal under pier

CLP ID: Y8LH8 GPS Datum: ~~Sampled between Bents~~ L.L. +36 and +37.

EPA split sample ID: ~~SD13-~~ L.L. NA

## Sediment Descriptions

Color: grayish-brown

Moisture: Dry Sl. Moist Moist V.Moist (Wet)

Major Description: Clay Silty Clay (Silt) Clayey Sand Sandy Clay Sand Gravelly Sand Gravel Grvly Clay

Minor Description: Organic Mottled Plastic M.Plastic Nodules vf f (coarse-grained) Ang / SA / SR / Rounded

Well / poorly / mod - sorted well / poorly / mod - cemented (Loose)

Other Descriptors:

Silty Sand with gravel and some shells.

## Photographic Log:

| Photo file name | Date | Initials | Subject of Photo |
|---|---|---|---|
| SD13-34-1 | 4/29/13 | L.L. | T.F. collecting sample |
| SD13-34-2 | 4/29/13 | L.L. | " " |
| SD13-34-3 | 4/29/13 | L.L. | outfall spitting flowing @ Bent +37 |
| SD13-34-4 | 4/29/13 | L.L. | Sediment sample in pan |

## Sample Parameters

| Parameters | Sample Containers |
|---|---|
| [X] Pesticides (EPA Method 8081A) | 1 x 4oz jar |
| [X] TOC (Walkley-Black) | > 1 gal Ziplock |
| [ ] Percent solids (ASTM Method D2216) | |
| [ ] percent moisture (ASTM Method D2216) | |
| [X] grain size ((ASTM Method D4464)) | |
| [ ] specific gravity (ASTM Method D854) | |
| [ ] Atterberg limits ((ASTM Method D4318) | |

Sampling Notes: Sample collected at Bent +37 beneath observed outfall (~ 3 ft from N of outfall). ~~Outfall~~ Water observed flowing through shot circle. Water sample was collected for ~~conductivity~~ L.L. & TDS analysis @ EPA lab. TDS ≤ 2400 ppm based on EPA analysis which is brackish water.

Sampler Name: Tamara Frank

Sample ID on chain of custody: SD13-38-0005

# SAMPLE COLLECTION FORM

(complete one form per sample)

**Event Name: United Heckathorn Source ID**

## Sample Collection Information

Date: 4/29/13 Time: 0800

Sample Type: ☑ Primary ☐ Field Duplicate ☐ Rinse blank ☐ Trip Blank ☐ Field/Ambient Blank

If FD, please list Primary sample _____

Matrix: Sediment

Depth (ft bgs): 0 (beginning depth) - 0.5 (ending depth) Water Depth NA /embankment

Sample Method: Grab w/disposable scoops (dedicated equipment being used?) Y

Weather: Clear Temperature: ~60°F

Sample Location ID: SD13-38 GPS (Northing/Easting): No signal under pier

CLP ID: V8RM9 GPS Datum: Sample collected between Berts +50 and +51

EPA split sample ID: SD13-38-0005

## Sediment Descriptions

**Color:** dark brown

**Moisture:** Dry Sl. Moist Moist V.Moist (Wet)

**Major Description:** (Clay) Silty Clay (Silt) Clayey Sand Sandy Clay (Sand) Gravelly Sand (Gravel) Grvly Clay

**Minor Description:** Organic Mottled Plastic M.Plastic Nodules vf f coarse-grained Ang / SA / SR / Rounded Well / poorly / mod - sorted well / poorly / mod - cemented (Loose)

**Other Descriptors:**

Rocks/gravel with some clay, sand, and silt. Some biological activity observed

**Photographic Log:**

| Photo file name | Date | Initials | Subject of Photo |
|---|---|---|---|
| SD13-38-1 | 4/29/13 | L.L. | T.F. collecting grab e embankment |
| SD13-38-2 | 4/29/13 | L.L. | " " |
| SD13-38-3 | 4/29/13 | L.L. | Sediment in pan |
| SD13-38-4 | 4/29/13 | L.L. | " " |

## Sample Parameters

| Parameters | Sample Containers |
|---|---|
| ☑ Pesticides (EPA Method 8081A) | 1 x 40z jar |
| ☑ TOC (Walkley-Black) | > 1 gal Ziplock |
| ☐ Percent solids (ASTM Method D2216) | |
| ☐ percent moisture (ASTM Method D2216) | |
| ☑ grain size ((ASTM Method D4464)) | |
| ☐ specific gravity (ASTM Method D854) | |
| ☐ Atterberg limits ((ASTM Method D4318) | |

Sampling Notes: _____

Sampler Name: Tamara Frank

Station Home Page
Station Information
Tide / Water Level Data
Tide Predictions
Current Data
Meteorological Observations
Conductivity
PORTS
Operational Forecast System
Bench Mark Sheets
Datums
Harmonic Constituents
Sea Level Trends
Measurement Specifications

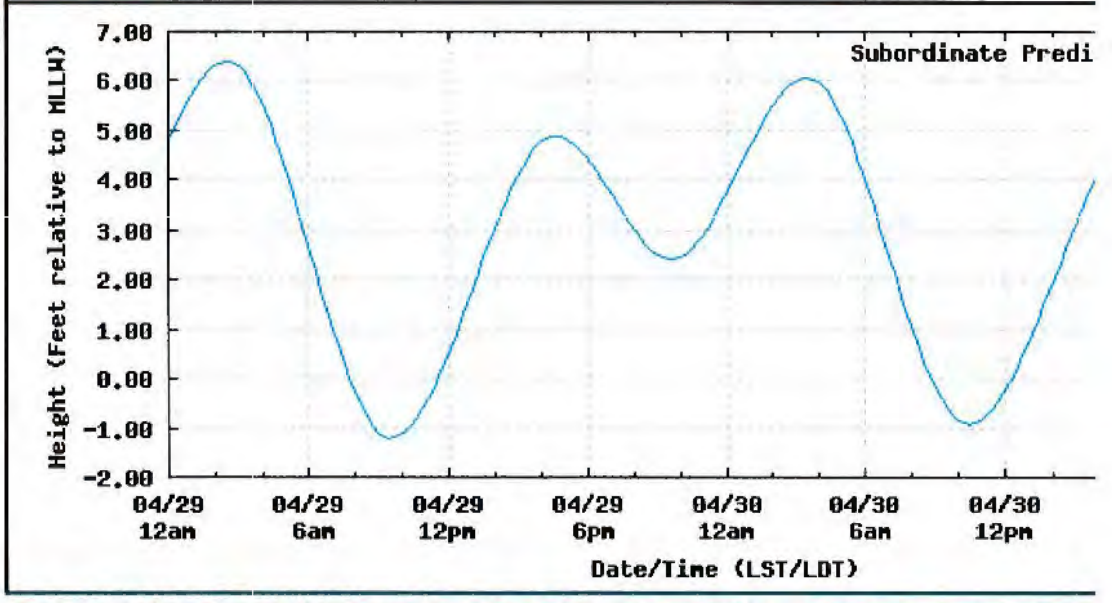
## Richmond Inner Harbor, CA StationId: 9414849

Referenced to Station: SAN FRANCISCO (Golden Gate) ( 9414290 )
Height offset in feet ( low:*0.98 high: * 1.04) Time offset in mins ( low:30 high: 16)

Daily Tide Prediction in **Feet**
Time Zone: **LST/LDT**
Datum: **MLLW**

◀ **2013/04/29 - 2013/04/30** ▶

Bacl




**Disclaimer: These data are based upon the latest information available as of the date of your request, published tide tables.**
**Note: For predictions of Subordinate stations, the solid blue line depicts a curve fit between the high a approximates the segments between.**

**Begin Date:** Apr 29 2013 ▶ **Time Range:** Daily **Time Zone:** LST/LDT **Data Units:** Feet Show Advanced Opt

Submit Reset

home | products | programs | partnerships | edu

Mobile Geographics Tides for iPhone

# Richmond Inner Harbor, San Francisco Bay, California
# Requested time: 2013-04-29 12:00 AM PDT

AdChoices
▶ NOAA Tide Tables
▶ High Tide Chart
▶ Tide

Seward / Anchorage COACH.
www.alaskacruisetransfer.com
Narrated Wildlife Tours or Shuttles ALL Day Tours with lunch and tram!
AdChoices

Save this tide table: subscribe (iCal) or download (WinDates or Mozilla)

SHARE

Richmond Inner Harbor, San Francisco Bay, California
37.9100° N, 122.3583° W

| | | | |
|---|---|---|---|
| 2013-04-29 | 2:41 AM PDT | 6.35 feet | High Tide |
| 2013-04-29 | 6:15 AM PDT | Sunrise | |
| 2013-04-29 | 9:35 AM PDT | -1.20 feet | Low Tide |
| 2013-04-29 | 4:44 PM PDT | 4.84 feet | High Tide |
| 2013-04-29 | 7:58 PM PDT | Sunset | |
| 2013-04-29 | 9:41 PM PDT | 2.42 feet | Low Tide |
| 2013-04-30 | 3:37 AM PDT | 6.01 feet | High Tide |
| 2013-04-30 | 6:14 AM PDT | Sunrise | |
| 2013-04-30 | 10:33 AM PDT | -0.92 feet | Low Tide |
| 2013-04-30 | 5:47 PM PDT | 4.87 feet | High Tide |
| 2013-04-30 | 7:59 PM PDT | Sunset | |
| 2013-04-30 | 10:56 PM PDT | 2.47 feet | Low Tide |
| 2013-05-01 | 4:40 AM PDT | 5.58 feet | High Tide |
| 2013-05-01 | 6:13 AM PDT | Sunrise | |
| 2013-05-01 | 11:35 AM PDT | -0.56 feet | Low Tide |
| 2013-05-01 | 6:50 PM PDT | 5.01 feet | High Tide |
| 2013-05-01 | 8:00 PM PDT | Sunset | |
| 2013-05-02 | 12:19 AM PDT | 2.31 feet | Low Tide |
| 2013-05-02 | 4:16 AM PDT | Last Quarter | |
| 2013-05-02 | 5:52 AM PDT | 5.15 feet | High Tide |
| 2013-05-02 | 6:11 AM PDT | Sunrise | |
| 2013-05-02 | 12:38 PM PDT | -0.20 feet | Low Tide |
| 2013-05-02 | 7:48 PM PDT | 5.22 feet | High Tide |
| 2013-05-02 | 8:01 PM PDT | Sunset | |
| 2013-05-03 | 1:39 AM PDT | 1.93 feet | Low Tide |

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## Time Control

Year: 2013 • Month: 4 • Day: 29 • Go

Note: predictions for some locations do not cover the full span of years. If your browser returns a blank page or a "no data" error, then the predictions

Station Home Page
Station Information
Tide / Water Level Data
Tide Predictions
Current Data
Meteorological Observations
Conductivity
PORTS
Operational Forecast System
Bench Mark Sheets
Datums
Harmonic Constituents
Sea Level Trends
Measurement Specifications

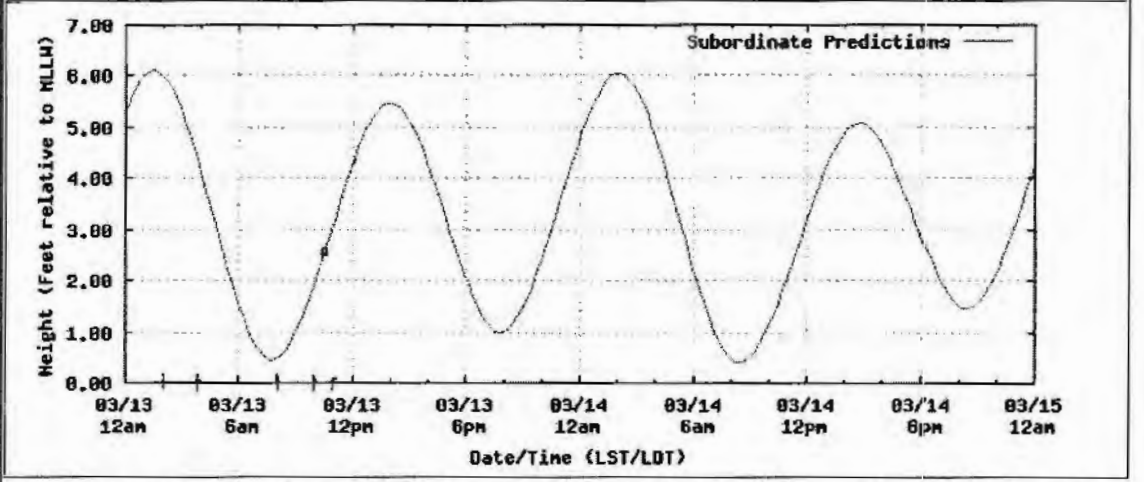
# Richmond Inner Harbor, CA StationId: 9414849

Referenced to Station: SAN FRANCISCO (Golden Gate) ( 9414290 )
Height offset in feet ( low:*0.98 high: * 1.04) Time offset in mins ( low:30 high: 16)

Daily Tide Prediction in **Feet**
Time Zone: **LST/LDT**
Datum: **MLLW**

◀ 2013/03/13 - 2013/03/14 ▶

Back to Station Listing
Bookmark
Help




**Disclaimer: These data are based upon the latest information available as of the date of your request, and may differ from the published tide tables.**

**Published Tide Tables Formats**
Annual PDF | Annual TXT | Annual XML

Get Adobe Reader

Printer Friendly

**High/Low Tide Predictions in Feet from 2013/03/13 - 2013/03/14**

Download: TXT XML

| Date | Day | Time | Hgt |
|---|---|---|---|
| 03/13 | Wed | 01:31 AM | 6.1 H |
| 03/13 | Wed | 07:43 AM | 0.46 L |
| 03/13 | Wed | 01:58 PM | 5.48 H |
| 03/13 | Wed | 07:47 PM | 0.99 L |
| 03/14 | Thu | 02:02 AM | 6.05 H |
| 03/14 | Thu | 08:25 AM | 0.41 L |
| 03/14 | Thu | 02:46 PM | 5.08 H |
| 03/14 | Thu | 08:24 PM | 1.45 L |

# Attachment 2
# Laboratory Chains of Custody

# E2 Consulting Engineers, Inc.

## CHAIN OF CUSTODY RECORD: UHSed_R9001

2013 Sediment Sampling

Project Name: United Heckathorn
Project Number: R13S55
Project Manager:
Sample Manager:
Cell Number:
Fax/Email:

| | |
|---|---|
| Container: | 4 oz glass jar |
| Preservatives: | 4C (+-2C) |
| Filtered: | n |
| Holding Time | 14 Days |

Ship To:
USEPA Region 9 Laboratory
1337 South 46th Street, Building 201
Richmond, CA 94804
510-412-2389
Sample Receiving

| SAMPLE ID | DATE | TIME | Matrix | Pesticides (SW8081A) | Number of Containers | COMMENTS |
|---|---|---|---|---|---|---|
| SD13-01-0005 | 3/13/13 | 1040 | Sed | X | 1 | |
| SD13-02-0005 | 3/13/13 | 1110 | Sed | X | 1 | |
| SD13-03-0005 | 3/13/13 | 1140 | Sed | X | 1 | |
| SD13-07-0005 | 3/13/13 | 1200 | Sed | X | 1 | |
| SD13-11-0005 | 3/13/13 | 1250 | Sed | X | 1 | |
| SD13-12-0005 | 3/13/13 | 1320 | Sed | X | 1 | |
| SD13-16-0005 | 3/13/13 | 1400 | Sed | X | 1 | |
| SD13-17-0005 | 3/13/13 | 1430 | Sed | X | 1 | |
| SD13-21-0005 | 3/13/13 | 1500 | Sed | X | 1 | |
| SD13-22-0005 | | | Sed | X | 1 | |
| ~~SD13-78-0005~~ SD13-0005 79 | 3/13/13 | 1500 | Sed | X | 1 | SD13-79-0005 |
| SD13-26-0005 | | | Sed | X | 1 | |
| | | | | TOTAL NUMBER OF CONTAINERS | 16 | |

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | Tamara Frank | 3/13/13 1645 |
| Relinquished by | | |
| Received by | | 3/13/13 1645 |
| Relinquished by | | |
| Received by | | |

Shipping Details
Method of shipment: hand delivered
Shipping Company:
On ice: yes / no:
Airbill No.:
Shipping Date:

Special Instructions:

Report Copy to:
Ruth Siegmund
ruthsiegmund@e2.com

# E2 Consulting Engineers, Inc.

## CHAIN OF CUSTODY RECORD: UHSed_R90429

**2013 Sediment Sampling**

Project Name: United Heckathorn
Project Number: R13S55
Project Manager:
Sample Manager:
Cell Number:
Fax/Email:

| | |
|---|---|
| Container: | 4 oz glass jar |
| Preservatives: | 4C (+-2C) |
| Filtered: | n |
| Holding Time | Days |

| SAMPLE ID | DATE | TIME | Matrix | Pesticides (SW8081A) | | Number of Containers | COMMENTS |
|---|---|---|---|---|---|---|---|
| SD13-30-0005 | 4/29/13 | 0905 | Sed | X | | 1 | |
| SD13-38-0005 | 4/29/13 | 0920 | Sed | X | | 1 | |
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| | | | | | | | |
| | | | | | TOTAL NUMBER OF CONTAINERS | 2 | |

Ship To:
USEPA Region 9 Laboratory
1337 South 46th Street, Building 201
Richmond, CA 94804
510-412-2389
Sample Receiving

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | Tamara Frank | 4/29/13 |
| Relinquished by | Tamara Frank | 4/29/13 |
| Received by | | |
| Relinquished by | | |
| Received by | | 4/29/13 1050 |

**Shipping Details**

Method of shipment: Hand delivered
Shipping Company:
On ice: yes / no:
Airbill No.: N/A
Shipping Date:

19°C

**Special Instructions:**

Report Copy to:
Ruth Siegmund
ruthsiegmund@e2.com

USEPA CLP Organics COC (LAB COPY)

DateShipped:

CarrierName:

AirbillNo:

CHAIN OF CUSTODY RECORD

Site #: CAD981436363

Case #: 43379

Cooler #:

No: 9-032813-140841-0005

Lab: KAP Technologies Inc.

Lab Contact: Rao Alsakani

Lab Phone: 281-367-0065

| Organic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Inorganic Sample # | For Lab use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RM4 | Sediment/ | Grab Power | CLP PEST | 1010 (4C (+-2C)) (1) | SD13-22-0005 | 4/29/13 1345 | | |
| Y8RM6 | Sediment/ | Grab | CLP PEST | 1011 (4C (+-2C)) (1) | SD13-26-0005 | 4/29/13 0930 | | |
| Y8RM7 | Sediment/ | Grab | CLP PEST | 1012 (4C (+-2C)) (1) | SD13-30-0005 | 4/29/13 0905 | | |
| Y8RM8 | Sediment/ | Grab | CLP PEST | 1013 (4C (+-2C)) (1) | SD13-34-0005 | 4/29/13 0940 | | |
| Y8RM9 | Sediment/ | Grab | CLP PEST | 1014 (4C (+-2C)) (1) | SD13-38-0005 | 4/29/13 0859 | ~~SD13-38-0005~~ | |

Special Instructions:

Shipment for Case Complete? N

Samples Transferred from Chain of Custody #

Analysis Key CLP PEST=CLP TCL Pesticides

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished by | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | [signature] | 4/30/13 | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

**USEPA CLP Organics COC (LAB COPY)**

DateShipped: 3/14/13
CarrierName: Fedex
AirbillNo: 8635 7985 7667

**CHAIN OF CUSTODY RECORD**

Case #: 43379
Cooler #:

**No: 9-031213-143450-0003**

Lab: KAP Technologies Inc.
Lab Contact: Rao Alsakani
Lab Phone: 281-367-0065

| Organic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Inorganic Sample # | For Lab Use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RL5 | Sed/ | Grab | CLP PEST | 1000 (4C (+-2C)) (1) | SD13-01-0005 | 3/13/13 1040 | | |
| Y8RL6 | Sed/ | Grab | CLP PEST | 1001 (4C (+-2C)) (1) | SD13-02-0005 | 3/13/13 1110 | | |
| Y8RL7 | Sed/ | Grab | CLP PEST | 1002 (4C (+-2C)) (1) | SD13-03-0005 | 3/13/13 1140 | | |
| Y8RL8 | Sed/ | Grab | CLP PEST | 1003 (4C (+-2C)) (1) | SD13-07-0005 | 3/13/13 1220 | | |
| Y8RL9 | Sed/ | Grab | CLP PEST | 1004 (4C (+-2C)) (1) | SD13-11-0005 | 3/13/13 1250 | | |
| Y8RM0 | Sed/ | Grab | CLP PEST | 1005 (4C (+-2C)) (1) | SD13-12-0005 | 3/13/13 1320 | | |
| Y8RM1 | Sed/ | Grab | CLP PEST | 1006 (4C (+-2C)) (1) | SD13-16-0005 | 3/13/13 1400 | | |
| Y8RM2 | Sed/ | Grab | CLP PEST | 1007 (4C (+-2C)) (1) | SD13-17-0005 | 3/13/13 1430 | | |
| Y8RM3 | Sed/ | Grab | CLP PEST | 1008 (4C (+-2C)) (1) | SD13-21-0005 | 3/13/13 1500 | | |
| ~~Y8RM4~~ | ~~Sed/~~ | ~~Grab~~ | ~~CLP PEST~~ | ~~1009 (4C (+-2C)) (1)~~ | ~~SD13-22-0005~~ | | | |
| Y8RM5 | Sed/ | Grab | CLP PEST | 1010 (4C (+-2C)) (1) | SD13-78-0005 | 3/13/13 1515 | | |
| ~~Y8RM6~~ | ~~Sed/~~ | ~~Grab~~ | ~~CLP PEST~~ | ~~1011 (4C (+-2C)) (1)~~ | ~~SD13-26-0005~~ | | | |
| ~~Y8RM7~~ | ~~Sed/~~ | ~~Grab~~ | ~~CLP PEST~~ | ~~1012 (4C (+-2C)) (2)~~ | ~~SD13-30-0005~~ | | | |
| ~~Y8RM8~~ | ~~Sed/~~ | ~~Grab~~ | ~~CLP PEST~~ | ~~1013 (4C (+-2C)) (1)~~ | ~~SD13-34-0005~~ | | | |
| ~~Y8RM9~~ | ~~Sed/~~ | ~~Grab~~ | ~~CLP PEST~~ | ~~1014 (4C (+-2C)) (1)~~ | SD13-38-0005 | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

Sample(s) to be used for Lab QC: ~~Y8RM7~~ Y8RM3

**Shipment for Case Complete? N**

**Samples Transferred From Chain of Custody #**

Analysis Key: CLP PEST=CLP TCL Pesticides

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished By | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| To Lab | Jamara Jack | 3/14/13 | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

# E2 Consulting Engineers, Inc.

**CHAIN OF CUSTODY RECORD: UHSed_PTS001**

**2013 Sediment Sampling**

Project Name: United Heckathorn
Project Number:
Project Manager:
Sample Manager:
Cell Number:
Fax/Email:

| | | | | Container: | Ziplock Bag | Ziplock Bag | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Preservatives: | None | None | | | |
| | | | | Filtered: | n | n | | | |
| | | | | Holding Time | 180 Days | 180 Days | | | |
| SAMPLE ID | DATE | TIME | Matrix | | Grain Size (D4464) | TOC (Walkley-Black) | | Number of Containers | COMMENTS |
| SD13-01-0005 | 3/13/13 | 1040 | Sed | | X | X | | 1 | |
| SD13-02-0005 | 3/13/13 | 1110 | Sed | | X | X | | 1 | |
| SD13-03-0005 | 3/13/13 | 1140 | Sed | | X | X | | 1 | |
| SD13-07-0005 | 3/13/13 | 1220 | Sed | | X | X | | 1 | |
| SD13-11-0005 | 3/13/13 | 1250 | Sed | | X | X | | 1 | |
| SD13-12-0005 | 3/13/13 | 1320 | Sed | | X | X | | 1 | |
| SD13-16-0005 | 3/13/13 | 1400 | Sed | | X | X | | 1 | |
| SD13-17-0005 | 3/13/13 | 1430 | Sed | | X | X | | 1 | |
| SD13-21-0005 | 3/13/13 | 1500 | Sed | | X | X | | 1 | MS/MSD on TOC |
| ~~SD13-22-0005~~ | TF 3/13/13 | | Sed | | X | X | | ~~1~~ | |
| ~~SD13-26-0005~~ | TF | | Sed | | X | X | | ~~1~~ | |
| ~~SD13-30-0005~~ | | | Sed | | X | X | | ~~1~~ | ~~MS/MSD on TOC~~ TF 3/13/13 |
| | | | | | | | TOTAL NUMBER OF CONTAINERS | 14 9 | |

Ship To:
PTS Laboratories, Inc.
8100 Secura Way
Santa Fe Springs, CA 90670
562-347-2504
Sample Receiving

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | Tamara Frank | 3/14/13 1200 |
| Relinquished by | | |
| Received by | | |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment: fedex overnight
Shipping Company:
On ice: (yes) no:
Airbill No.: 8635 7985 7656
Shipping Date: 3/14/13

**Special Instructions:**

Report Copy to:
Ruth Siegmund
ruthsiegmund@e2.com

E2 Consulting Engineers, Inc.

# CHAIN OF CUSTODY RECORD: UHSed_PTSD429

2013 Sediment Sampling

| Project Name: United Hackathorn | Container: | Ziplock Bag | Ziplock Bag | | | |
|---|---|---|---|---|---|---|
| | Preservatives: | None | None | | | |
| Project Number: | | | | | | |
| Project Manager: | Filtered: | n | n | | | |
| Sample Manager: | Holding Time | 180 Days | 180 Days | | | |
| Cell Number: | | Grain Size (D4464) | TOC (Walkley-Black) | | Number of Containers | Ship To: PTS Laboratories, Inc. 8100 Secura Way Santa Fe Springs, CA 90670 562-347-2504 Sample Receiving |
| Fax/Email: | | | | | | |
| SAMPLE ID | DATE TIME Matrix | | | | | COMMENTS |
| SD13-22-0005 | 4/29/13 1145 Sed | X | X | | 1 | |
| SD13-26-0005 | 4/29/13 0930 Sed | X | X | | 1 | |
| SD13-30-0005 | 4/29/13 0905 Sed | X | X | | 1 | |
| SD13-34-0005 | 4/29/13 0840 Sed | X | X | | 1 | |
| SD13-38-0005 | 4/29/13 0800 Sed | X | X | | 1 | |
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| | | | | | | |
| | | | | TOTAL NUMBER OF CONTAINERS | 5 | |

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | | 4/29/13 1800 |
| Received by | | |
| Relinquished by | | |
| Received by | | |

Shipping Details

Method of shipment: FedEx 1st Overnight

Shipping Company:

On ice: yes / no:

AirBill No.:

Shipping Date:

Special Instructions:

Report Copy to:

Ruth Siegmund

ruthsiegmund@e2.com

# Attachment 3
# Photograph Log

Photograph 1: SD13-01-0005 in the Ekman sampler

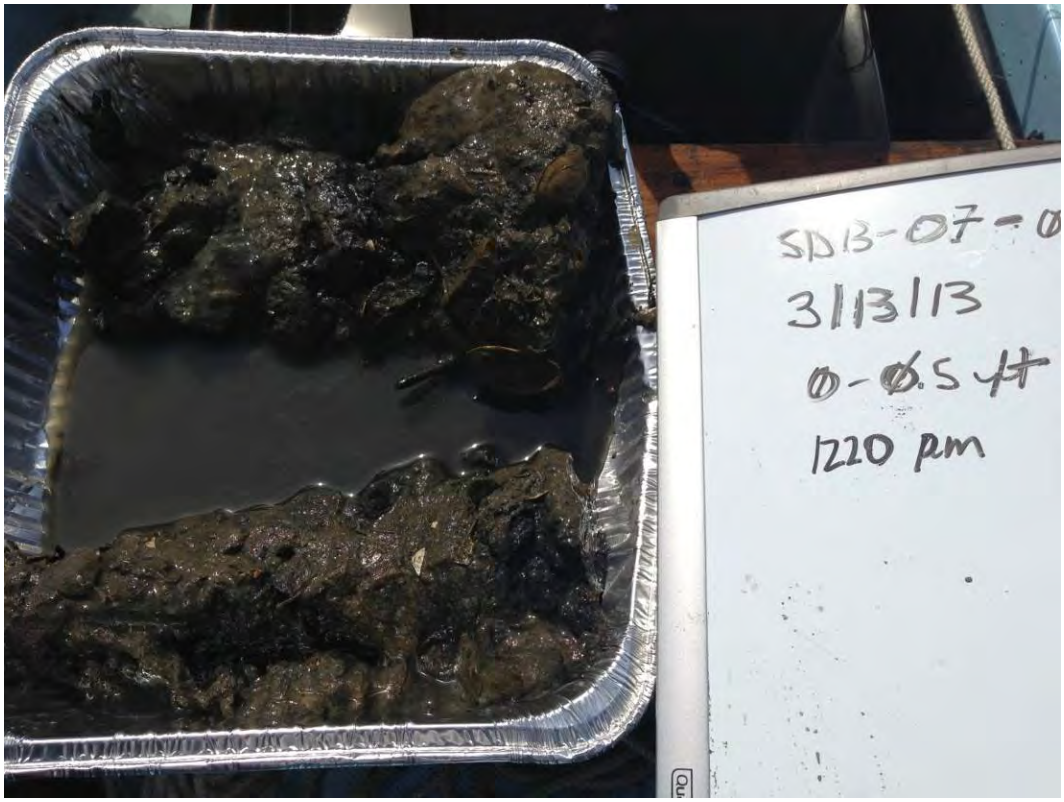
Photograph 2: SD13-01-0005 combined sample from two partially filled Ekman samples

Photograph 3: SD13-02-0005 in the Ekman sampler

Photograph 4: SD13-03-0005 in the Ekman sampler

Photograph 5: SD13-03-0005 combined material from Ekman samples

Photograph 6: SD13-07-0005 in the Ekman sampler



Photograph 7: SD13-07-0005 sample from successful deployment of Ekman sampler

Photograph 8: SD13-11-0005 in the Ekman sampler

Photograph 9: SD13-11-0005 sample from successful deployment of Ekman sampler

Photograph 10: SD13-11-0005 closeup showing small black specs uniformally distributed

Photograph 11: SD13-12-0005 combined sample from three partially filled Ekman samples

Photograph 12: SD13-16-0005 combined sample from partially filled Ekman samples. Clay clumps were present in the sample.

Photograph 13: SD13-17-0005 in Ekman sampler.

Photograph 14: SD13-21-0005 in Ekman sampler.

Photograph 15: SD13-21-0005 showing closeup of clay clump assumed to be Older Bay Mud.

Photograph 16: SD13-22-0005 showing composited samples from Ekman Sampler.

Photograph 17: SD13-26 showing embankment. Red arrow shows location of sample.

Photograph 18: SD13-26-0005 showing composited samples from Ekman Sampler.

Photograph 19: SD13-30 showing embankment and sampling location.

Photograph 20: SD13-30-0005 showing composited sample.

Photograph 21: SD13-34 showing embankment looking north.

Photograph 22: SD13-34 showing embankment looking south during sampling. Red arrow shows seep.

Photograph 23: SD13-34 showing seep at bent number 37.

Photograph 24: SD13-34-005 showing composited sample.

Photograph 25: SD13-38 showing embankment.

Photograph 26: SD13-38-005 showing composited sample.

# Attachment 4
# Bent Number 37 Seep Sampling Photograph, Field Notes, and Laboratory Chains of Custody

Photograph 1: Closeup of seep at bent number 37 as sampled on July 24, 2013.

7/24/13 United Heckathorn. Seep Sample
0 Arrive, meet Tony
0 In boat
at 37 blocked by barge
er at bent 39, walk over to seep

Collect sample
2x 1L Amber for Pest unfiltered
2x 1L Amber for Pest filtered
3x 250mL for TSS

pH = 7.01
Temp = 20.3°C
EC = 5.534 mS/cm
"TDS" = 0.0034 kg/L

Bottle fill time 1L (about 30% to 50% of flow captured
12 sec
13 sec
12 sec
14 sec

ENVIRONMENTAL PROTECTION AGENCY
Region 9 Laboratory

# CHAIN OF CUSTODY RECORD

1337 S. 46th St., Bldg. 201
Richmond, CA 94804-4698

| PROJ. NO. | PROJECT NAME | NO. OF CON-TAINERS | 155 | REMARKS |
|---|---|---|---|---|
| | United Heckathorn | | | |

SAMPLERS: *(Signature)* Will Fell William Frohlich

| DATE | TIME | MATRIX | COMP. | GRAB | SAMPLE IDENTIFICATION | NO. OF CON-TAINERS | 155 | REMARKS |
|---|---|---|---|---|---|---|---|---|
| 7.24.13 | 0745 | SW | | ✓ | SW13-P4-16 | 3 | X | |

| Relinquished by: *(Signature)* | Date / Time | Received by: *(Signature)* | Relinquished by: *(Signature)* | Date / Time | Received by: *(Signature)* |
|---|---|---|---|---|---|
| Will Fell | 7.24.13 0905 | | | | |
| Relinquished by: *(Signature)* | Date / Time | Received by: *(Signature)* | Relinquished by: *(Signature)* | Date / Time | Received by: *(Signature)* |
| | | | | | |
| Received for Laboratory by: *(Signature)* | Date / Time | Temp. | Seals Intact (Y/N) | Conditions / Remarks | |
| R9Lab | 7/24/13 0905 | 20C | Y hand delivered | Hand delivered | |

Distribution: Original Accompanies Shipment; Copy to Coordinator Field Files

9-1033

# E2 Consulting Engineers, Inc.

**CHAIN OF CUSTODY RECORD: UHSW_V001**

**2013 Seep Sampling**

Project Name: United Heckathorn
Project Number:
Project Manager:
Sample Manager: Bill Frohlich
Cell Number: 925 209.0881
Fax/Email: bill.frohlich@ch2m.com

| | |
|---|---|
| Container: | 1 L Amber Glass |
| Preservatives: | 4C (+-2C) |
| Filtered: | n |
| Holding Time | 7 Days |

| SAMPLE ID | DATE | TIME | Matrix | Pesticides (E1699) | | Number of Containers | COMMENTS |
|---|---|---|---|---|---|---|---|
| SW13-P4-15 | 7.24.13 | 0745 | SW | X | 2 | 1 | Filter on Receipt, Additional volume for MS/MSD 2 |
| SW-P4-16 | 7.29.13 | 0745 | SW | X | | 2 | Nt Filter |
| | | | | | | | |
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| | | | | | | | |
| | | | | | TOTAL NUMBER OF CONTAINERS | 1 | |

Ship To:
Vista Analytical Laboratory
1104 Windfield Way
El Dorado Hills, CA 95762
916-673-1520
Sample Receiving

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | Will Lill | 7.24.13 0745 |
| Relinquished by | Will Lill | 7.29.13 1115 |
| Received by | | |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment: Fed Ex
Shipping Company:
On ice: (yes / no)
Airbill No.: 7963 0645 4779
Shipping Date:

**Special Instructions:**

Report Copy to:
Ruth Siegmund
ruth.siegmund@e2.com

# Chain of Custody Anomaly/Sample Acceptance Form

Vista Analytical Laboratory

CH2M Hill
Brenda McConathy
brenda.mcconathy@ch2m.com
(415) 294-0446

Workorder Number: 1300533
Date Received: 25-Jul-13 08:41
Documented by/date: AEW 7/25/13

Please review the following information and complete the Client Authorization section. To comply with NELAC regulations, we must receive authorization before proceeding with sample analysis.

Thank you,

Martha Maier
mmaier@vista-analytical.com
916-673-1520

[X] Sample IDs on Chain of Custody do not match Sample Container Labels

| Chain of Custody ID | Container Label ID |
|---|---|
| SW-P4-16 | SW13-P4-16 |

**Client Authorization**

Proceed with Analysis: (YES) NO Signature and Date Brenda McConathy

Client Comments/Instructions Please assign SW13-P4-16F to filtered result

# Summary of Field Activities to Support the Source Identification Study United Heckathorn Superfund Site, Richmond, California

PREPARED FOR: United States Environmental Protection Agency Region 9

PREPARED BY: CH2M HILL

DATE: July 25, 2013

PROJECT NUMBER: USEPA CONTRACT NO. EP-S9-08-04
USEPA WORK ASSIGNMENT NO. 025-RIFS-09R3
CH2M HILL PROJECT NO. 385441

## Background

Sediment core samples were collected as part of the sediment sampling activities described in the Final Focused Feasibility Study Data Gaps Sampling and Analysis Plan Addendum #2 Source Identification Study United Heckathorn Superfund Site (SAP) (CH2M HILL, 2013). A total of twenty-four sediment cores were collected from locations positioned on a sampling grid in the Lauritzen Channel, and three sediment cores were collected in the Santa Fe Channel. The cores were advanced to collect intact samples of Younger Bay Mud (YBM), down to the contact with the Older Bay Mud (OBM). The target depth of penetration was the effective length of the core barrel (7.5 feet) or refusal, which was defined as the depth where the rate of core penetration approached zero.

This technical memorandum summarizes the vibracore sediment sampling activities on April 1 – 5, 2013. The results will be used to support the Source Identification Study and Tier 2 Sediment Transport Study for the site.

## Sample Collection Activities

The sampling platform, provided by Dixon Marine Services, was mobilized on April 1, 2013. Sediment cores were collected at all 27 of the proposed sample locations in the Lauritzen and Santa Fe Channels on April 2 and 3, 2013.

Target coordinates for the sampling locations were loaded into the on-board navigation system. The platform was anchored at each location by tying off to above water anchor points (e.g., pier supports or anchored barges) on the port and starboard sides of the bow and maintaining position using the boat engine to tension the lines. The water depth was recorded using a weighted disk attached to the end of a spooled measuring tape (lead line) and the as-sampled location was recorded using differential global positioning system (GPS). Sampling information including the time, date, water depth,

tide height, core penetration, and recovery was recorded in the log book and on the core log sheets. The cores were labeled with indelible marker showing the core identification number and orientation.

The cores were collected using a Rossfelder P-5 electric vibracore head equipped with a metal 4-inch core barrel fitted with a 3.75-inch interior diameter, clear polycarbonate liner. A stainless steel driller's basket (core catcher) and nose cone were installed in the end of the core barrel to retain the core during penetration and recovery. The vibracore was mounted on *M/V Walter Marie*, a 32-foot work vessel equipped with a bow-mounted A-frame used to deploy and retrieve the vibracore. The vibracore was positioned on the bottom of the canal within 9 feet of the proposed location. The vibracore was advanced to 7.5 feet (the effective length of the core barrel) or refusal. The vibracore was retrieved, and the core liner was removed from the core barrel. If recovery was less than 70 percent of penetration, or if no plug of OBM was observed in the core catcher at locations with less than 7.5 feet of penetration, a second core was attempted. The core barrel was cleaned with an Alconox solution, rinsed with site water, loaded with a new, clean liner and prepared for the next location. Figure 1 presents the locations of the 27 sediment core samples collected (Figure 1 is located at the end of this technical memorandum).

At locations SD13-05 and SD13-09, where cores were collected for fine-interval sampling, the cores were maintained upright during the entire collection process. During retrieval, a cap was placed over the core catcher at the bottom of the liner, the connection between the catcher and the barrel was loosened, and the exterior core barrel was mechanically lifted while a worker held the capped liner upright. This procedure ensured that the liner remained vertical during collection, minimizing the disturbance of the soft upper sediment/water interface.

The cores were transported to the U.S. Environmental Protection Agency (EPA) Region 9 Laboratory on April 2 and 3, 2013 where they were placed in a walk-in refrigerator and allowed to settle overnight before processing.

## Sample Processing Activities

The sediment cores were processed from April 3 through April 5, 2013 in the shipping bay of the Region 9 Laboratory. An area of the bay was covered with heavy plastic to contain any spilled mud and debris. A table was covered in plastic and aluminum foil strips to help contain any flowable mud that was present in the top of the core. Whole cores were allowed to settle and consolidate overnight in a refrigerator maintained at 4°C, and were removed from the refrigerator immediately before processing. The core was held upright in a tub within the plastic-lined processing area and a small cut was made in the liner approximately ½ inch above the sediment-water interface to allow the overlying water to slowly drain out. When the top of the core was free of water, the cut was completed through the core liner and the core cap was reinstalled on the cut end of the liner.

The intact core was then carefully placed on the table. Two parallel cuts were made in the core liner, each starting at the bottom of the core and moving toward the top,

allowing a section of the liner to be removed exposing the complete core or allowing the core to be split in half longitudinally, allowing for the interior sediment structure to be observed. Any material that had smeared along the outer edge of the core or along the surface where the core was sliced in half was scraped away using disposable scoops to minimize cross-contamination and allow photographic documentation of the core. Photos were taken at 2-foot intervals along the entire core; each photo included a measuring tape and white board with sample information to allow identification of photos. The core were visually characterized for sediment type, color, moisture content, texture, grain size and shape, consistency, visible evidence of contamination, odor, and any other observations. The colors were designated using a Munsell color chart. Odors were categorized as no odor, unclassified odor, sulfur-like odor and/or petroleum hydrocarbon-like odor.

A summary of key field data and observations is provided in Table 1 (all tables are located at the end of this technical memorandum). OBM was observed in 15 cores and evidence of the sand layer placed in the channel in 1997 was observed in 9 cores. At one location (SD13-20), the core barrel was advanced to 7.5 feet without exhibiting refusal or penetrating OBM. Generally, the YBM was observed to be wet to very wet, black or dark gray, silts and clays. Where observed, the sand layer was typically dark gray, medium sand that was firm to hard and generally dry to slightly moist.

After the photos were taken and the cores were characterized, the cores were sub-sampled for chemical and physical analyses. Sediments from the targeted sample interval were removed using clean, disposable scoops and transferred to a disposable aluminum pan, where they were thoroughly mixed and transferred to pre-labeled sample containers. The samples collected for chemical and physical analyses are summarized in Table 2.

Sample containers were labeled with the date and time that the core was sub-sampled. Labels were covered with clear tape. The containers to be submitted for chemical analyses were placed in a freezer and the containers to be submitted for physical analyses were placed in a refrigerator until shipment.

All sediment that remained in the core liners and all used sampling equipment and personal protective equipment (PPE) were transferred to buckets which were then transferred to appropriately-labeled investigation-derived waste (IDW) drums storied at the Levin Richmond Terminal Corporation in a designated IDW storage area.

Samples were collected at each location for pesticides analysis (EPA Method 8081A) and total organic carbon (TOC) (Walkley-Black method). Samples were submitted from selected locations for Atterberg limits (ASTM Method D4318), specific gravity (ASTM Method D854), percent solids (ASTM Method D2216), and grain size (ASTM Method D4464). Samples were stored on ice inside a cooler until the completion of the sampling activities. Samples submitted to the EPA Contract Laboratory Program (CLP) laboratory, KAP Technologies, Inc., included 111 normal samples collected for pesticides analysis and 11 samples submitted as field duplicates. Split samples from 14 locations were submitted to the EPA Region 9 Laboratory. Physical parameters included 66 grain size, 9 Atterberg Limits, 27 specific gravity, percent solids,

and 109 TOC submitted to PTS Laboratories, Inc. Samples for pesticide analyses were shipped to KAP laboratory and samples for physical parameters were shipped to PTS Laboratories via FedEx Priority Overnight for Saturday delivery on April 5. All samples were shipped on ice. Split samples for pesticide analyses by the Region 9 Laboratory were hand delivered on April 5. Laboratory Chains-of-Custody are included in Attachment 1.

The sediment sample collection forms are presented in Attachment 2 and the photograph log for this sampling event is presented in Attachment 3. Selected photos of the sample collection are provided within this document; however, the complete photograph log will provided electronically to the EPA.

## References

CH2M HILL. 2013. Final *Focused Feasibility Study Data Gaps Sampling and Analysis Plan Addendum #2 Source Identification Study United Heckathorn Superfund Site.* February.

# Tables

TABLE 1
Summary of Vibracore Observations - 2013 Source Identification Investigation
*United Heckathorn Superfund Site, Richmond, California*

| Location | Field Longitude (X) | Field Latitude (Y) | Measured Water Depth (ft) | Observed/Verified Tide (ft MLLW)[1] | Penetration (ft) | Recovery (ft) | Refusal (Y/N) | Core Barrel Advanced to Full Length (Y/N) | OBM in core (Y/N) | Thickness of YBM (Corrected) (ft)[2] | Elevation of YBM Surface (ft MLLW) | Elevation of OBM[3] (ft MLLW) | Evidence of 1997 Benthic Sand Layer (Y/N) | Additional Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SD13-4 | 6023234.68 | 2164441.03 | 14.6 | 0.74 | 7.17 | 1.50 | Y | N | N | 7.17 | -13.86 | *-21.0* | N | Rocks and riprap were observed along the seafloor on west side of channel. Three attempts at this location all resulted sufficient penetration but minimal recovery. The vibracore head continued to slip downslope due to unfavorable bottom conditions. Attempt 3, located approximately 9.8' east of the target location was retained for sampling. Core was black silt and sand over gravel; petroleum hydrocarbon odor noted, stronger in gravel. The core catcher contained OBM. |
| SD13-5 | 6023274.05 | 2164435.49 | 17.7 | 0.36 | 5.50 | 4.10 | Y | N | N | 4.75 | -17.34 | *-22.1* | N | Fine interval core. Entire core dominantly sticky black clay/silt with trace to minor sand. Increased sand and gravel at bottom of core. Strong hydrocarbon-type odor at 3.3' below TOC. |
| SD13-6 | 6023328.85 | 2164430.36 | 13.5 | 2.41 | 5.33 | 5.00 | Y | N | N | 5.33 | -11.09 | *-16.4* | Y | The first attempt at this location hit a rocky bottom. The boat was moved into deeper water slightly to the west of the proposed location. When the core liner was removed from the core barrel, it was noted that the core catcher contained rocks, not OBM. Since no OBM was observed a third attempt was made to collect a core including the YBM/OBM interface. The third attempt had approximately 4' penetration which was stopped by rock. The senior field staff confirmed that 2 attempts at the offset location were sufficient and the third attempt was discarded. Below 2 feet, core is dominantly sand, increasing gravel and decreasing silt/clay content with depth to 4.2 feet. Below 4.2 feet to BOC no gravel and less clay/silt. |
| SD13-8 | 6023181.39 | 2164245.71 | 19.6 | -0.21 | 7.17 | 5.60 | N | Y | Y | 5.57 | -19.81 | -25.4 | N | Transition zone to OBM from 4 to 4.3 feet from TOC. |
| SD13-9 | 6023248.50 | 2164238.21 | 20.7 | -0.37 | 6.00 | 5.50 | N | N | Y | 3.75 | -21.07 | -24.8 | Y | This location was identified as the fine interval sample. The first core retrieved was allowed to rest horizontally for a brief period of time, during barge movement. Since this location is designated as a fine interval sample, a second core was collected. Nose cone was cut off during processing and not included in processed length. Sand layer observed above 0.6 feet of consolidated, black, clay/silt YBM. Due to OBM observation in first core, second core was stopped once a depth of 6 feet had been reached to minimize consolidation of YBM. |
| SD13-10 | 6023307.69 | 2164238.02 | 12.4 | -0.12 | 6.67 | 6.60 | Y | N | Y | 1.87 | -12.52 | -14.4 | N | Minor sand was observed from 0.9 to 1.8 feet below TOC. |
| SD13-13 | 6023160.53 | 2164049.90 | 14.1 | 1.06 | 7.00 | 2.50 | Y | N | Y | 5.60 | -13.04 | -18.6 | N | Sandy silt/clay observed in top 0.6 feet. Penetration was 7' and the operator felt the vibracore tilt when OBM was encountered. OBM was encountered, so despite a low recovery, no additional attempts were required. Since vibracore head tipped over the penetration is overestimated. |
| SD13-14 | 6023212.77 | 2164041.92 | 20.2 | 0.63 | 6.67 | 6.40 | Y | N | Y | 1.17 | -19.57 | -20.7 | N | Top 0.4 feet of core included coarse, dark gray to black sand with clay and silt, approximately 80% sand. |
| SD13-15 | 6023278.51 | 2164034.84 | 14.3 | 0.1 | 6.25 | 4.90 | Y | N | Y | 3.35 | -14.20 | -17.6 | Y | Dark gray to black medium sand (drier than interval above) observed from 1.6 to 2 feet from TOC. |
| SD13-18 | 6023087.22 | 2163850.25 | 21.6 | 2.05 | 6.42 | 6.50 | Y | N | Y | 1.00 | -19.55 | -20.6 | Y | Observed approximately 1 inch of dark gray, medium sand right above OBM. |
| SD13-19 | 6023185.28 | 2163842.50 | 31.5 | 2.26 | 6.00 | 6.10 | Y | N | Y | 4.00 | -29.24 | -33.2 | Y | From 1.8 to 2.7 feet below TOC transition from black clay/silt to medium, dark gray firm, slightly moist sand - decreasing fines with depth noted. From 2.7 to 4 feet below TOC observed dark gray, fine to medium sand, dry and hard. Minor shell hash from 2.7 to 3 feet. Transition to OBM at 4 feet below TOC. |
| SD13-20 | 6023255.11 | 2163837.51 | 25.1 | 1.7 | 7.25 | 5.17 | N | Y | N | 7.25 | -23.40 | NA | N | YBM included black silt/clay with pockets of gravel or gravel with fine sand throughout. |
| SD13-23 | 6023066.85 | 2163651.19 | 21.4 | 1.21 | 4.33 | 3.70 | Y | N | Y | 4.33 | -20.19 | -24.5 | Y | Sand observed from 0.9 to 1.5 feet from TOC - medium, dark gray, trace to minor fines and trace shell hash. Below 1.5 feet black silt/clay was observed interspersed with hard, fat gray-brown clay. No clear transition observed and there appeared to be fingers of silt/clay that comprises YBM into the firmer, drier OBM. From 3 to 3.7 feet, there was less of the black silt/clay. Slight petroleum hydrocarbon odor (observed as diesel-like odor) was noted at bottom of core. |
| SD13-24 | 6023139.40 | 2163642.13 | 32.5 | 0.78 | 6.92 | 6.00 | Y | N | Y | 0.92 | -31.72 | -32.6 | N | Top 0.7 feet of core was soft, black clay/silt (clearly YBM) and from 0.7 to 4.1 feet below TOC, sediment appeared to be OBM; however from 4.1 to 5.2 feet below the TOC, material became wet again and gravel observed at bottom of this interval. From 5.2 to 6.0 the sediment was soft clay/silt with gravel and pockets of black silt/clay (presumed to be YBM sediment). |
| SD13-25 | 6023211.18 | 2163646.43 | 33.9 | 1.59 | 6.83 | 5.90 | Y | N | N | 6.83 | -32.31 | *-39.1* | Y | Sand observed in bottom interval of core (5.3 to BOC at 5.9 feet). Transition from YBM to sand was abrupt, material below sand interval not observed. |
| SD13-27 | 6022989.83 | 2163456.36 | 13.2 | -0.2 | 5.00 | 3.10 | Y | N | N | 5.00 | -13.40 | *-18.4* | N | Core appeared to be highly disturbed and contained multiple, relatively thin, layers of sediment ranging from black clay/silt and poorly sorted sand and coarse gravel to very hard, dry clay with gravel. |
| SD13-28 | 6023091.65 | 2163452.79 | 34.3 | 0.22 | 6.50 | 6.00 | Y | N | N | 6.50 | -34.08 | *-40.6* | N | At 3 feet from TOC, an abrupt transition in moisture content and firmness observed. Pockets of dark olive-brown to dark gray silt/clay were observed between 4 and 6 feet. |
| SD13-29 | 6023189.47 | 2163438.66 | 34.2 | 0.06 | 6.67 | 6.20 | Y | N | N | 6.67 | -34.14 | *-40.8* | N | Entire core silt/clay with trace fine sand (YBM). PHC odor noted throughout, but was notably stronger near bottom of core. At 5.7 feet from TOC, increased gravel and sand content observed, but there was not a distinct "sand" layer. |
| SD13-31 | 6022972.31 | 2163263.24 | 14.6 | -0.27 | 4.83 | 5.00 | Y | N | Y | 0.00 | N/A | -15.5 | N | Entire core was OBM; the top 2 feet contained areas of mottled dark gray clay/silt and appeared disturbed compared to the sediment below 2 feet. |
| SD13-32 | 6023070.70 | 2163251.79 | 33.5 | -0.3 | 6.75 | 6.10 | Y | N | N | 6.75 | -33.79 | *-40.5* | N | Entire core silt/clay with trace fine sand (YBM). PHC odor noted throughout. Notable transition at 3 feet; sediment above is very cohesive, wet, and sticky; below material is still silt/clay but less wet. At 4.4 feet from TOC observed a clast of black, organic rich material. |
| SD13-33 | 6023168.50 | 2163239.19 | 33.7 | -0.2 | 6.92 | 6.20 | Y | N | N | 6.92 | -33.90 | *-40.8* | N | Entire core is black silt/clay (YBM) with pockets of firmer gray-brown clay observed below 2 feet. |
| SD13-35 | 6022947.27 | 2163061.12 | 30.7 | 0.62 | 6.58 | 5.80 | Y | N | Y | 6.58 | -30.08 | -36.7 | Y | Medium, dark gray sand observed from 2.6 to 2.9 feet from TOC and from 3.4 to 4.6 feet from TOC; trace shell hash observed in lower interval. From 4.6 feet to BOC soft, wet, black silt clay. Plug of OBM observed at very bottom of core. |
| SD13-36 | 6023044.53 | 2163055.96 | 36.5 | 1.71 | 6.58 | 6.50 | Y | N | N | 6.58 | -34.79 | *-41.4* | Y | Sand layer observed from 4.3 to 4.5 feet and 5.2 to 5.4 feet below TOC. Remainder of core clay/silt with varying degrees of firmness and moisture (all YBM). |
| SD13-37 | 6023145.91 | 2163043.31 | 35.3 | -0.19 | 6.58 | 6.00 | Y | N | N | 6.58 | -35.49 | *-42.1* | N | Gravel and rocks noted at bottom of core during processing. |

TABLE 1
Summary of Vibracore Observations - 2013 Source Identification Investigation
*United Heckathorn Superfund Site, Richmond, California*

| Location | Field Longitude (X) | Field Latitude (Y) | Measured Water Depth (ft) | Observed/Verified Tide (ft MLLW)[1] | Penetration (ft) | Recovery (ft) | Refusal (Y/N) | Core Barrel Advanced to Full Length (Y/N) | OBM in core (Y/N) | Thickness of YBM (Corrected) (ft)[2] | Elevation of YBM Surface (ft MLLW) | Elevation of OBM[3] (ft MLLW) | Evidence of 1997 Benthic Sand Layer (Y/N) | Additional Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SD13-39 | 6022756.43 | 2162979.33 | 40 | 4.06 | 5.58 | 4.90 | Y | N | Y | 4.08 | -35.94 | -40.0 | N | From 4.8 to 5.2 feet below TOC a layer of coarse, angular gravel with sand and silt observed; YBM present below this layer. At 5.6 feet below TOC there is a layer of black, organic rich material, approximately 3/8" thick that had a strong, chemical-type odor. |
| SD13-40 | 6022921.50 | 2162662.19 | 41.5 | 3.07 | 4.92 | 4.00 | Y | N | Y | 2.92 | -38.43 | -41.4 | N | Penetration likely overestimated due to the very soft nature of the surface sediment. From 3 to 3.4 feet the OBM contained what appeared to be black inclusions of YBM. |
| SD13-41 | 6023057.92 | 2162400.50 | 39.1 | 2.25 | 6.42 | 6.50 | Y | N | Y | 3.92 | -36.85 | -40.8 | N | Transition from YBM to OBM observed at 4 feet below TOC. From 4 to 5 feet the clay was broken into angular, gravel-sized clumps, from 4.9 to 5 feet this transitioned into a hard, dark gray clay. |

Notes:
1. Verified tide data from National Oceanographic and Atmospheric Adminstration Station 9414863, Richmond, California. Accessed May 6, 2013.
2. Thickness of the YBM has been corrected to account for less than 100 percent core recovery.
3. Where OBM was not directly observed in cores that met refusal, the inferred elevation of the OBM surface was calculated by subtracting the corrected thickness of YBM from the YBM surface elevation. The inferred values are italicized.
BOC - bottom of core
ft - feet
MLLW - mean lower low water
N/A - not applicable
OBM - Old Bay Mud
TOC - top of core
YBM - Young Bay Mud

TABLE 2
Summary of Samples Collected from Sediment Cores - 2013 Source Identification Investigation
*United Heckathorn Superfund Site, Richmond, California*

| Location | Field Longitude (X) | Field Latitude (Y) | Sample ID | CLP Sample Number | Duplicate Sample ID or MS/MSD | Type of Sample (OBM or YBM) | Top Depth (ft) (from TOC) | Bottom Depth (ft) (from TOC) |
|---|---|---|---|---|---|---|---|---|
| SD13-4 | 6023234.68 | 2164441.03 | SD13-04-0005 | Y8RN1 | | YBM | 0.0 | 0.5 |
| | | | SD13-04-0515 | Y8RN2 | | YBM | 0.5 | 1.5 |
| SD13-5 | 6023274.05 | 2164435.49 | SD13-05-0002 | Y8RN6 | | YBM | 0.0 | 0.2 |
| | | | SD13-05-0203 | Y8RN7 | | YBM | 0.2 | 0.3 |
| | | | SD13-05-0305 | Y8RN8 | | YBM | 0.3 | 0.5 |
| | | | SD13-05-0507 | Y8RN9 | | YBM | 0.5 | 0.7 |
| | | | SD13-05-0708 | Y8RO0 | | YBM | 0.7 | 0.8 |
| | | | SD13-05-0810 | Y8RO1 | | YBM | 0.8 | 1.0 |
| | | | SD13-05-1020 | Y8RO2 | | YBM | 1.0 | 2.0 |
| | | | SD13-05-2040 | Y8RO3 | | YBM | 2.0 | 4.0 |
| SD13-6 | 6023328.85 | 2164430.36 | SD13-06-0005 | Y8RO5 | | YBM | 0.0 | 0.5 |
| | | | SD13-06-0520 | Y8RO6 | | YBM | 0.5 | 2.0 |
| | | | SD13-06-2040 | Y8RO7 | | YBM | 2.0 | 4.0 |
| | | | SD13-06-4059 | Y8RO8 | | YBM | 4.0 | 4.9 |
| SD13-8 | 6023181.39 | 2164245.71 | SD13-08-0005 | Y8RO9 | | YBM | 0.0 | 0.5 |
| | | | SD13-08-0520 | Y8RP0 | Y8RP1 | YBM | 0.5 | 2.0 |
| | | | SD13-08-2040 | Y8RP2 | | YBM | 2.0 | 4.0 |
| | | | Non-sampled Interval | | | OBM | 4.0 | 4.6 |
| | | | SD13-08-4055 | Y8RP3 | | OBM | 4.6 | 5.5 |
| SD13-9 | 6023248.50 | 2164238.21 | SD13-09-0002 | Y8RP4 | | YBM | 0.0 | 0.2 |
| | | | SD13-09-0203 | Y8RP5 | | YBM | 0.2 | 0.3 |
| | | | SD13-09-0305 | Y8RP6 | | YBM | 0.3 | 0.5 |
| | | | SD13-09-0507 | Y8RP7 | | YBM | 0.5 | 0.7 |
| | | | SD13-09-0708 | Y8RP8 | | YBM | 0.7 | 0.8 |
| | | | SD13-09-0810 | Y8RP9 | | YBM | 0.8 | 1.0 |
| | | | SD13-09-1020 | Y8RQ0 | | YBM | 1.0 | 2.0 |
| | | | SD13-09-2040 | Y8RQ1 | | YBM | 2.0 | 4.0 |
| | | | SD13-09-4055 | Y8RQ2 | | OBM | 4.0 | 5.5 |
| SD13-10 | 6023307.69 | 2164238.02 | SD13-10-0005 | Y8RQ3 | | YBM | 0.0 | 0.5 |
| | | | SD13-10-0520 | Y8RQ4 | | YBM/OBM | 0.5 | 2.0 |
| | | | SD13-10-2040 | Y8RQ5 | MS/MSD | YBM/OBM | 2.0 | 4.0 |
| | | | SD13-10-4060 | Y8RQ6 | | OBM | 4.0 | 6.0 |
| | | | SD13-10-6066 | Y8RR2 | | OBM | 6.0 | 6.6 |
| SD13-13 | 6023160.53 | 2164049.90 | SD13-13-0005 | Y8RQ7 | Y8RQ8 | YBM | 0.0 | 0.5 |
| | | | SD13-13-0520 | Y8RQ9 | | YBM/OBM | 0.5 | 2.0 |
| | | | SD13-13-2025 | Y8RR0 | Y8RR1 | OBM | 2.0 | 2.5 |
| SD13-14 | 6023212.77 | 2164041.92 | SD13-14-0005 | Y8RR3 | | YBM | 0.0 | 0.5 |
| | | | SD13-14-0509 | Y8RR4 | | YBM | 0.5 | 0.9 |
| | | | Non-sampled Interval | | | OBM | 0.9 | 1.0 |
| | | | SD13-14-1020 | Y8RR5 | | OBM | 1.0 | 2.0 |
| | | | SD13-14-2040 | Y8RR6 | | OBM | 2.0 | 4.0 |
| SD13-15 | 6023278.51 | 2164034.84 | SD13-15-0005 | Y8RR7 | | YBM | 0.0 | 0.5 |
| | | | SD13-15-0520 | Y8RR8 | | YBM | 0.5 | 2.0 |
| | | | SD13-15-2040 | Y8RR9 | | OBM | 2.0 | 4.0 |
| | | | SD13-15-4049 | Y8RS0 | | OBM | 4.0 | 4.9 |
| SD13-18 | 6023087.22 | 2163850.25 | SD13-18-0005 | Y8RS1 | | YBM | 0.0 | 0.5 |
| | | | SD13-18-0510 | Y8RS2 | | YBM | 0.5 | 1.0 |
| | | | Non-sampled Interval | | | | 1.0 | 1.5 |
| | | | SD13-18-1030 | Y8RS3 | Y8RS5 | OBM | 1.5 | 3.0 |
| SD13-19 | 6023185.28 | 2163842.50 | SD13-19-0005 | Y8RS6 | | YBM | 0.0 | 0.5 |
| | | | SD13-19-0520 | Y8RS7 | | YBM | 0.5 | 2.0 |
| | | | SD13-19-2040 | Y8RS8 | | YBM | 2.0 | 4.0 |
| | | | Non-sampled Interval | | | -- | 4.0 | 4.5 |
| | | | SD13-19-4560 | Y8RS9 | | OBM | 4.5 | 6.0 |

TABLE 2
Summary of Samples Collected from Sediment Cores - 2013 Source Identification Investigation
*United Heckathorn Superfund Site, Richmond, California*

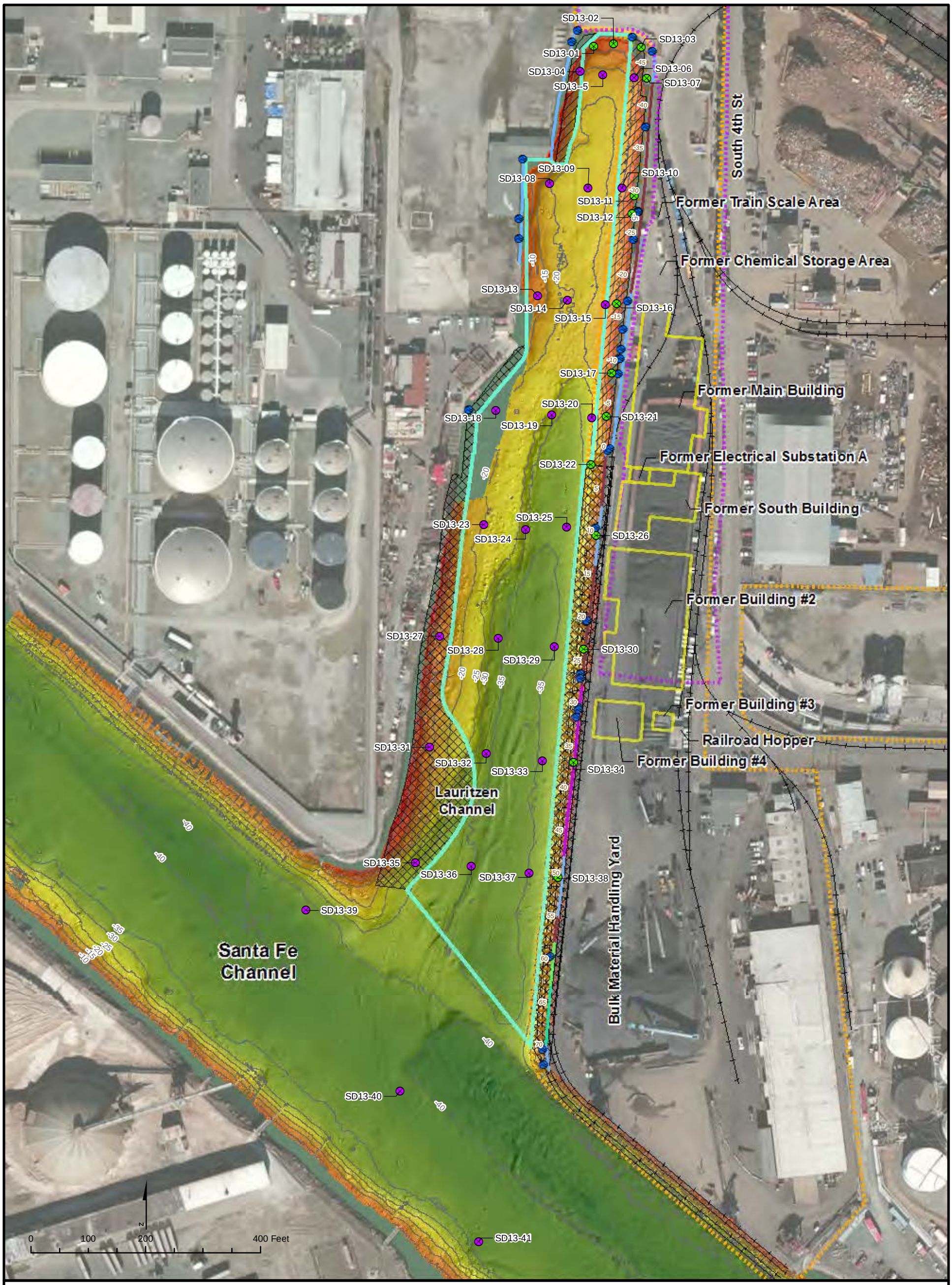
| Location | Field Longitude (X) | Field Latitude (Y) | Sample ID | CLP Sample Number | Duplicate Sample ID or MS/MSD | Type of Sample (OBM or YBM) | Top Depth (ft) (from TOC) | Bottom Depth (ft) (from TOC) |
|---|---|---|---|---|---|---|---|---|
| SD13-20 | 6023255.11 | 2163837.51 | SD13-20-0005 | Y8RT0 | | YBM | 0.0 | 0.5 |
| | | | SD13-20-0520 | Y8RT1 | | YBM | 0.5 | 2.0 |
| | | | SD13-20-2040 | Y8RT2 | MS/MSD | YBM | 2.0 | 4.0 |
| | | | SD13-20-4052 | Y8RT3 | | YBM | 4.0 | 5.2 |
| SD13-23 | 6023066.85 | 2163651.19 | SD13-23-0005 | Y8RT4 | | YBM | 0.0 | 0.5 |
| | | | SD13-23-0520 | Y8RT5 | Y8RT6 | YBM | 0.5 | 2.0 |
| | | | SD13-23-2037 | Y8RT7 | | YBM/OBM | 2.0 | 3.7 |
| SD13-24 | 6023139.40 | 2163642.13 | SD13-24-0005 | Y8RT9 | | YBM | 0.0 | 0.5 |
| | | | SD13-24-0520 | Y8RU0 | | YBM/OBM | 0.5 | 2.0 |
| | | | SD13-24-2040 | Y8RU1 | | YBM/OBM | 2.0 | 4.0 |
| | | | SD13-24-4060 | Y8RU2 | | YBM/OBM | 4.0 | 6.0 |
| SD13-25 | 6023211.18 | 2163646.43 | SD13-25-0005 | Y8RU3 | | YBM | 0.0 | 0.5 |
| | | | SD13-25-0520 | Y8RU4 | | YBM | 0.5 | 2.0 |
| | | | SD13-25-2040 | Y8RU5 | Y8RU6 | YBM | 2.0 | 4.0 |
| | | | SD13-25-4059 | Y8RU7 | | YBM | 4.0 | 5.9 |
| SD13-27 | 6022989.83 | 2163456.36 | SD13-27-0005 | Y8RU8 | MS/MSD | YBM | 0.0 | 0.5 |
| | | | SD13-27-0520 | Y8RU9 | | YBM | 0.5 | 2.0 |
| | | | SD13-27-2031 | Y8RV0 | | YBM | 2.0 | 3.1 |
| SD13-28 | 6023091.65 | 2163452.79 | SD13-28-0005 | Y8RV2 | | YBM | 0.0 | 0.5 |
| | | | SD13-28-0520 | Y8RV3 | | YBM | 0.5 | 2.0 |
| | | | SD13-28-2040 | Y8RV4 | | YBM | 2.0 | 4.0 |
| | | | SD13-28-4060 | Y8RV5 | | YBM | 4.0 | 6.0 |
| SD13-29 | 6023189.47 | 2163438.66 | SD13-29-0005 | Y8RV6 | | YBM | 0.0 | 0.5 |
| | | | SD13-29-0520 | Y8RV7 | Y8RV8 | YBM | 0.5 | 2.0 |
| | | | SD13-29-2040 | Y8RV9 | | YBM | 2.0 | 4.0 |
| | | | SD13-29-4060 | Y8RW0 | | YBM | 4.0 | 6.0 |
| SD13-31 | 6022972.31 | 2163263.24 | SD13-31-0005 | Y8RW1 | | OBM | 0.0 | 0.5 |
| | | | SD13-31-0520 | Y8RW2 | | OBM | 0.5 | 2.0 |
| | | | SD13-31-2040 | Y8RW3 | Y8RW5 | OBM | 2.0 | 4.0 |
| SD13-32 | 6023070.70 | 2163251.79 | SD13-32-0005 | Y8RW6 | | YBM | 0.0 | 0.5 |
| | | | SD13-32-0520 | Y8RW7 | | YBM | 0.5 | 2.0 |
| | | | SD13-32-2040 | Y8RW8 | | YBM | 2.0 | 4.0 |
| | | | SD13-32-4060 | Y8RW9 | | YBM | 4.0 | 6.0 |
| SD13-33 | 6023168.50 | 2163239.19 | SD13-33-0005 | Y8RX0 | | YBM | 0.0 | 0.5 |
| | | | SD13-33-0520 | Y8RX1 | MS/MSD | YBM | 0.5 | 2.0 |
| | | | SD13-33-2040 | Y8RX2 | | YBM | 2.0 | 4.0 |
| | | | SD13-33-4060 | Y8RX3 | | YBM | 4.0 | 6.0 |
| SD13-35 | 6022947.27 | 2163061.12 | SD13-35-0005 | Y8RX4 | Y8RX5 | YBM | 0.0 | 0.5 |
| | | | SD13-35-0520 | Y8RX6 | | YBM | 0.5 | 2.0 |
| | | | SD13-35-2040 | Y8RX7 | | YBM | 2.0 | 4.0 |
| | | | SD13-35-4058 | Y8RX8 | | YBM | 4.0 | 5.8 |
| SD13-36 | 6023044.53 | 2163055.96 | SD13-36-0005 | Y8RX9 | | YBM | 0.0 | 0.5 |
| | | | SD13-36-0520 | Y8RY0 | | YBM | 0.5 | 2.0 |
| | | | SD13-36-2040 | Y8RY1 | | YBM | 2.0 | 4.0 |
| | | | SD13-36-4065 | Y8RY2 | | YBM | 4.0 | 6.5 |
| SD13-37 | 6023145.91 | 2163043.31 | SD13-37-0005 | Y8RY3 | Y8RY4 | YBM | 0.0 | 0.5 |
| | | | SD13-37-0520 | Y8RY5 | | YBM | 0.5 | 2.0 |
| | | | SD13-37-2040 | Y8RY6 | | YBM | 2.0 | 4.0 |
| | | | SD13-37-4060 | Y8RY7 | | YBM | 4.0 | 6.0 |
| SD13-39 | 6022756.43 | 2162979.33 | SD13-39-0005 | Y8RY8 | | YBM | 0.0 | 0.5 |
| | | | SD13-39-0520 | Y8RY9 | | YBM | 0.5 | 2.0 |
| | | | SD13-39-2040 | Y8RZ0 | | YBM | 2.0 | 3.4 |
| | | | Non-sampled Interval | -- | | YBM | 3.4 | 4.0 |
| | | | SD13-39-4049 | Y8RZ1 | | OBM | 4.0 | 4.9 |

TABLE 2
Summary of Samples Collected from Sediment Cores - 2013 Source Identification Investigation
*United Heckathorn Superfund Site, Richmond, California*

| Location | Field Longitude (X) | Field Latitude (Y) | Sample ID | CLP Sample Number | Duplicate Sample ID or MS/MSD | Type of Sample (OBM or YBM) | Top Depth (ft) (from TOC) | Bottom Depth (ft) (from TOC) |
|---|---|---|---|---|---|---|---|---|
| SD13-40 | 6022921.50 | 2162662.19 | SD13-40-0005 | Y8RZ2 | | YBM | 0.0 | 0.5 |
| | | | SD13-40-0520 | Y8RZ3 | | YBM | 0.5 | 2.0 |
| | | | SD13-40-2040 | Y8RZ4 | | OBM | 2.0 | 4.0 |
| SD13-41 | 6023057.92 | 2162400.50 | SD13-41-0005 | Y8RZ6 | | YBM | 0.0 | 0.5 |
| | | | SD13-41-0520 | Y8RZ7 | | YBM | 0.5 | 2.0 |
| | | | SD13-41-2040 | Y8RZ8 | | YBM | 2.0 | 4.0 |
| | | | SD13-41-4049 | Y8RZ9 | Y8RA0 | YBM/OBM | 4.0 | 4.9 |
| | | | Non-sampled Interval | | | OBM | 4.9 | 5.5 |
| | | | SD13-41-5565 | Y8RW4 | | OBM | 5.5 | 6.5 |

Notes:
-- = Not Available
CLP - Contract Laboratory Program
ft = feet
MS/MSD - matrix spike/matrix spike duplicate
OBM = Old Bay Mud
TOC = Top of Core
YBM = Young Bay Mud
The coordinate system is : NAD 1983 California State Plane Zone 3 (feet)

# Figure




**LEGEND**

- Sediment Grab Sample Location
- Vibracore Sample Location

**Bathymetry**

- 1 ft
- 44 ft
- Bathymetric Contour (5 foot Interval)

- Outfall Location
- Former Pier Pilings
- Pier Pilings
- Railroad
- Former Buildings
- Dredged Area
- Partially Dredged Area
- Un-Dredged Area

- Concrete
- Rock/Rip Rap
- Rock/Rip Rap and Concrete
- Shotcrete
- Sheet Pile
- Sheet Pile and Concrete

**FIGURE 1**
**2013 Sediment Sampling Locations**
*United Heckathorn Superfund Site*
*Richmond, California*

CH2MHILL

Document Path: D:\Projects\EPA_UnitedHeckathorn\MapFiles\2013\July\SedimentSampleLocations.mxd

# Attachment 1
# Laboratory Chains of Custody

USEPA CLP Organics COC (LAB COPY)
DateShipped:
CarrierName:
AirbillNo:

**CHAIN OF CUSTODY RECORD**
Site #: CAD981438363
Case #: 43379
Cooler #:

**No: 9-032913-100145-0009**
Lab: KAP Technologies Inc.
Lab Contact: Rao Alsakani
Lab Phone: 281-367-0065

| Organic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Inorganic Sample # | For Lab use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RN1 | Sediment/ | | CLP PEST | 1000 (4C (+-2C)) (1) | SD13-04-0005 | 4/3/13 0905 | | |
| Y8RN2 | Sediment/ | | CLP PEST | 1001 (4C (+-2C)) (1) | SD13-04-0520 | 4/3/13 0905 | | |
| ~~Y8RN3~~ | ~~Sediment/~~ | | ~~CLP PEST~~ | ~~1002 (4C (+-2C)) (1)~~ | ~~SD13-04-20~~ | | | |
| ~~Y8RN4~~ | ~~Sediment/~~ | | ~~CLP PEST~~ | ~~1003 (4C (+-2C)) (1)~~ | ~~SD13-04-20~~ | | | |
| ~~Y8RN5~~ | ~~Sediment/~~ | | ~~CLP PEST~~ | ~~1004 (4C (+-2C)) (1)~~ | ~~SD13-04-40~~ | | | |
| Y8RO5 | Sediment/ | | CLP PEST | 1014 (4C (+-2C)) (1) | SD13-06-0005 | 4/5/13 0830 | | |
| Y8RO6 | Sediment/ | | CLP PEST | 1015 (4C (+-2C)) (1) | SD13-06-0520 | 4/5/13 0830 | | |
| Y8RO7 | Sediment/ | | CLP PEST | 1016 (4C (+-2C)) (1) | SD13-06-2040 | 4/6/13 0830 | | |
| Y8RO8 | Sediment/ | | CLP PEST | 1017 (4C (+-2C)) (1) | SD13-06-4060 | 4/5/13 0830 | | |

Special Instructions:

**Shipment for Case Complete? N**

**Samples Transferred from Chain of Custody #**

Analysis Key CLP PEST=CLP TCL Pesticides

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished by | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | [signature] | 4/8/13 | | | | | | | | | |
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USEPA CLP Organics COC (LAB COPY)
DateShipped:
CarrierName:
AirbillNo:

CHAIN OF CUSTODY RECORD
Site #: CAD981436383
Case #: 48379
Cooler #:

No: 9-032913-095753-0007
Lab: KAP Technologies Inc.
Lab Contact: Rao Alsakani
Lab Phone: 281-367-0065

| Organic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Inorganic Sample # | For Lab use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RN6 | Sediment/ | | CLP PEST | 1005 (4C (+-2C)) (1) | SD13-05-0002 | 4/3/13 1320 | | |
| Y8RN7 | Sediment/ | | CLP PEST | 1006 (4C (+-2C)) (1) | SD13-05-0203 | 4/3/13 1320 | | |
| Y8RN8 | Sediment/ | | CLP PEST | 1007 (4C (+-2C)) (1) | SD13-05-0305 | 4/3/13 1320 | | |
| Y8RN9 | Sediment/ | | CLP PEST | 1008 (4C (+-2C)) (1) | SD13-05-0507 | 4/3/13 1320 | | |
| Y8RO0 | Sediment/ | | CLP PEST | 1009 (4C (+-2C)) (1) | SD13-05-0708 | 4/3/13 1320 | | |
| Y8RO1 | Sediment/ | | CLP PEST | 1010 (4C (+-2C)) (1) | SD13-05-0810 | 4/3/13 1320 | | |
| Y8RO2 | Sediment/ | | CLP PEST | 1011 (4C (+-2C)) (1) | SD13-05-1020 | 4/3/13 1320 | | |
| Y8RO3 | Sediment/ | | CLP PEST | 1012 (4C (+-2C)) (1) | SD13-05-2040 | 4/3/13 1320 | | |
| ~~Y8RO4~~ | ~~Sediment/~~ | TB 4/3/13 | ~~CLP PEST~~ | ~~1013 (4C (+-2C)) (1)~~ | ~~SD13-05-40~~ | | | |

| Special Instructions: | Shipment for Case Complete? N |
|---|---|
| | Samples Transferred from Chain of Custody # |
| Analysis Key CLP PEST=CLP TCL Pesticides | |

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished by | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | James Jack | 4/5/13 | | | | | | | | | |
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USEPA CLP Organics COC (LAB COPY)
DateShipped:
CarrierName:
AirbillNo:

CHAIN OF CUSTODY RECORD
Site #: CAD981436363
Case # 43379
Cooler #:

No: 9-032913-102240-0010
Lab: KAP Technologies Inc.
Lab Contact: Rao Alsakani
Lab Phone: 281-367-0065

| Organic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Inorganic Sample # | For Lab use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RO9 | Sediment/ | | CLP PEST | 1018 (4C (+-2C)) (1) | SD13-08-0005 | 4/5/13 1300 | | |
| Y8RP0 | Sediment/ | | CLP PEST | 1019 (4C (+-2C)) (1) | SD13-08-0520 | 4/5/13 1300 | | |
| Y8RP1 | Sediment/ | | CLP PEST | 1020 (4C (+-2C)) (1) | SD13-92-0520 | 4/5/13 1300 | | |
| Y8RP2 | Sediment/ | | CLP PEST | 1021 (4C (+-2C)) (1) | SD13-08-2040 | 4/5/13 1300 | | |
| Y8RP3 | Sediment/ | | CLP PEST | 1022 (4C (+-2C)) (1) | SD13-08-4060 | 4/5/13 1300 | | |
| Y8RQ3 | Sediment/ | | CLP PEST | 1032 (4C (+-2C)) (1) | SD13-10-0005 | 4/4/13 1550 | | |
| Y8RQ4 | Sediment/ | | CLP PEST | 1033 (4C (+-2C)) (1) | SD13-10-0520 | 4/4/13 1550 | | |
| Y8RQ5 | Sediment/ | | CLP PEST | 1034 (4C (+-2C)) (2) | SD13-10-2040 | 4/4/13 1550 | | |
| Y8RQ6 | Sediment/ | | CLP PEST | 1035 (4C (+-2C)) (1) | SD13-10-4060 | 4/4/13 1550 | | |
| Y8RR2 | Sediment | | CLP PEST | " | SD13-[illegible] | 4/4/13 1550 | | |
| | | | | | [illegible] | 4/4/13 1550 | * | |

Special Instructions: Extra volume Y8RQ5 for MS/MSD

Shipment for Case Complete? N

Samples Transferred from Chain of Custody #

Analysis Key CLP PEST=CLP TCL Pesticides

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished by | Date | Received by | Date | Time |
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| | [signature] | 4/5/13 | | | | | | | | | |
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USEPA CLP Organics COC (LAB COPY)
DateShipped:
CarrierName:
AirbillNo:

CHAIN OF CUSTODY RECORD
Site #: CAD981436363
Case #: 43379
Cooler #:

No: 9-032913-095847-0008
Lab: KAP Technologies Inc.
Lab Contact: Rao Alsakani
Lab Phone: 281-367-0065

| Organic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Inorganic Sample # | For Lab use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RP4 | Sediment/ | | CLP PEST | 1023 (4C (+-2C)) (1) | SD13-09-0002 | 4/3/13 1120 | | |
| Y8RP5 | Sediment/ | | CLP PEST | 1024 (4C (+-2C)) (1) | SD13-09-0203 | 4/3/13 1120 | | |
| Y8RP6 | Sediment/ | | CLP PEST | 1025 (4C (+-2C)) (1) | SD13-09-0305 | 4/3/13 1120 | | |
| Y8RP7 | Sediment/ | | CLP PEST | 1026 (4C (+-2C)) (1) | SD13-09-0507 | 4/3/13 1120 | | |
| Y8RP8 | Sediment/ | | CLP PEST | 1027 (4C (+-2C)) (1) | SD13-09-0708 | 4/3/13 1120 | | |
| Y8RP9 | Sediment/ | | CLP PEST | 1028 (4C (+-2C)) (1) | SD13-09-0810 | 4/3/13 1120 | | |
| Y8RQ0 | Sediment/ | | CLP PEST | 1029 (4C (+-2C)) (1) | SD13-09-1020 | 4/3/13 1120 | | |
| Y8RQ1 | Sediment/ | | CLP PEST | 1030 (4C (+-2C)) (1) | SD13-09-2040 | 4/3/13 1120 | | |
| Y8RQ2 | Sediment/ | | CLP PEST | 1031 (4C (+-2C)) (1) | SD13-09-4055 | 4/3/13 1120 | | |
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Special Instructions:

Shipment for Case Complete? N

Samples Transferred from Chain of Custody #

Analysis Key CLP PEST=CLP TCL Pesticides

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished by | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jamera Jones | 4/9/13 | | | | | | | | | |
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| | | | | | | | | | | | |

USEPA CLP Organics COC (LAB COPY)
DateShipped:
CarrierName:
AirbillNo:

CHAIN OF CUSTODY RECORD
Site #: CAD981436363
Case #: 43379
Cooler #:

No: 9-032913-102317-0011
Lab: KAP Technologies Inc.
Lab Contact: Rao Alsekani
Lab Phone: 281-367-0065

| Organic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Inorganic Sample # | For Lab use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RQ7 | Sediment/ | | CLP PEST | 1036 (4C (+-2C)) (1) | SD13-13-0005 | 4/3/13 0950 | | |
| Y8RQ8 | Sediment/ | | CLP PEST | 1037 (4C (+-2C)) (1) | SD13-67-0005 | 4/3/13 0950 | | |
| Y8RQ9 | Sediment/ | | CLP PEST | 1038 (4C (+-2C)) (1) | SD13-13-0520 | 4/3/13 0950 | | |
| Y8RR0 | Sediment/ | | CLP PEST | 1039 (4C (+-2C)) (1) | SD13-13-2025 | 4/3/13 0950 | | |
| Y8RR1 | Sediment/ | | CLP PEST | 1040 (4C (+-2C)) (1) | SD13-67-2025 | 4/3/13 0950 | | |
| ~~Y8RR2~~ | ~~Sediment/~~ | | ~~CLP PEST~~ | ~~1041 (4C (+-2C)) (1)~~ | ~~SD13-13-40~~ | | | |
| Y8RR3 | Sediment/ | | CLP PEST | 1042 (4C (+-2C)) (1) | SD13-14-0005 | 4/3/13 1145 | | |
| Y8RR4 | Sediment/ | | CLP PEST | 1043 (4C (+-2C)) (1) | SD13-14-0520 | 4/5/13 1145 | | |
| Y8RR5 | Sediment/ | | CLP PEST | 1044 (4C (+-2C)) (1) | SD13-14-20 | 4/5/13 1145 | | |
| Y8RR6 | Sediment/ | | CLP PEST | 1045 (4C (+-2C)) (2) | SD13-14-40 | 4/5/13 1145 | | |

Special Instructions: extra volume Y8RR6 -MS/MSD

Shipment for Case Complete? N
Samples Transferred from Chain of Custody #

Analysis Key CLP PEST=CLP TCL Pesticides

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished by | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | [signature] | 4/5/13 | | | | | | | | | |
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| | | | | | | | | | | | |
| | | | | | | | | | | | |

USEPA CLP Organics COC (LAB COPY)

DateShipped:

CarrierName:

AirbillNo:

CHAIN OF CUSTODY RECORD

Site #: CAD981436363

Case #: 43379

Cooler #:

No: 9-032913-102350-0012

Lab: KAP Technologies Inc.

Lab Contact: Rao Alsakani

Lab Phone: 281-367-0065

| Organic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Inorganic Sample # | For Lab use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RR7 | Sediment/ | | CLP PEST | 1046 (4C (+-2C)) (1) | SD13-15-0005 | 4/3/13 1540 | | |
| Y8RR8 | Sediment/ | | CLP PEST | 1047 (4C (+-2C)) (1) | SD13-15-0520 | 4/3/13 1540 | | |
| Y8RR9 | Sediment/ | | CLP PEST | 1048 (4C (+-2C)) (1) | SD13-15-2040 | 4/3/13 1540 | | |
| Y8RS0 | Sediment/ | | CLP PEST | 1049 (4C (+-2C)) (1) | SD13-15-4049 | 4/3/13 1540 | | |
| Y8RS1 | Sediment/ | | CLP PEST | 1050 (4C (+-2C)) (1) | SD13-18-0005 | 4/4/13 1220 | | |
| Y8RS2 | Sediment/ | | CLP PEST | 1051 (4C (+-2C)) (1) | SD13-18-0520 | 4/4/13 1220 | | |
| Y8RS3 | Sediment/ | | CLP PEST | 1052 (4C (+-2C)) (1) | SD13-18-2040 | 4/4/13 1220 | | |
| ~~Y8RS4~~ | ~~Sediment/~~ | | ~~CLP PEST~~ | ~~1053 (4C (+-2C)) (1)~~ | ~~SD13-18-4049~~ | ~~4/4/13 1220~~ | | |
| Y8RS5 | Sediment/ | | CLP PEST | 1054 (4C (+-2C)) (1) | SD13-82-4049 | 4/4/13 1220 | | |

Special Instructions:

Shipment for Case Complete? N

Samples Transferred from Chain of Custody #

Analysis Key CLP PEST=CLP TCL Pesticides

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished by | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
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USEPA CLP Organics COC (LAB COPY)
DateShipped:
CarrierName:
AirbillNo:

CHAIN OF CUSTODY RECORD
Site #: CAD981436363
Case #: 43379
Cooler #:

No: 9-032913-102415-0013
Lab: KAP Technologies Inc.
Lab Contact: Rao Alsakani
Lab Phone: 281-367-0065

| Organic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Inorganic Sample # | For Lab use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RS6 | Sediment/ | | CLP PEST | 1055 (4C (+-2C)) (1) | SD13-19-0005 | 4/5/13 1225 | | |
| Y8RS7 | Sediment/ | | CLP PEST | 1056 (4C (+-2C)) (1) | SD13-19-0520 | 4/5/13 1225 | | |
| Y8RS8 | Sediment/ | | CLP PEST | 1057 (4C (+-2C)) (1) | SD13-19-2040 | 4/5/13 1225 | | |
| Y8RS9 | Sediment/ | | CLP PEST | 1058 (4C (+-2C)) (1) | SD13-19-4060 | 4/5/13 1225 | | |
| Y8RT0 | Sediment/ | | CLP PEST | 1059 (4C (+-2C)) (1) | SD13-20-0005 | 4/3/13 1440 | | |
| Y8RT1 | Sediment/ | | CLP PEST | 1060 (4C (+-2C)) (1) | SD13-20-0520 | 4/3/13 1440 | | |
| Y8RT2 | Sediment/ | | CLP PEST | 1061 (4C (+-2C)) (2) | SD13-20-2040 | 4/3/13 1440 | | |
| Y8RT3 | Sediment/ | | CLP PEST | 1062 (4C (+-2C)) (1) | SD13-20-4052 | 4/3/13 1440 | | |
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Special Instructions: Extra volume for Y8RT2 MS/MSD

Shipment for Case Complete? N
Samples Transferred from Chain of Custody #

Analysis Key CLP PEST=CLP TCL Pesticides

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished by | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | [signature] | 4/5/13 | | | | | | | | | |
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USEPA CLP Organics COC (LAB COPY)
DateShipped:
CarrierName:
AirbillNo:

CHAIN OF CUSTODY RECORD
Site #: CAD981436363
Case #: 43379
Cooler #:

No: 9-032913-102441-0014
Lab: KAP Technologies Inc.
Lab Contact: Rao Alsekani
Lab Phone: 281-367-0065

| Organic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Inorganic Sample # | For Lab use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RT4 | Sediment/ | | CLP PEST | 1063 (4C (+-2C)) (1) | SD13-23-0005 | 4/4/13 1135 | | |
| Y8RT5 | Sediment/ | | CLP PEST | 1064 (4C (+-2C)) (1) | SD13-23-0520 | 4/4/13 1135 | | |
| Y8RT6 | Sediment/ | | CLP PEST | 1065 (4C (+-2C)) (1) | SD13-77-0520 | 4/4/13 1135 | | |
| Y8RT7 | Sediment/ | | CLP PEST | 1066 (4C (+-2C)) (1) | SD13-23-2037 | 4/4/13 1135 | | |
| ~~Y8RT8~~ | ~~Sediment/~~ | | ~~CLP PEST~~ | ~~1067 (4C (+-2C)) (1)~~ | ~~SD13-26-10~~ | | | |
| Y8RT9 | Sediment/ | | CLP PEST | 1068 (4C (+-2C)) (1) | SD13-24-0005 | 4/4/13 1015 | | |
| Y8RU0 | Sediment/ | | CLP PEST | 1069 (4C (+-2C)) (1) | SD13-24-0520 | 4/4/13 1015 | | |
| Y8RU1 | Sediment/ | | CLP PEST | 1070 (4C (+-2C)) (1) | SD13-24-2040 | 4/4/13 1015 | | |
| Y8RU2 | Sediment/ | | CLP PEST | 1071 (4C (+-2C)) (1) | SD13-24-4060 | 4/4/13 1015 | | |

Special Instructions:

Shipment for Case Complete? N

Samples Transferred from Chain of Custody #

Analysis Key CLP PEST=CLP TCL Pesticides

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished by | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | [signature] | 4/5/13 | | | | | | | | | |
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USEPA CLP Organics COC (LAB COPY)
DateShipped:
CarrierName:
AirbillNo:

CHAIN OF CUSTODY RECORD
Site #: CAD981436363
Case #: 43379
Cooler #:

No: 9-032913-102823-0015
Lab: KAP Technologies Inc.
Lab Contact: Rao Alsakani
Lab Phone: 281-367-0065

| Organic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Inorganic Sample # | For Lab use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RU3 | Sediment/ | | CLP PEST | 1072 (4C (+-2C)) (1) | SD13-25-0005 | 4/5/13 0745 | | |
| Y8RU4 | Sediment/ | | CLP PEST | 1073 (4C (+-2C)) (1) | SD13-25-0520 | 4/5/13 0745 | | |
| Y8RU5 | Sediment/ | | CLP PEST | 1074 (4C (+-2C)) (1) | SD13-25-2040 | 4/5/13 0745 | | |
| Y8RU6 | Sediment/ | | CLP PEST | 1075 (4C (+-2C)) (1) | SD13-25-2040 | 4/5/13 0745 | | |
| Y8RU7 | Sediment/ | | CLP PEST | 1076 (4C (+-2C)) (1) | SD13-25-4059 | 4/5/13 0745 | | |
| Y8RU8 | Sediment/ | | CLP PEST | 1077 (4C (+-2C)) (2) | SD13-27-0005 | 4/4/13 0930 | | |
| Y8RU9 | Sediment/ | | CLP PEST | 1078 (4C (+-2C)) (1) | SD13-27-0520 | 4/4/13 0930 | | |
| Y8RV0 | Sediment/ | | CLP PEST | 1079 (4C (+-2C)) (1) | SD13-27-2031 | 4/4/13 0930 | | |
| ~~Y8RV1~~ | ~~Sediment/~~ | | ~~CLP PEST~~ | ~~1080 (4C (+-2C)) (1)~~ | ~~SD13-27-40~~ | | | |

Special Instructions: MS/MSD extra volume on Y8RU8

Shipment for Case Complete? N
Samples Transferred from Chain of Custody #

Analysis Key CLP PEST=CLP TCL Pesticides

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished by | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 4/5/13 | | | | | | | | | |
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USEPA CLP Organics COC (LAB COPY)
DateShipped:
CarrierName:
AirbillNo:

CHAIN OF CUSTODY RECORD
Site #: CAD981436363
Case #: 43379
Cooler #:

No: 9-032913-102849-0016
Lab: KAP Technologies Inc.
Lab Contact: Rao Alsakarl
Lab Phone: 281-367-0065

| Organic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Inorganic Sample # | For Lab use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RV2 | Sediment/ | | CLP PEST | 1081 (4C (+-2C)) (1) | SD13-28-0005 | 4/4/13 0840 | | |
| Y8RV3 | Sediment/ | | CLP PEST | 1082 (4C (+-2C)) (1) | SD13-28-0520 | 4/4/13 0840 | | |
| Y8RV4 | Sediment/ | | CLP PEST | 1083 (4C (+-2C)) (1) | SD13-28-2040 | 4/4/13 0840 | | |
| Y8RV5 | Sediment/ | | CLP PEST | 1084 (4C (+-2C)) (1) | SD13-28-4060 | 4/4/13 0840 | | |
| Y8RV6 | Sediment/ | | CLP PEST | 1085 (4C (+-2C)) (1) | SD13-29-0005 | 4/5/13 950 | | |
| Y8RV7 | Sediment/ | | CLP PEST | 1086 (4C (+-2C)) (1) | SD13-29-0520 | 4/5/13 950 | | |
| Y8RV8 | Sediment/ | | CLP PEST | 1087 (4C (+-2C)) (1) | SD13-71-0520 | 4/5/13 950 | | |
| Y8RV9 | Sediment/ | | CLP PEST | 1088 (4C (+-2C)) (1) | SD13-29-2040 | 4/5/13 950 | | |
| Y8RW0 | Sediment/ | | CLP PEST | 1089 (4C (+-2C)) (1) | SD13-29-4060 | 4/5/13 950 | | |

Special Instructions

Shipment for Case Complete? N

Samples Transferred from Chain of Custody #

Analysis Key CLP PEST=CLP TCL Pesticides

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished by | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | James Jack | 4/5/13 | | | | | | | | | |
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**USEPA CLP Organics COC (LAB COPY)**
DateShipped:
CarrierName:
AirbillNo:

**CHAIN OF CUSTODY RECORD**
Site #: CAD981436363
Case #: 43379
Cooler #:

**No: 9-032913-102917-0017**
Lab: KAP Technologies Inc.
Lab Contact: Rao Alsakani
Lab Phone: 281-367-0065

| Organic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Inorganic Sample # | For Lab use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RW1 | Sediment/ | | CLP PEST | 1090 (4C (+-2C)) (1) | SD13-31-0005 | 4/4/13 1500 | | |
| Y8RW2 | Sediment/ | | CLP PEST | 1091 (4C (+-2C)) (1) | SD13-31-0520 | 4/4/13 1500 | | |
| Y8RW3 | Sediment/ | | CLP PEST | 1092 (4C (+-2C)) (1) | SD13-31-2040 | 4/4/13 1500 | | |
| ~~Y8RW4~~ | ~~Sediment/~~ | | ~~CLP PEST~~ | ~~1093 (4C (+-2C)) (1)~~ | ~~SD13-31-40~~ | | | |
| Y8RW5 | Sediment/ | | CLP PEST | 1094 (4C (+-2C)) (1) | SD13-~~31~~-2040 | 4/4/13 1500 | | |
| Y8RW6 | Sediment/ | | CLP PEST | 1095 (4C (+-2C)) (1) | SD13-32-0005 | 4/5/13 0910 | | |
| Y8RW7 | Sediment/ | | CLP PEST | 1096 (4C (+-2C)) (1) | SD13-32-0520 | 4/5/13 0910 | | |
| Y8RW8 | Sediment/ | | CLP PEST | 1097 (4C (+-2C)) (1) | SD13-32-2040 | 4/5/13 0910 | | |
| Y8RW9 | Sediment/ | | CLP PEST | 1098 (4C (+-2C)) (1) | SD13-32-4060 | 4/5/13 0910 | | |

Special Instructions:

Shipment for Case Complete? N

Samples Transferred from Chain of Custody #

Analysis Key CLP PEST=CLP TCL Pesticides

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished by | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | James Ford | 4/5/13 | | | | | | | | | |
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USEPA CLP Organics COC (LAB COPY)
DateShipped:
CarrierName:
AirbillNo:

CHAIN OF CUSTODY RECORD
Site #: CAD981436363
Case #: 43379
Cooler #:

No: 9-032913-102950-0018
Lab: KAP Technologies Inc.
Lab Contact: Rao Alsakani
Lab Phone: 281-367-0065

| Organic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Inorganic Sample # | For Lab use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RX0 | Sediment/ | | CLP PEST | 1099 (4C (+-2C)) (1) | SD13-33-0005 | 4/4/13 1100 | | |
| Y8RX1 | Sediment/ | | CLP PEST | 1100 (4C (+-2C)) (2) | SD13-33-0520 | 4/4/13 1100 | | |
| Y8RX2 | Sediment/ | | CLP PEST | 1101 (4C (+-2C)) (1) | SD13-33-2040 | 4/4/13 1100 | | |
| Y8RX3 | Sediment/ | | CLP PEST | 1102 (4C (+-2C)) (1) | SD13-33-4060 | 4/4/13 1100 | | |
| Y8RX4 | Sediment/ | | CLP PEST | 1103 (4C (+-2C)) (1) | SD13-35-0005 | 4/4/13 1420 | | |
| Y8RX5 | Sediment/ | | CLP PEST | 1104 (4C (+-2C)) (1) | SD13-35-0005 | 4/4/13 1420 | | |
| Y8RX6 | Sediment/ | | CLP PEST | 1105 (4C (+-2C)) (1) | SD13-35-0520 | 4/4/13 1420 | | |
| Y8RX7 | Sediment/ | | CLP PEST | 1106 (4C (+-2C)) (1) | SD13-35-2040 | 4/4/13 1420 | | |
| Y8RX8 | Sediment/ | | CLP PEST | 1107 (4C (+-2C)) (1) | SD13-35-4060 | 4/4/13 1420 | | |

Special Instructions: Extra volume only Y8RX1 for MS/MSD

Shipment for Case Complete? N
Samples Transferred from Chain of Custody #

Analysis Key CLP PEST=CLP TCL Pesticides

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished by | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | J Jones | 4/5/13 | | | | | | | | | |
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USEPA CLP Organics COC (LAB COPY)
DateShipped:
CarrierName:
AirbillNo:

**CHAIN OF CUSTODY RECORD**
Site #: CAD981436863
Case #: 43379
Cooler #:

**No: 9-032913-103020-0019**
Lab: KAP Technologies Inc
Lab Contact: Rao Alsakani
Lab Phone: 281-367-0065

| Organic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Inorganic Sample # | For Lab use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RX9 | Sediment/ | | CLP PEST | 1108 (4C (+-2C)) (1) | SD13-36-0005 | 4/4/13 1300 | | |
| Y8RY0 | Sediment/ | | CLP PEST | 1109 (4C (+-2C)) (1) | SD13-36-0520 | 4/4/13 1300 | | |
| Y8RY1 | Sediment/ | | CLP PEST | 1110 (4C (+-2C)) (1) | SD13-36-2040 | 4/4/13 1300 | | |
| Y8RY2 | Sediment/ | | CLP PEST | 1111 (4C (+-2C)) (1) | SD13-36-4060 | 4/4/13 1300 | | |
| Y8RY3 | Sediment/ | | CLP PEST | 1112 (4C (+-2C)) (1) | SD13-37-0005 | 4/5/13 1030 | | |
| Y8RY4 | Sediment/ | | CLP PEST | 1113 (4C (+-2C)) (1) | SD13-63-0005 | 4/5/13 1030 | | |
| Y8RY5 | Sediment/ | | CLP PEST | 1114 (4C (+-2C)) (1) | SD13-37-0520 | 4/5/13 1030 | | |
| Y8RY6 | Sediment/ | | CLP PEST | 1115 (4C (+-2C)) (1) | SD13-37-2040 | 4/5/13 1030 | | |
| Y8RY7 | Sediment/ | | CLP PEST | 1116 (4C (+-2C)) (1) | SD13-37-4060 | 4/5/13 1030 | | |

Special Instructions:

Shipment for Case Complete? N

Samples Transferred from Chain of Custody #

Analysis Key CLP PEST=CLP TCL Pesticides

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished by | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | James Frank | 4/5/13 | | | | | | | | | |
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USEPA CLP Organics COC (LAB COPY)
DateShipped: 4/5/13
CarrierName: fedEx
AirbillNo: 801554311030

CHAIN OF CUSTODY RECORD
Site #: CAD981436363
Case #: 43379
Cooler #:

No: 9-032913-103046-0020
Lab: KAP Technologies Inc.
Lab Contact: Rao Alsakani
Lab Phone: 281-367-0065

| Organic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Inorganic Sample # | For Lab use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RY8 | Sediment/ | | CLP PEST | 1117 (4C (+-2C)) (1) | SD13-39-0005 | 4/4/13 1345 | | |
| Y8RY9 | Sediment/ | | CLP PEST | 1118 (4C (+-2C)) (1) | SD13-39-0520 | 4/4/13 1345 | | |
| Y8RZ0 | Sediment/ | | CLP PEST | 1119 (4C (+-2C)) (1) | SD13-39-2040 | 4/4/13 1345 | | |
| Y8RZ1 | Sediment/ | | CLP PEST | 1120 (4C (+-2C)) (1) | SD13-39-4049 | 4/4/13 1345 | | |
| Y8RZ2 | Sediment/ | | CLP PEST | 1121 (4C (+-2C)) (1) | SD13-40-0005 | 4/4/13 1540 | | |
| Y8RZ3 | Sediment/ | | CLP PEST | 1122 (4C (+-2C)) (1) | SD13-40-0520 | 4/4/13 1540 | | |
| Y8RZ4 | Sediment/ | | CLP PEST | 1123 (4C (+-2C)) (1) | SD13-40-2040 | 4/4/13 1540 | | |
| ~~Y8RZ5~~ | ~~Sediment/~~ | | ~~CLP PEST~~ | ~~1124 (4C (+-2C)) (1)~~ | ~~SD13-40-40~~ | 4/4/13 1540 | | |

Special Instructions: Y8RZ4 extra volume for MS/MSD

Shipment for Case Complete? N
Samples Transferred from Chain of Custody #

Analysis Key CLP PEST=CLP TCL Pesticides

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished by | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | J Frank | 4/5/13 | | | | | | | | | |
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USEPA CLP Organics COC (LAB COPY)
DateShipped:
CarrierName:
AirbillNo:

**CHAIN OF CUSTODY RECORD**
Site #: CAD981436363
Case #: 43379
Cooler #:

**No: 9-032913-103115-0021**
Lab: KAP Technologies Inc.
Lab Contact: Rao Alsakani
Lab Phone: 281-367-0065

| Organic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Inorganic Sample # | For Lab use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RZ6 | Sediment/ | | CLP PEST | 1125 (4C (+-2C)) (1) | SD13-41-0005 | 4/5/13 1100 | | |
| Y8RZ7 | Sediment/ | | CLP PEST | 1126 (4C (+-2C)) (1) | SD13-41-0520 | 4/5/13 1100 | | |
| Y8RZ8 | Sediment/ | | CLP PEST | 1127 (4C (+-2C)) (1) | SD13-41-2040 | 4/5/13 1100 | | |
| Y8RZ9 | Sediment/ | | CLP PEST | 1128 (4C (+-2C)) (1) | SD13-41-4049 | 4/5/13 1100 | | |
| Y8SA0 | Sediment/ | | CLP PEST | 1129 (4C (+-2C)) (1) | SD13-59-40 49 | 4/5/13 1100 | | |
| Y8RW4 | " | | " | " | SD13-41 5565 | 4/5/13 1100 | | |

Special Instructions:

**Shipment for Case Complete? N**
**Samples Transferred from Chain of Custody #**

Analysis Key CLP PEST=CLP TCL Pesticides

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished by | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jessica Jones | 4/5/13 | | | | | | | | | |

# E2 Consulting Engineers, Inc.

CHAIN OF CUSTODY RECORD: UHSed_PTS0406

2013 Sediment Sampling

Project Name: United Heckathorn

Project Number:

Project Manager:

Sample Manager:

Cell Number:

Fax/Email:

| | Container: | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag |
|---|---|---|---|---|---|---|
| | Preservatives: | None | None | None | None | None |
| | Filtered: | n | n | n | n | n |
| | Holding Time | 180 Days | 180 Days | 180 Days | 180 Days | 180 Days |
| SAMPLE ID | DATE / TIME / Matrix | Percent Solids (D2216) | Atterberg Limits (D4318) | Specific Gravity (D854) | Grain Size (D4464) | TOC (Walkley-Black) |
| SD13-04-0015 | 4/3/13 0905 Sed | X | X | X | | |
| SD13-04-0005 | 4/3/13 0905 Sed | | | | X | X |
| SD13-04-0515 | 4/3/13 0905 Sed | | | | | X |
| ~~SD13-04-20~~ | ~~Sed~~ | | | | ~~X~~ | ~~X~~ |
| ~~SD13-04-40~~ | ~~Sed~~ | | | | | ~~X~~ |
| SD13-05-0050 | 4/5/13 0830 Sed | X | X | X | | |
| SD13-05-0005 | 4/5/13 0830 Sed | | | | X | X |
| SD13-05-0520 | 4/5/13 0830 Sed | | | | | X |
| SD13-05-2040 | 4/5/13 0830 Sed | | | | X | X |
| SD13-05-4060 | 4/5/13 0830 Sed | | | | | X |
| | | | | | | |
| | | | | | | |

| | Number of Containers | COMMENTS |
|---|---|---|
| SD13-04-0015 | 1 | |
| SD13-04-0005 | 1 | |
| SD13-04-0515 | 1 | |
| ~~SD13-04-20~~ | ~~1~~ | |
| ~~SD13-04-40~~ | ~~1~~ | |
| SD13-05-0050 | 1 | |
| SD13-05-0005 | 1 | |
| SD13-05-0520 | 1 | |
| SD13-05-2040 | 1 | |
| SD13-05-4060 | 1 | |
| | | |
| | | |
| TOTAL NUMBER OF CONTAINERS | 10 | |

Ship To:
PTS Laboratories, Inc.
8100 Secura Way
Santa Fe Springs, CA 90670
562-347-2504
Sample Receiving

| Signatures | Date/Time |
|---|---|
| Sampled by: | |
| Relinquished by: | |
| Received by: | |
| Relinquished by: | |
| Received by: | |

**Shipping Details**

Method of shipment:
Shipping Company:
On Ice: yes / no:
Airbill No.:
Shipping Date:

Special Instructions:

Report Copy to:
Ruth Siegmund
ruthsiegmund@e2.com

# E2 Consulting Engineers, inc.

## CHAIN OF CUSTODY RECORD: UHSed_PTS05

2013 Sediment Sampling

| Project Name: United Heckathorn | Container: | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Preservatives: | None | None | None | None | None | | | |
| Project Number: | | | | | | | | | |
| Project Manager: | Filtered: | n | n | n | n | n | | | |
| Sample Manager: | Holding Time | 180 Days | 180 Days | 180 Days | 180 Days | 180 Days | | | |
| Cell Number: | | Percent Solids (D2216) | Atterberg Limits (D4318) | Specific Gravity (D854) | Grain size (D422) | TOC (Walkley-Black) | | | |
| Fax/Email: | | | | | | | | | |
| SAMPLE ID | DATE | TIME | Matrix | | | | | | Number of Containers |
| SD13-05-0040 | 4/3/13 | 1320 | Sed | X | X | X | | | 1 |
| SD13-05-0002 | 4/3/13 | 1320 | Sed | | | | X | X | 1 |
| SD13-05-0203 | 4/3/13 | 1320 | Sed | | | | X | X | 1 |
| SD13-05-0305 | 4/3/13 | 1320 | Sed | | | | X | X | 1 |
| SD13-05-0507 | 4/3/13 | 1320 | Sed | | | | X | X | 1 |
| SD13-05-0709 | 4/3/13 | 1320 | Sed | | | | X | X | 1 |
| SD13-05-0810 | 4/3/13 | 1320 | Sed | | | | X | X | 1 |
| SD13-05-1020 | 4/3/13 | 1320 | Sed | | | | X | X | 1 |
| SD13-05-2040 | 4/3/13 | 1320 | Sed | | | | X | X | 1 |
| ~~SD13-05-40~~ | | | ~~Sed~~ | | | | X | X | 1 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | TOTAL NUMBER OF CONTAINERS | | 30 |

Ship To:
PTS Laboratories, Inc.
8100 Secura Way
Santa Fe Springs, CA 90670
562-347-2504
Sample Receiving

COMMENTS

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | | |
| Received by | | |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment:
Shipping Company:
On Ice: yes / no:
Airbill No.:
Shipping Date:

Special Instructions:

Report Copy to:
Ruth Siegmund
ruthsiegmund@e2.com

# E2 Consulting Engineers, Inc.

## CHAIN OF CUSTODY RECORD: UHSed_PTS0810

2013 Sediment Sampling

| Project Name: United Hackathorn | Container: | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Preservatives: | None | None | None | None | None | | | |
| Project Number: | | | | | | | | | |
| Project Manager: | Filtered: | n | n | n | n | n | | | |
| Sample Manager: | Holding Time | 180 Days | 180 Days | 180 Days | 180 Days | 180 Days | | | |
| Cell Number: | | Percent Solids (D2216) | Atterberg Limits (D4318) | Specific Gravity (D854) | Grain Size (D4464) | TOC (Walkley-Black) | | | |
| Fax/Email: | | | | | | | | | |
| SAMPLE ID | DATE / TIME / Matrix | | | | | | | Number of Containers | COMMENTS |
| SD13-08-0040 | 4/5/13 1300 Sed | X | X | X | | | | 1 | |
| SD13-08-0005 | 4/5/13 1300 Sed | | | | X | X | | 1 | |
| SD13-08-0520 | 4/5/13 1300 Sed | | | | | X | | 1 | |
| SD13-08-2040 | 4/5/13 1300 Sed | | | | X | X | | 1 | |
| SD13-08-4055 | 4/5/13 1300 Sed | | | | | X | | 1 | |
| SD13-10-0064 | 4/4/13 1550 Sed | X | X | X | | | | 1 | |
| SD13-10-0005 | 4/4/13 1550 Sed | | | | X | X | | 1 | |
| SD13-10-0520 | 4/4/13 1550 Sed | | | | | X | | 1 | |
| SD13-10-2040 | 4/4/13 1550 Sed | | | | X | X | | 1 | MS/MSD on TOC |
| SD13-10-4064 | 4/4/13 1550 Sed | | | | | X | | 1 | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | TOTAL NUMBER OF CONTAINERS | 10 | |

Ship To:
PTS Laboratories, Inc.
8100 Secura Way
Santa Fe Springs, CA 90670
562-347-2504
Sample Receiving

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | | |
| Received by | | |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment:
Shipping Company:
On Ice: yes / no:
Airbill No.:
Shipping Date:

**Special Instructions:**

Report Copy to:
Ruth Siegmund
ruthsiegmund@e2.com

# E2 Consulting Engineers, Inc.

CHAIN OF CUSTODY RECORD: UHSed_PTS09

2013 Sediment Sampling

| Project Name: United Heckathorn | Container: | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Preservatives: | None | None | None | None | None | | | |
| Project Number: | | | | | | | | | |
| Project Manager: | Filtered: | n | n | n | n | n | | | |
| Sample Manager: | Holding Time | 180 Days | 180 Days | 180 Days | 180 Days | 180 Days | | | Ship To: PTS Laboratories, Inc. 8100 Secura Way Santa Fe Springs, CA 90670 562-347-2504 Sample Receiving |
| Cell Number: | | | | | | | | | |
| Fax/Email: | | Percent Solids (D2216) | Atterberg Limits (D4318) | Specific Gravity (D854) | Grain size (D422) | TOC (Walkley-Black) | | Number of Containers | |
| SAMPLE ID | DATE TIME Matrix | | | | | | | | COMMENTS |
| SD13-09-0055 | 4/3/13 1120 Sed | X | X | X | | | | 1 | |
| SD13-09-0002 | 4/3/13 1120 Sed | | | | X | X | | 1 | |
| SD13-09-0203 | 4/3/13 1120 Sed | | | | X | X | | 1 | |
| SD13-09-0305 | 4/3/13 1120 Sed | | | | X | X | | 1 | |
| SD13-09-0507 | 4/3/13 1120 Sed | | | | X | X | | 1 | |
| SD13-09-0708 | 4/3/13 1120 Sed | | | | X | X | | 1 | |
| SD13-09-0810 | 4/3/13 1120 Sed | | | | X | X | | 1 | |
| SD13-09-1020 | 4/3/13 1120 Sed | | | | X | X | | 1 | |
| SD13-09-2040 | 4/3/13 1120 Sed | | | | X | X | | 1 | |
| SD13-09-4055 | 4/3/13 1120 Sed | | | | X | X | | 1 | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | TOTAL NUMBER OF CONTAINERS | 10 | |

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | | |
| Received by | | |
| Relinquished by | | |
| Received by | | |

| Shipping Details |
|---|
| Method of shipment: |
| Shipping Company: |
| On Ice: yes / no: |
| Airbill No.: |
| Shipping Date: |

| Special Instructions: |
|---|
| Report Copy to: Ruth Siegmund ruthsiegmund@e2.com |

# E2 Consulting Engineers, Inc.

**CHAIN OF CUSTODY RECORD: UHSed_PTS1314**

**2013 Sediment Sampling**

Project Name: United Heckathorn

Project Number:

Project Manager:

Sample Manager:

Cell Number:

Fax/Email:

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Container: | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | | | | |
| | | | Preservatives: | None | None | None | None | None | | | | |
| | | | Filtered: | n | n | n | n | n | | | | |
| | | | Holding Time | 180 Days | 180 Days | 180 Days | 180 Days | 180 Days | | | | |
| SAMPLE ID | DATE | TIME | Matrix | Percent Solids (D2216) | Atterberg Limits (D4318) | Specific Gravity (D854) | Grain Size (D4464) | TOC (walkley-black) | | Number of Containers | Ship To: PTS Laboratories, Inc. 8100 Secura Way Santa Fe Springs, CA 90670 562-347-2504 Sample Receiving | COMMENTS |
| SD13-13-0025 | 4/3/13 | 0950 | Sed | X | X | X | | | | 1 | | |
| SD13-13-0006 | 4/3/13 | 0950 | Sed | | | | X | X | | 1 | | |
| SD13-13-0520 | 4/3/13 | 0950 | Sed | | | | | X | | 1 | | |
| SD13-13-2025 | 4/3/13 | 0950 | Sed | | | | X | X | | 1 | | |
| SD13-13-40 | | | Sed | | | | | X | TS 4/3/13 | 1 | | |
| SD13-14-0009 | 4/5/13 | 1145 | Sed | X | X | X | | | | 1 | | |
| SD13-14-0006 | 4/5/13 | 1145 | Sed | | | | X | X | | 1 | | |
| SD13-14-0520 09 | 4/5/13 | 1145 | Sed | | | | | X | | 1 | | |
| SD13-14-2025 20 | 4/5/13 | 1145 | Sed | | | | X | X | | 1 | | |
| SD13-14-40 2040 | 4/5/13 | 1145 | Sed | | | | | X | | 1 | | MS/MSD on TOC |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | TOTAL NUMBER OF CONTAINERS | 10 | | |

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | | |
| Received by | | |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment:
Shipping Company:
On ice: yes / no:
Airbill No.:
Shipping Date:

**Special Instructions:**

Report Copy to:
Ruth Siegmund
ruthsiegmund@e2.com

# E2 Consulting Engineers, Inc.

CHAIN OF CUSTODY RECORD: UHSed_PTS1618

2013 Sediment Sampling

Project Name: United Heckathorn

Project Number:

Project Manager:

Sample Manager:

Cell Number:

Fax/Email:

| | Container: | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Preservatives: | None | None | None | None | None | | | |
| | Filtered: | n | n | n | n | n | | | |
| | Holding Time | 180 Days | 180 Days | 180 Days | 180 Days | 180 Days | | | |
| SAMPLE ID | DATE / TIME / Matrix | Percent Solids (D2216) | Atterberg Limits (D4318) | Specific Gravity (D854) | Grain Size (D4464) | TOC (Walkley-Black) | | Number of Containers | COMMENTS |
| SD13-15-0049 | 4/3/13 1540 Sed | X | X | X | | | | 1 | |
| SD13-15-0005 | 4/3/13 1540 Sed | | | | X | X | | 1 | |
| SD13-15-0520 | 4/3/13 1540 Sed | | | | | X | | 1 | |
| SD13-15-2045 | 4/3/13 1540 Sed | | | | X | X | | 1 | |
| SD13-15-4044 | 4/3/13 1540 Sed | | | | | X | | 1 | |
| SD13-18-0010 | 4/4/13 1220 Sed | X | | X | | | | 1 | |
| SD13-18-0005 | 4/4/13 1220 Sed | | | | X | X | | 1 | |
| SD13-18-0510 | 4/4/13 1220 Sed | | | | | X | | 1 | |
| SD13-18-1530 | 4/4/13 1220 Sed | | | | X | X | | 1 | |
| ~~SD13-18-~~ | ~~4/4/13 1220 Sed~~ | | | | | | | ~~1~~ | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | TOTAL NUMBER OF CONTAINERS | 10 | |

Ship To:
PTS Laboratories, Inc.
8100 Secura Way
Santa Fe Springs, CA 90670
562-347-2504
Sample Receiving

| Signatures | Date/Time |
|---|---|
| Sampled by | |
| Relinquished by | |
| Received by | |
| Relinquished by | |
| Received by | |

**Shipping Details**

Method of shipment:
Shipping Company:
On Ice: yes / no:
Airbill No.:
Shipping Date:

**Special Instructions:**

Report Copy to:
Ruth Siegmund
ruthsiegmund@e2.com

# E2 Consulting Engineers, Inc.

CHAIN OF CUSTODY RECORD: UHSed_PTS1920

2013 Sediment Sampling

Project Name: United Hecathorn

Project Number:

Project Manager:

Sample Manager:

Cell Number:

Fax/Email:

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Container: | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | | | Ship To: PTS Laboratories, Inc. 8100 Secure Way Santa Fe Springs, CA 90670 562-347-2504 Sample Receiving |
| | | | Preservatives: | None | None | None | None | | | |
| | | | Filtered: | n | n | n | n | | | |
| | | | Holding Time | 180 Days | 180 Days | 180 Days | 180 Days | | | |
| SAMPLE ID | DATE | TIME | Matrix | Percent Solids (D2216) | Specific Gravity (D854) | Grain Size (D4464) | TOC (Walkley-Black) | | Number of Containers | COMMENTS |
| SD13-19-0040 | 4/5/13 | 1225 | Sed | X | X | | | | 1 | |
| SD13-19-0005 | 4/5/13 | 1225 | Sed | | | X | X | | 1 | |
| SD13-19-0520 | 4/5/13 | 1225 | Sed | | | | X | | 1 | |
| SD13-19-2040 | 4/5/13 | 1225 | Sed | | | X | X | | 1 | |
| SD13-19-4045 60 | 4/5/13 | 1225 | Sed | | | | X | | 1 | |
| SD13-20-0052 | 4/3/13 | 1440 | Sed | X | X | | | | 1 | |
| SD13-20-0005 | 4/3/13 | 1440 | Sed | | | X | X | | 1 | |
| SD13-20-0520 | 4/3/13 | 1440 | Sed | | | | X | | 1 | |
| SD13-20-2040 | 4/3/13 | 1440 | Sed | | | X | X | | 1 | MS/MSD on TOC. |
| SD13-20-4052 | 4/3/13 | 1440 | Sed | | | | X | | 1 | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | TOTAL NUMBER OF CONTAINERS | 10 | |

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | | |
| Received by | | |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment:

Shipping Company:

On ice: yes / no:

Airbill No.:

Shipping Date:

**Special Instructions:**

Report Copy to:

Ruth Siegmund

ruthsiegmund@e2.com

# E2 Consulting Engineers, Inc.

CHAIN OF CUSTODY RECORD: UHSed_PTS2324

2013 Sediment Sampling

Project Name: United Hackathorn

Project Number:

Project Manager:

Sample Manager:

Cell Number:

Fax/Email:

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Container: | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | | | | | | |
| Preservatives: | None | None | None | None | | | | | | |
| Filtered: | n | n | n | n | | | | | | |
| Holding Time | 180 Days | 180 Days | 180 Days | 180 Days | | | | | | |
| SAMPLE ID | DATE | TIME | Matrix | Percent Solids (D2216) | Specific Gravity (D854) | Grain Size (D4464) | TOC (walkley-black) | | Number of Containers | COMMENTS |
| SD13-23-00 37 | 4/4/13 | 1135 | Sed | X | X | | | | 1 | |
| SD13-23-0005 | 4/4/13 | 1135 | Sed | | | X | X | | 1 | |
| SD13-23-0520 | 4/4/13 | 1135 | Sed | | | | X | | 1 | |
| SD13-23-2037 | 4/4/13 | 1135 | Sed | | | X | X | | 1 | |
| ~~SD13-23-40~~ | | | Sed | | | | X | | 1 | |
| SD13-24-00 00 | 4/4/13 | 1015 | Sed | X | X | | | | 1 | |
| SD13-24-0005 | 4/4/13 | 1015 | Sed | | | X | X | | 1 | |
| SD13-24-0520 | 4/4/13 | 1015 | Sed | | | | X | | 1 | |
| SD13-24-2040 | 4/4/13 | 1015 | Sed | | | X | X | | 1 | |
| SD13-24-40 60 | 4/4/13 | 1015 | Sed | | | | X | | 1 | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | TOTAL NUMBER OF CONTAINERS | 10 | |

Ship To:
PTS Laboratories, Inc.
8100 Secure Way
Santa Fe Springs, CA 90670
562-347-2504
Sample Receiving

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | | |
| Received by | | |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment:
Shipping Company:
On Ice: yes / no:
Airbill No.:
Shipping Date:

Special Instructions:

Report Copy to:
Ruth Siegmund
ruthsiegmund@e2.com

# E2 Consulting Engineers, Inc.

CHAIN OF CUSTODY RECORD: UHSed_PTS2527

2013 Sediment Sampling

Project Name: United Heckathorn
Project Number:
Project Manager:
Sample Manager:
Cell Number:
Fax/Email:

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Container: | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | | | |
| | | | Preservatives: | None | None | None | None | | | |
| | | | Filtered: | n | n | n | n | | | |
| | | | Holding Time | 180 Days | 180 Days | 180 Days | 180 Days | | | |
| SAMPLE ID | DATE | TIME | Matrix | Percent Solids (D2216) | Specific Gravity (D854) | Grain Size (D4464) | TOC (Walkley-Black) | | Number of Containers | COMMENTS |
| SD13-25-0059 | 4/5/13 | 0746 | Sed | X | X | | | | 1 | |
| SD13-25-0005 | 4/5/13 | 0745 | Sed | | | X | X | | 1 | |
| SD13-25-0520 | 4/5/13 | 0745 | Sed | | | | X | | 1 | |
| SD13-25-2042 | 4/5/13 | 0745 | Sed | | | X | X | | 1 | |
| SD13-25-4069 | 4/5/13 | 0745 | Sed | | | | X | | 1 | |
| SD13-27-0031 | 4/4/13 | 0930 | Sed | X | X | | | | 1 | |
| SD13-27-0006 | 4/4/13 | 0930 | Sed | | | X | X | | 1 | MS/MSD on TOC |
| SD13-27-0520 | 4/4/13 | 0930 | Sed | | | | X | | 1 | |
| SD13-27-2031 | 4/4/13 | 0930 | Sed | | | X | X | | 1 | |
| ~~SD13-27-40~~ | | | ~~Sed~~ | | | | | | ~~1~~ | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | TOTAL NUMBER OF CONTAINERS | 10 | |

Ship To:
PTS Laboratories, Inc.
8100 Secura Way
Santa Fe Springs, CA 90670
562-347-2504
Sample Receiving

| Signatures | Date/Time |
|---|---|
| Sampled by | |
| Relinquished by | |
| Received by | |
| Relinquished by: | |
| Received by | |

**Shipping Details**

Method of shipment:
Shipping Company:
On Ice: yes / no:
Airbill No.:
Shipping Date:

**Special Instructions:**

Report Copy to:
Ruth Siegmund
ruthsiegmund@e2.com

# E2 Consulting Engineers, Inc.

CHAIN OF CUSTODY RECORD: UHSed_PTS2829

2013 Sediment Sampling

Project Name: United Hackathorn

Project Number:

Project Manager:

Sample Manager:

Cell Number:

Fax/Email:

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Container: | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | | | |
| | | | Preservatives: | None | None | None | None | | | |
| | | | Filtered: | n | n | n | n | | | |
| | | | Holding Time | 180 Days | 180 Days | 180 Days | 180 Days | | | |
| SAMPLE ID | DATE | TIME | Matrix | Percent Solids (D2216) | Specific Gravity (D854) | Grain Size (D4464) | TOC (Walkley-Black) | | Number of Containers | COMMENTS |
| SD13-28-00@0 | 4/4/13 | 0840 | Sed | X | X | | | | 1 | |
| SD13-28-0005 | 4/4/13 | 0840 | Sed | | | X | X | | 1 | |
| SD13-28-0520 | 4/4/13 | 0840 | Sed | | | | X | | 1 | |
| SD13-28-2040 | 4/4/13 | 0840 | Sed | | | X | X | | 1 | |
| SD13-28-40@0 | 4/4/13 | 0840 | Sed | | | | X | | 1 | |
| SD13-29-00@0 | 4/5/13 | 950 | Sed | X | X | | | | 1 | |
| SD13-29-0005 | 4/5/13 | 950 | Sed | | | X | X | | 1 | |
| SD13-29-0520 | 4/5/13 | 950 | Sed | | | | X | | 1 | |
| SD13-29-2040 | 4/5/13 | 950 | Sed | | | X | X | | 1 | |
| SD13-29-40@0 | 4/5/13 | 960 | Sed | | | | X | | 1 | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | TOTAL NUMBER OF CONTAINERS | 10 | |

Ship To:
PTS Laboratories, Inc.
8100 Secura Way
Santa Fe Springs, CA 90670
562-347-2504
Sample Receiving

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | | |
| Received by | | |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment:
Shipping Company:
On ice: yes / no:
Airbill No.:
Shipping Date:

Special Instructions:

Report Copy to:
Ruth Siegmund
rsiegmund@e2.com

# E2 Consulting Engineers, Inc.

CHAIN OF CUSTODY RECORD: UHSed_PTS3132

2013 Sediment Sampling

Project Name: United Heckathorn

Project Number:

Project Manager:

Sample Manager:

Cell Number:

Fax/Email:

| | Container: | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | | | |
|---|---|---|---|---|---|---|---|---|
| | Preservatives: | None | None | None | None | | | |
| | Filtered: | n | n | n | n | | | |
| | Holding Time | 180 Days | 180 Days | 180 Days | 180 Days | | | |
| SAMPLE ID | DATE | TIME | Matrix | Percent Solids (D2216) | Specific Gravity (D854) | Grain Size (D4464) | TOC (Walkley-Black) | | Number of Containers | COMMENTS |
| SD13-31-0020 | 4/4/13 | 1500 | Sed | X | X | | | | 1 | |
| SD13-31-0005 | 4/4/13 | 1500 | Sed | | | X | X | | 1 | |
| SD13-31-0520 | 4/4/13 | 1500 | Sed | | | | X | | 1 | |
| SD13-31-2040 | 4/4/13 | 1500 | Sed | | | X | X | | 1 | |
| SD13-31-40 | | | Sed | | | | X | | 1 | |
| SD13-32-0060 | 4/5/13 | 0910 | Sed | X | X | | | | 1 | |
| SD13-32-0005 | 4/5/13 | 0910 | Sed | | | X | X | | 1 | |
| SD13-32-0520 | 4/5/13 | 0910 | Sed | | | | X | | 1 | |
| SD13-32-2040 | 4/5/13 | 0910 | Sed | | | X | X | | 1 | |
| SD13-32-4060 | 4/5/13 | 0910 | Sed | | | | X | | 1 | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | TOTAL NUMBER OF CONTAINERS = | 10 | |

Ship To:
PTS Laboratories, Inc.
8100 Secura Way
Santa Fe Springs, CA 90670
562-347-2504
Sample Receiving

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | | |
| Received by | | |
| Relinquished by | | |
| Received by | | |

Shipping Details

Method of shipment:
Shipping Company:
On Ice: yes / no:
Airbill No.:
Shipping Date:

Special Instructions:

Report Copy to:
Ruth Siegmund
ruthsiegmund@e2.com

# E2 Consulting Engineers, Inc.

**CHAIN OF CUSTODY RECORD: UHSed_PTS3335**

**2013 Sediment Sampling**

Project Name: United Hackathorn
Project Number:
Project Manager:
Sample Manager:
Cell Number:
Fax/Email:

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Container: | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | | | |
| | | | Preservatives: | None | None | None | None | | | |
| | | | Filtered: | n | n | n | n | | | |
| | | | Holding Time | 180 Days | 180 Days | 180 Days | 180 Days | | | |
| | | | | Percent Solids (D2216) | Specific Gravity (D854) | Grain Size (D4464) | TOC (Walkley-Black) | | Number of Containers | |
| SAMPLE ID | DATE | TIME | Matrix | | | | | | | COMMENTS |
| SD13-33-0060 | 4/4/13 | 1100 | Sed | X | X | | | | 1 | |
| SD13-33-0005 | 4/4/13 | 1100 | Sed | | | X | X | | 1 | |
| SD13-33-0520 | 4/4/13 | 1100 | Sed | | | | X | | 1 | MS/MSD on TOC |
| SD13-33-2040 | 4/4/13 | 1100 | Sed | | | X | X | | 1 | |
| SD13-33-4060 | 4/4/13 | 1100 | Sed | | | | X | | 1 | |
| SD13-35-0059 | 4/4/13 | 1420 | Sed | X | X | | | | 1 | |
| SD13-35-0005 | 4/4/13 | 1420 | Sed | | | X | X | | 1 | |
| SD13-35-0520 | 4/4/13 | 1420 | Sed | | | | X | | 1 | |
| SD13-35-2040 | 4/4/13 | 1420 | Sed | | | X | X | | 1 | |
| SD13-35-4060 | 4/4/13 | 1420 | Sed | | | | X | | 1 | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | TOTAL NUMBER OF CONTAINERS | 10 | |

**Ship To:**
PTS Laboratories, Inc.
8100 Secura Way
Santa Fe Springs, CA 90670
562-347-2504
Sample Receiving

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | | |
| Received by | | |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment:
Shipping Company:
On ice: yes / no:
Airbill No.:
Shipping Date:

**Special Instructions:**

Report Copy to:
Ruth Sigmund
ruthsigmund@e2.com

# E2 Consulting Engineers, Inc.

CHAIN OF CUSTODY RECORD: UHSed_PTS3637

2013 Sediment Sampling

| Project Name: United Hechathorn | Container: | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | | | |
|---|---|---|---|---|---|---|---|---|
| | Preservatives: | None | None | None | None | | | |
| Project Number: | | | | | | | | |
| Project Manager: | Filtered: | n | n | n | n | | | |
| Sample Manager: | Holding Time | 180 Days | 180 Days | 180 Days | 180 Days | | | |
| Cell Number: | | Percent Solids (D2216) | Specific Gravity (D854) | Grain Size (D4464) | TOC (Walkley-Black) | | Number of Containers | Ship To: PTS Laboratories, Inc. 8100 Secure Way Santa Fe Springs, CA 90670 562-347-2604 Sample Receiving |
| Fax/Email: | | | | | | | | |
| SAMPLE ID | DATE TIME Matrix | | | | | | | COMMENTS |
| SD13-36-0000-05 | 4/4/13 1300 Sed | X | X | | | | 1 | |
| SD13-36-0005 | 4/4/13 1300 Sed | | | X | X | | 1 | |
| SD13-36-0520 | 4/4/13 1300 Sed | | | | X | | 1 | |
| SD13-36-2040 | 4/4/13 1300 Sed | | | X | X | | 1 | |
| SD13-36-4060 | 4/4/13 1300 Sed | | | | X | | 1 | |
| SD13-37-00 00 | 4/5/13 1030 Sed | X | X | | | | 1 | |
| SD13-37-0005 | 4/5/13 1030 Sed | | | X | X | | 1 | |
| SD13-37-0520 | 4/5/13 1030 Sed | | | | X | | 1 | |
| SD13-37-2040 | 4/5/13 1030 Sed | | | X | X | | 1 | |
| SD13-37-40 60 | 4/5/13 1030 Sed | | | | X | | 1 | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | TOTAL NUMBER OF CONTAINERS | 10 | |

| Signatures | | Date/Time | Shipping Details | Special Instructions: |
|---|---|---|---|---|
| Sampled by | | | Method of shipment: | |
| Relinquished by | | | Shipping Company: | Report Copy to: |
| Received by | | | On Ice: yes / no: | Ruth Siegmund |
| Relinquished by | | | Airbill No.: | ruthsiegmund@e2.com |
| Received by | | | Shipping Date: | |

# E2 Consulting Engineers, Inc.

**CHAIN OF CUSTODY RECORD: UHSed_PTS3940**

**2013 Sediment Sampling**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Project Name: United Heckathorn | | | Container: | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | | | Ship To: PTS Laboratories, Inc. 8100 Secura Way Santa Fe Springs, CA 90670 562-347-2504 Sample Receiving | |
| | | | Preservatives: | None | None | None | None | | | | |
| Project Number: | | | | | | | | | | | |
| Project Manager: | | | Filtered: | n | n | n | n | | | | |
| Sample Manager: | | | Holding Time | 180 Days | 180 Days | 180 Days | 180 Days | | | | |
| Cell Number: | | | | | | | | | | | |
| Fax/Email: | | | | Percent Solids (D2216) | Specific Gravity (D854) | Grain Size (D4464) | TOC (Walkley-Black) | | Number of Containers | | |
| SAMPLE ID | DATE | TIME | Matrix | | | | | | | COMMENTS | |
| SD13-39-~~0047~~ 0034 | 4/4/13 | 1345 | Sed | X | X | | | | 1 | | |
| SD13-39-0005 | 4/4/13 | 1345 | Sed | | | X | X | | 1 | | |
| SD13-39-0520 | 4/4/13 | 1345 | Sed | | | | X | | 1 | | |
| SD13-39-20~~45~~ 34 | 4/4/13 | 1345 | Sed | | | X | X | | 1 | | |
| SD13-39-4049 | 4/4/13 | 1345 | Sed | | | | X | | 1 | | |
| SD13-40-0040 | 4/4/13 | 1540 | Sed | X | X | | | | 1 | | |
| SD13-40-0005 | 4/4/13 | 1540 | Sed | | | X | X | | 1 | | |
| SD13-40-0520 | 4/4/13 | 1540 | Sed | | | | X | | 1 | | |
| SD13-40-2040 | 4/4/13 | 1540 | Sed | | | X | X | | 1 | MS/MSD on TOC | |
| ~~SD13-40-40~~ | ~~4/4/13~~ | ~~1540~~ | ~~Sed~~ | | | | X | | ~~1~~ | ~~MS/MSD on TOC~~ | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | TOTAL NUMBER OF CONTAINERS | 10 | | |

| Signatures | | Date/Time | Shipping Details | Special Instructions: |
|---|---|---|---|---|
| Sampled by | | | Method of shipment: | |
| Relinquished by | | | Shipping Company: | Report Copy to: |
| Received by | | | On Ice: yes / no: | Ruth Siegmund |
| Relinquished by | | | Airbill No.: | ruthsiegmund@e2.com |
| Received by | | | Shipping Date: | |

# E2 Consulting Engineers, Inc.

**CHAIN OF CUSTODY RECORD: UHSed_PTS41**

**2013 Sediment Sampling**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project Name:** United Heckathorn | | | | **Container:** | Ziplock Bag | Ziplock Bag | Ziplock Bag | Ziplock Bag | | | |
| | | | | **Preservatives:** | None | None | None | None | | | |
| **Project Number:** | | | | | | | | | | | |
| **Project Manager:** | | | | **Filtered:** | n | n | n | n | | | |
| **Sample Manager:** | | | | **Holding Time** | 180 Days | 180 Days | 180 Days | 180 Days | | | |
| **Cell Number:** | | | | | Percent Solids (D2216) | Specific Gravity (D854) | Grain Size (D4464) | TOC (Walkley-Black) | | | |
| **Fax/Email:** | | | | | | | | | | | |
| **SAMPLE ID** | | **DATE** | **TIME** | **Matrix** | | | | | | **Number of Containers** | **COMMENTS** |
| SD13-41-0049 | 1100 | 4/5/13 | 1100 | Sed | X | X | | | | 1 | |
| SD13-41-0005 | 1100 | 4/5/13 | 1100 | Sed | | | X | X | | 1 | |
| SD13-41-0520 | 1100 | 4/5/13 | 1100 | Sed | | | | X | | 1 | |
| SD13-41-2040 | 1100 | 4/5/13 | 1100 | Sed | | | X | X | | 1 | |
| SD13-41-4049 | 1100 | 4/5/13 | 1100 | Sed | | | | X | | 1 | |
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| | | | | | | | | | TOTAL NUMBER OF CONTAINERS | 5 | |

**Ship To:**
PTS Laboratories, Inc.
8100 Secura Way
Santa Fe Springs, CA 90670
562-347-2504
Sample Receiving

| **Signatures** | | **Date/Time** |
|---|---|---|
| Sampled by | | |
| Relinquished by | | |
| Received by | | |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment:
Shipping Company:
On ice: yes / no:
Airbill No.:
Shipping Date:

**Special Instructions:**

Report Copy to:
Ruth Siegmund
ruthsiegmund@e2.com

# E2 Consulting Engineers, Inc.

## CHAIN OF CUSTODY RECORD: UHSed_R90406

2013 Sediment Sampling

| | |
|---|---|
| Project Name: United Heckathorn | Container: 4 oz glass jar |
| | Preservatives: 4C (+-2C) |
| Project Number: R13S55 | |
| Project Manager: | Filtered: n |
| Sample Manager; | Holding Time Days |
| Cell Number: | |
| Fax/Email: | |

| SAMPLE ID | DATE | TIME | Matrix | Pesticides (SW8081A) | Number of Containers | COMMENTS |
|---|---|---|---|---|---|---|
| SD13-04-~~0520~~-0515 | 4/3/13 | 0905 | Sed | X | 1 | |
| ~~SD13-00-40~~ | | | ~~Sed~~ | ~~X~~ | ~~1~~ | |
| SD13-00-4050 | 4/5/13 | 0830 | Sed | X | 1 | |
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| TOTAL NUMBER OF CONTAINERS | | | | | ~~1~~ 2 | |

**Ship To:**
USEPA Region 9 Laboratory
1337 South 46th Street, Building 201
Richmond, CA 94804
510-412-2389
Sample Receiving

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | | 4/5/13 |
| Received by | | |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment:
Shipping Company:
On ice: yes / no:
Airbill No.:
Shipping Date:

**Special Instructions:**

Report Copy to:
Ruth Siegmund
ruthsiegmund@e2.com

# E2 Consulting Engineers, Inc.

## CHAIN OF CUSTODY RECORD: UHSed_R90813

**2013 Sediment Sampling**

| | |
|---|---|
| **Project Name:** United Heckathorn | **Container:** 4 oz glass jar |
| | **Preservatives:** 4C (+-2C) |
| **Project Number:** R13S55 | |
| **Project Manager:** | **Filtered:** n |
| **Sample Manager:** | **Holding Time** Days |
| **Cell Number:** | |
| **Fax/Email:** | |

| SAMPLE ID | DATE | TIME | Matrix | Pesticides (SW8081A) | | Number of Containers | COMMENTS |
|---|---|---|---|---|---|---|---|
| SD13-08-2040 | 4/5/13 | 1300 | Sed | X | | 1 | |
| SD13-13-0520 | 4/3/13 | 0950 | Sed | X | | 1 | |
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| | | | | | TOTAL NUMBER OF CONTAINERS | 2 | |

**Ship To:**
USEPA Region 9 Laboratory
1337 South 46th Street, Building 201
Richmond, CA 94804
510-412-2389
Sample Receiving

| | Signatures | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | James Jones | 4/5/13 |
| Received by | | |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment:
Shipping Company:
On ice: yes / no:
Airbill No.:
Shipping Date:

**Special Instructions:**

Report Copy to:
Ruth Siegmund
ruthsiegmund@e2.com

# E2 Consulting Engineers, Inc.

## CHAIN OF CUSTODY RECORD: UHSed_R91518

**2013 Sediment Sampling**

| | |
|---|---|
| Project Name: United Heckathorn | Container: 4 oz glass jar |
| | Preservatives: 4C (+-2C) |
| Project Number: R13S55 | |
| Project Manager: | Filtered: n |
| Sample Manager: | Holding Time Days |
| Cell Number: | |
| Fax/Email: | |

| SAMPLE ID | DATE | TIME | Matrix | Pesticides (SW8081A) | Number of Containers | COMMENTS |
|---|---|---|---|---|---|---|
| SD13-15-2000 | 4/3/13 | 1540 | Sed | X | 1 | |
| SD13-18-0510 | 4/4/13 | 1220 | Sed | X | 1 | |
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| | | | | TOTAL NUMBER OF CONTAINERS | 2 | |

**Ship To:**
USEPA Region 9 Laboratory
1337 South 46th Street, Building 201
Richmond, CA 94804
510-412-2389
Sample Receiving

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | [signature] | 4/4/13 |
| Received by | | |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment:
Shipping Company:
On ice: yes / no:
Airbill No.:
Shipping Date:

**Special Instructions:**

Report Copy to:
Ruth Siegmund
ruthsiegmund@e2.com

# E2 Consulting Engineers, Inc.

## CHAIN OF CUSTODY RECORD: UHSed_R91923

**2013 Sediment Sampling**

| | |
|---|---|
| Project Name: United Heckathorn | Container: 4 oz glass jar |
| | Preservatives: 4C (+-2C) |
| Project Number: R13S55 | |
| Project Manager: | Filtered: n |
| Sample Manager: | Holding Time Days |
| Cell Number: | |
| Fax/Email: | |

| SAMPLE ID | DATE | TIME | Matrix | Pesticides (SW8081A) | Number of Containers | COMMENTS |
|---|---|---|---|---|---|---|
| SD13-19-2040 | 4/5/13 | 1225 | Sed | X | 1 | |
| SD13-23-0005 | 4/4/13 | 1135 | Sed | X | 1 | |
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| TOTAL NUMBER OF CONTAINERS | | | | | 2 | |

**Ship To:**
USEPA Region 9 Laboratory
1337 South 46th Street, Building 201
Richmond, CA 94804
510-412-2389
Sample Receiving

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | [signature] | 4/5/13 |
| Received by | | |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment:
Shipping Company:
On ice: yes / no:
Airbill No.:
Shipping Date:

**Special Instructions:**

Report Copy to:
Ruth Siegmund
ruthsiegmund@e2.com

# E2 Consulting Engineers, Inc.

**CHAIN OF CUSTODY RECORD: UHSed_R92527**

**2013 Sediment Sampling**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Project Name:** United Heckathorn | | | **Container:** | 4 oz glass jar | | | | |
| | | | **Preservatives:** | 4C (+-2C) | | | | |
| **Project Number:** R13S55 | | | | | | | | |
| **Project Manager:** | | | **Filtered:** | n | | | | |
| **Sample Manager:** | | | **Holding Time** | Days | | | | |
| **Cell Number:** | | | | | | | | |
| **Fax/Email:** | | | | | | | | |
| **SAMPLE ID** | **DATE** | **TIME** | **Matrix** | **Pesticides (SW8081A)** | | | **Number of Containers** | **COMMENTS** |
| SD13-25-20 40 | 4/5/13 | 0745 | Sed | X | | | 1 | |
| SD13-27-~~40~~ 0520 | 4/4/13 | 0930 | Sed | X | | | 1 | |
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| | | | | | | TOTAL NUMBER OF CONTAINERS | 2 | |

**Ship To:**
**USEPA Region 9 Laboratory**
**1337 South 46th Street, Building 201**
**Richmond, CA 94804**
**510-412-2389**
**Sample Receiving**

| **Signatures** | | **Date/Time** |
|---|---|---|
| Sampled by | James Jank | 4/5/13 |
| Relinquished by | | |
| Received by | | |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment:
Shipping Company:
On ice: yes / no:
Airbill No.:
Shipping Date:

**Special Instructions:**

**Report Copy to:**
Ruth Siegmund
ruthsiegmund@e2.com

# E2 Consulting Engineers, Inc.

## CHAIN OF CUSTODY RECORD: UHSed_R92832

2013 Sediment Sampling

Project Name: United Heckathorn
Project Number: R13S55
Project Manager:
Sample Manager:
Cell Number:
Fax/Email:

| | |
|---|---|
| Container: | 4 oz glass jar |
| Preservatives: | 4C (+-2C) |
| Filtered: | n |
| Holding Time | Days |

| SAMPLE ID | DATE | TIME | Matrix | Pesticides (SW8081A) | Number of Containers | COMMENTS |
|---|---|---|---|---|---|---|
| SD13-28-0520 | 4/4/13 | 0840 | Sed | X | 1 | |
| SD13-32-0005 | 4/5/13 | 0910 | Sed | X | 1 | |
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| TOTAL NUMBER OF CONTAINERS | | | | | 2 | |

Ship To:
USEPA Region 9 Laboratory
1337 South 46th Street, Building 201
Richmond, CA 94804
510-412-2389
Sample Receiving

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | [signature] | 4/5/13 |
| Received by | | |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment:
Shipping Company:
On ice: yes / no:
Airbill No.:
Shipping Date:

**Special Instructions:**

Report Copy to:
Ruth Siegmund
ruthsiegmund@e2.com

E2 Consulting Engineers, Inc.

CHAIN OF CUSTODY RECORD: UHSed_R93540

2013 Sediment Sampling

Project Name: United Heckathorn

Project Number: R13S55

Project Manager:

Sample Manager:

Cell Number:

Fax/Email:

Container: 4 oz glass jar

Preservatives: 4C (+-2C)

Filtered: n

Holding Time: Days

Ship To:
USEPA Region 9 Laboratory
1337 South 46th Street, Building 201
Richmond, CA 94804
510-412-2389
Sample Receiving

| SAMPLE ID | DATE | TIME | Matrix | Pesticides (SW8081A) | Number of Containers | COMMENTS |
|---|---|---|---|---|---|---|
| SD13-35-40 50 | 4/4/13 | 1420 | Sed | X | 1 | |
| SD13-40-20 40 | 4/4/13 | 1540 | Sed | X | 1 | |
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| | | | | TOTAL NUMBER OF CONTAINERS | 2 | |

| | Signatures | Date/Time |
|---|---|---|
| Sampled by | Jamara Jarvis | 4/5/13 |
| Relinquished by | | |
| Received by | | |
| Relinquished by | | |
| Received by | | |

Shipping Details

Method of shipment:
Shipping Company:
On ice: yes / no:
Airbill No.:
Shipping Date:

Special Instructions:

Report Copy to:
Ruth Siegmund
ruthsiegmund@e2.com

# Attachment 2
# Sample Collection Forms

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441.FI.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | ~~SD-04~~ cc SD13-04 | Northing: | 2164441.03 | Attempt 1 | Refusal? Y/N |
| Sampling | C Cisneros/CH2M HILL | Easting: | 6023234.68 | Penetration (ft): | 5.9 |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft) | inches - Discarded |
| | | Depth (ft) | 11.1' | Date/Time: | 4/2/2013 |
| | | Pred Tide (ft): | 1.54 ft MLLW | | 918 |
| | | St. Arrival: | 918 | Attempt 2 | Refusal? Y/N |
| Vessel: | Walter Marie | St.Depart | 1010 | Penetration ~~(ft)~~ cc in | 105.5 |
| Collection: | vibracore | Logged by: | T Himmer/CH2M; T Frank/E2 | Recovery (ft) | cc ~~21 inches~~ |
| Contact Information: | Theresa Himmer/CH2M HILL theresa.himmer@ch2m.com 781 378 2088 | | | Date/Time: | 4/2/13 0940 |

Attempt 3 | Attempt 2 | Attempt 3
7 ft, 2 in | 14.9 | 14.6
2 inches | 1.22 | 0.87
4/2/13 1000

1.5' measured during processing

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/Density | Cementation/Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample IDs (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YBM+ Gravel | 0.5 | | MH/ 04 | Blk 10YR 2/1 | VS S F | N ↓ | H ↓ | W ↓ | F-MSN | FAINT PHC | 0 | 50 25 ↓ | 50 75 ↓ | A | Make 3rd attempt further from shore during from slope |
| 1.5' | 1 | | GM-GC | | | | | | G | * | 75 | 15 | 10 | B | C |
| | 2 | | | | | | | | | | | | | | 3rd Att. Retained |
| | 3 | | | | | | | | | | | | | | ODOR STRONGER IN GRAVEL 1.3 - 1.5' |
| | 4 | | | | | | | | | | | | | | 0-0.4' loose f-m sand w/ fines. gravel @ bottom of interval, |
| | 5 | | | | | | | | | | | | | | 0.5-1.3' f-m sand w/ fines, firmer, wet, trace gravel |
| | 6 | | | | | | | | | | | | | | 1.3-1.5' gravel w/ sand and fines strong odor. |
| | 7 | | | | | | | | | | | | | | |
| | 8 | | | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | * R9 split for pest. |

Sample Summary (check boxes for analysis):

| | Sample ID | Sample Type (N/FD/MS/MSD) | Sample Date/Time (4/3/2013) | Depth Interval (ft) | Pesticides | GS | TOC | GS + Atterberg |
|---|---|---|---|---|---|---|---|---|
| A | Y8RN1 SD13-04-0005 | | 9:05 | 0-0.5 | ✓ | ✓ | ✓ | |
| B | Y8RN2 SD13-04-0515 | * R9 * | ↓ | 0.5-1.5 | ✓ | | ✓ | |
| C | SD13-04-0015 | | | 0-1.5 | | | | ✓ |
| D | | | | | | | | |
| E | | | | | | | | |
| F | | | | | | | | |

Reviewed by: Date:

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441.F1.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

FINE INTERVAL CORE

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | ~~SD05~~ SD13-05 cc | Northing: | 2164435.49 | Attempt 1 | Refusal? Y/N |
| Sampling | C Cisneros/CH2M HILL | Easting: | 6023274.05 | Penetration (ft): | 5.5 |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft) | 4ft, 8inches |
| | | Depth (ft) | 17.7 | Date/Time: | 4/2/13 1020 |
| | | Pred Tide (ft): | 0.48 ft MLLW | | |
| | | St. Arrival: | 1012 | Attempt 2 | Refusal? Y/N |
| Vessel: | Walter Marie | St.Depart | 1034 | Penetration (ft): | |
| Collection: | vibracore | Logged by: | T.Himmer/CH2M, L Frank/E2 | Recovery (ft) | NA |
| Contact Information: | Theresa.Himmer/CH2M HILL, theresa.himmer@ch2m.com, 781 378 3080 | | | Date/Time: | |

4.1 @ processing had to cut core catcher off. Material in catcher not included in sample

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/Density | Cementation/Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample ID (letter-corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YBM | 0.5 | ~~YBM~~ TH | ~~OH~~ OH | 10YR 2/1 Blk | S. to t. | N | H | v. wet to wet | f.s | slight PHC | trace to 5% | ~10 | 85-90 | A-F | only top ~~1/2~~ 1/4 to 1/2 inch v. soft. Rest of sediment core quite cohesive & stichey |
| | 1 | | | | | | | | | | | | | G | |
| | 2 | | OH OH | | | | | | MD sand | | | 2.5' 25 to 30% | 70-75% | H see below | |
| | 3 | | | | | | | | | Strong PHC 3.3 | | | | | entire core dominantly stichy black clay/silt w/ trace to minor sand. See increasing sand + gravel ~2.5' Strong hydrocarbon odor @ 3.3' (diesel/oil-type odor) |
| 4.1 | 4 | | | | | | | wet to moist | | | | | | | |
| | 5 | | | | | | | | | | | | | | |
| | 6 | | | | | | | | | | | | | | |
| | 7 | | | | | | | | | | | | | | |
| | 8 | | | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | |

Sample Summary (check boxes for analysis):

| | Sample ID | | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | GS | TOC | Alt. Spgr., % moist. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Y8RN6 | SD13-05-0002 | | 4/3/13 | 0-.2 | ✓ | ✓ | ✓ | | | | | | |
| B | Y8RN7 | SD13-05-0203 | | 13:20 | 0.2-0.5 | ✓ | ✓ | ✓ | | | | | | |
| C | Y8RN8 | SD13-05-0305 | | | 0.3-0.5 | ✓ | ✓ | ✓ | | | | | | |
| D | Y8RN9 | SD13-05-0507 | | | 0.5-0.7 | ✓ | ✓ | ✓ | | | | | | |
| E | Y8R00 | SD13-05-0708 | | | 0.7-0.8 | ✓ | ✓ | ✓ | | | | | | |
| F | Y8R01 | SD13-05-0810 | | | 0.8-1.0 | ✓ | ✓ | ✓ | | | | | | |

Reviewed by Date

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| G | Y8R02 | SD-05-1020 | | 1.0-2.0 | ✓ | ✓ | ✓ | |
| H | Y8R03 | SD-05-2040 | | 2.0-4.0 | ✓ | ✓ | ✓ | ✓ |
| I | | SD-05-0040 | | 0.0-4.0 | | | | |

Site Name: United Heckathorn
Project Number: 385441 FI.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: SD13-03 (2nd) | Northing: 2164429.97 | | Penetration (ft): 64 in | Attempt 1 Refusal? N | |
| Sampling: C Cisneros/CH2M HILL | Easting: 6023327.06 | | Recovery (ft): 66 in | | |
| Crew/Company: Dixon Marine | Datum: NAD83 CA State Plane Zn III | 2nd 13.10 | Date/Time: 4/2/2013 0830 | | |
| | Depth (ft): 13.5 | 2.22 | | | |
| | Pred Tide (ft): 2.78 ft MLLW | | | | |
| | St. Arrival: 815 | | | Attempt 2 Refusal? Y/N | |
| Vessel: RV Walter Marie | St.Depart: ~855 | | Penetration (ft): 4 ft | | |
| Collection: vibracore | Logged by: T.Hemmer/CH2M, T.Frank/E2 | | Recovery (ft): ~1 ft - DISCarded | | |
| Contact Information: Theresa Hemmer/CH2M HILL, theresa.hemmer@ch2m.com, 781.376.2089 | | | Date/Time: 4/2/13 0852 | | |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/ Density | Cementation/ Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample ID/ Sample Interval (ft) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4BM | 0.5 | | OL/OH | 2.5 4/2 2.5/1 | V.S | N | H | wet | n. sand/pbl | strong | D | 5-10 | 90-95 | A | 0-2' v.stiff. black silt/clay, v. stick w/ minor |
| | 1 | | | | | | | | | | | | | B | |
| SAND gravel + clay/ silt | 2 | | SP-SM | 4/1 + 2.5/1 | F | | | moist | M. sand | | 0 | 80-85 | 15-20 | | med. to fine sand. small cobble @ 1.7' |
| | 3 | | | | | | | | | | | | | C | 2' Dk gray to black sand. |
| | 4 | | | | | | | | M. GR. | | 10-20 | 65-70 | 15 | | f. med, trace shell hash, |
| 5.0' | 5 | | | | | | | | | | | | | D | pockets of wet, black silt clay. |
| | 6 | | | mussel shell @ 4' plastic @ 3' | | | | | | | | | | | 3-4' SAA w/ more gravel + more clay |
| | 7 | | | | | | | | | | | | | | 4.2 to BOC - Dkgy Dk gray to black sand, as above, w/ no gravel + less clay/ silt. |
| | 8 | | | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | |

Sample Summary (check boxes for analysis):

| Sample ID | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | TOC | EAH | Archive (Stage) | Archive (LL) |
|---|---|---|---|---|---|---|---|---|
| A 03ROS SD13-06-0005 | | 4/5/13 | 0-0.5 | ✓ | ✓ | | | |
| B 03ROU SD13-06-0520 | | 0830 | 0.5-2.0 | ✓ | | | | |
| C 03ROT SD13-06-2040 | | | 2.0-4.0 | ✓ | ✓ | | | |
| D 03ROS SD13-06-4059 | | | 4.0-5.9 | ✓ | ✓ | ✓ | | |
| E SD13-06-0059 | | | 0.0-5.9 | | | | ✓ | |
| F | | | | | | | | |

Reviewed by: Date:

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441 FI 01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD13-08 | Northing: | 2164245.71 | Attempt 1 | Refusal? Y/N |
| Sampling | C.Cisneros/CH2M HILL | Easting: | 6023181.39 | Penetration (ft): | 7ft 2in |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft) | 5ft 10in |
| | | Depth (ft) | 19.6 | Date/Time: | 4/2/13 1308 |
| | | Pred Tide (ft): | 0.06 ft MLLW | | |
| | | St. Arrival: | 1305 | Attempt 2 | Refusal? Y/N |
| Vessel: | Walter Marie | St.Depart | 1320 | Penetration (ft): | NA |
| Collection: | vibracore | Logged by: | T.Himmer/CH2M; T.Frank/E2 | Recovery (ft) | |
| Contact Information: | Theresa Himmer/CH2M HILL, theresa.himmer@ch2m.com, 731 378 2086 | | | Date/Time: | |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/Density | Cementation/Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample IDs (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YBM | 0-6 | | OH/OL | 2.5 YR 2/1 + 4/1 | VS ↓ S | N | H | v. wet | ~~slight~~ ts | slight PHC | 0 | tr | 100 | A | 0-4 very soft to soft black to dk gray silt + clay, v. wet to wet. slightly increasing firmness w/ depth. |
| | 1 | | | | | | | | | | | | | B | |
| | 2 | | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | | | |
| | 3 | | | | | | | WET ↓ | | MOD PHC | | | | C | |
| | 4 | | | | | | | | | | | | | X | |
| Transition OBM | | 4.6 | CH CL ↓ | ~~[illegible]~~ .0YR 5/1 6/6 | H ↓ | slight N | H ↓ | ~~dry~~ moist ↓ | Z CS | MOD PHC (*) | — | — | 100 | | |
| | 5 | | | | | | | | | | — | 90 | 10 | D | |
| | 5.6 | | | | | | | | | | | | | | 4 to 4.3 transition to OBM - w/ olive brown - gray, slightly plastic, dry clay. |
| | 6 | | | | | | | | | | | | | | |
| | 7 | | | | | | | | | | | | | | |
| | 8 | | | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | |

@ 3' - organic material (grass/fibrous)
(*) moderate diesel like odor
@ 4.3'

4.6 to BOC - clay/silt, ~~dry~~, moist hard, orange/brown w/ gray mottles or possibly burrows - lense of ~~to~~ dk brown. cs. sand from 5.2 to 5.5

4.6 to BOC

Sample Summary (check boxes for analysis):

| | Sample ID | | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | GS | TOC | EPA pest | Spgr/ % solids | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Y8RO9 | SD13-08-0005 | | 4/5/13 | 0-0.5 | ✓ | ✓ | ✓ | | | | | | |
| B | Y8RP0 | SD13-08-0520 | FD | 1300 | 0.5-2.0 | ✓ | | ✓ | | FD = Y8RP1 | | | | |
| C | Y8RP2 | SD13-08-2040 | | | 2.0-4.0 | ✓ | ✓ | ✓ | | | | | | |
| D | Y8RP3 | SD13-08-4055 | | | 4.6-5.5 | ✓ | X | ✓ | ✓ | | | | | |
| E | | SD13-08-0040 | | | 0-4.0 | | | | | ✓ | | | | |
| F | | | | | | | | | | | | | | |

Reviewed by: Date:

4

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441.FI.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

SD13-09

FINE INTERVAL CORE

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | ~~SD-09~~ CC | Northing: | 2164238.21 | Attempt 1 | Refusal? Y/N |
| Sampling | C.Cisneros/CH2M HILL | Easting: | 6023248.50 | Penetration (ft): | 78 inches |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III #2 | Recovery (ft) | lain down |
| | | Depth (ft) | 20.6' 20.7 | Date/Time: | 4/2/13 1135 |
| | | Pred Tide (ft): | -0.21' ft MLLW -0.27 | | |
| | | St. Arrival: | 11:24 | Attempt 2 | Refusal? Y/N |
| Vessel: | WALTER MARIE | St.Depart | 1211 | Penetration (ft): | 6ft (deliberately) |
| Collection: | vibracore | Logged by: | T.Himmel/CH2M; T.Frank/E2 | Recovery (ft) | 6ft, 4 in recovery (incl nose cone) |
| Contact Information: | Theresa Himmel/CH2M HILL, theresa.himmel@ch2m.com, 781 373 2086 | | | Date/Time: | 4/2/13 1200 |

| Depth (ft) | Depth below water surface (ft) | Lithology | Type | Color (Munsell) | Consistency/Density | Cementation/Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample ID's (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.5 | | YBM | OL/MH | 10YR 2/1 | V.S S | N | HO | V.M. | Z to vfs | slight organic | trace | 0-5 | 95-100 | A to F ~~B~~ G | Had to cut nose cone off of core when processing final processed core length doesnt include material in core. |
| 1 | | | | | MOD F. | | | | | | | | | | |
| 2 | | SAND | SP-SM | 2.7 10YR 3/1 | F. to VH | | | Moist | M.S | PHC -mod- | trace | 85 | 15 | H ~~C~~ | |
| 3 | | | OL/MH | 3.4 10YR 2/1 | F. | | | Moist to wet | vfs | slight org. | 0 | 5 | 95 | | top to 2.7 - clay/silt/black varying moisture + firmness. |
| 4 | | OBM | CH | 10YR 5/4 | | Plastic | H | Moist to slight moist | Z | None | none | 100 | 0 | I ~~D~~ | 5.5' firmness increases w/depth |
| 5 | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | 2.7-3.4 - Dark gray sand, f-med. trace shell hash, w/fines Dk gray to black. |
| 7 | | | | | | | | | | | | | | | 3.4-4 → cons. black clay/silt. moist, trace vfs. |
| 8 | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | |

Top 1 ft of core ~ cohesive except for top ~ 1/2 inch.

consolidated YBM ~~from~~ to ~ 4.1 to 4.2' w/ OBM.
- slight diesel odor

Sample Summary (check boxes for analysis):

| Sample ID | | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | GS | TOC | Atterberg ~~B~~ Geotech |
|---|---|---|---|---|---|---|---|---|
| A Y8RP4 | SD13-09-0002 | | 4/3/2013 | 0-0.2' | ✓ | ✓ | ✓ | |
| B Y8RP5 | SD13-09-0203 | | 11:20 | 0.2-0.3 | ✓ | ✓ | ✓ | |
| C Y8RP6 | SD13-09-0305 | | | 0.3-0.5 | ✓ | ✓ | ✓ | |
| D Y8RP7 | SD13-09-0507 | | | 0.5-0.7 | ✓ | ✓ | ✓ | |
| E Y8RP8 | SD13-09-0708 | | | 0.7-0.8 | ✓ | ✓ | ✓ | |
| F Y8RP9 | SD13-09-0810 | | | 0.8-1.0 | ✓ | ✓ | ✓ | |

Reviewed by: Date:

| | | | | | |
|---|---|---|---|---|---|
| G Y8RQ0 | SD13-09-1020 | 1-2 | ✓ | ✓ | ✓ |
| H Y8RQ1 | SD13-09-2040 | 2-4 | ✓ | ✓ | ✓ |
| I Y8RQ2 | SD13-09-4055 | 4-5.5 | ✓ | ✓ | ✓ |
| J Y | SD13-09-0055 | 0-5.5 | | | ✓ |

Site Name: United Heckathorn
Project Number: 385441.Ft.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: SD13-10 | Northing: 2164238.02 | | Attempt 1 | Refusal? Y/N |
| Sampling: S. Cisneros | Easting: 6023307.69 | Penetration (ft): | 6'8" | Y |
| Crew/Company: Dixon Marine | Datum: NAD83 CA State Plane Zn III | Recovery (ft) | 6'7" | |
| | Depth (ft): 12.4 ft | Date/Time: | 4/2/13 | |
| | Pred Tide (ft): 0.02 ft MLLW | | | |
| | St. Arrival: 1050 | | Attempt 2 | Refusal? Y/N |
| Vessel: Walter Marie | St.Depart: 11:10 | Penetration (ft): | | |
| Collection: vibracore | Logged by: T.Hemmer/CH2M, T.Frank/E2 | Recovery (ft) | | NA |
| Contact Information: | Theresa Hemmer/CH2M HILL, theresa.hemmer@ch2m.com, 781.378.2080 | Date/Time: | | |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/ Density | Cementation/ Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample IDs (letter references to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YBM | 0.5 | | OH/OL | 10YR 2/1 | V.S | N | H | wet | MS | HS+ PHC mod to strong | ~~5~~ | 10-15 | 85-90 | A | strong sulfur odor when opened. |
| | 1 | | | 10YR 3/1 | | | | | | | | | | B | |
| Trans to OBM | 2 | | | | | | | | | | | | | | 0-0.9 organic silt trace shell hash black, wet, soft, minor sand |
| | 2.0 | | CH | 10YR 5/1 | V.Firm ft | plastic | | moist | Z | None | — | — | 100 | C | |
| OBM | 3 | | | | | | | | | | | | | | 0.9-1.8 Dk gray silt soft, wet |
| | 4 | | | | | | | | | | | | | | |
| | 4.2 | | CH-CL | 10YR 5/2 | mod F. to firm | N | | | CS. | | ~~tr.~~ | 10-15 | 85-90 | D | 1.8-2.5 transition to v. firm light |
| | 5 | | | | | | | | | | | | | | |
| OBM | 6 | | | | | | | | | | | | | E | gray, slightly moist clay. |
| | 6.0 | | | | | | | | | | | | | | 2.5-4.2 - clay |
| | 7 | | | | | | | | | | | | | | 4.2-6.5 mod to firm, dk. gray clay w/ sand (f-med) decreasing sand @ bottom of interval |
| | 8 | | | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | |

No distinct sand layer observed

V. strong sulfur odor @ 2' noted during sampling

Sample Summary (check boxes for analysis):

| Sample ID | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | TOC | Att, %Solids, Spgr |
|---|---|---|---|---|---|---|
| A 48RQ3 | SD13-10-0005 | 4/4/13 | 0-0.5 | ✓ | ✓ | |
| B 48RQ4 | SD13-10-0520 | 1550 | 0.5-2.0 | ✓ | ✓ | |
| C 48RQ5 | SD13-10-2040 | MS/MSD | 2.0-4.0 | ✓ | ✓ | |
| D 48RQ6 | SD13-10-4060 | | 4.0-6.0 | ✓ | ✓ | |
| E 48RR2 | SD13-10-6066 | | 6.0-6.6 | ✓ | | ✓ |
| F | SD13-10-0066 | | | | | |

Reviewed by: Date:

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441 FI.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD13-13 | Northing: | 2164049.90 | Attempt 1 | Refusal? Y/N |
| Sampling | C.Cisneros/CH2M HILL | Easting: | 6023160.53 | Penetration (ft): | 7 ft (X) |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft) | 31 in |
| | | Depth (ft) | 14.1 | Date/Time: | 4/2/13 1428 |
| | | Pred Tide (ft): | 1.12 ft MLLW | | |
| | | St. Arrival: | 1425 | Attempt 2 | Refusal? Y/N |
| Vessel: | Walter Marie | St.Depart | 1450 | Penetration (ft): | |
| Collection: | vibracore | Logged by: | T.Himmer/CH2M; T.Frank/E2 | Recovery (ft) | |
| Contact Information: | Theresa Himmer/CH2M HILL, theresa.himmer@ch2m.com, 781 378 2086 | | | Date/Time: | |

2.5' @ processing

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/Density | Cementation/Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample IDs (letter corresponds to boxes) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SP-SM | 0.5 | ← | sandy YBB silt clay | 10YR 4/1 DK gray | vs. f. ↓ | N | H | v.m. to wet | ms. gr. | faint organic | 5 10 g | 20 | 75 | A | Lost small amt of v.wet material from top interval during opening - captured on foil + added to sample |
| | 1 | - - - | 1.1 CL | | v.f. | plastic | ↓ | moist | ZFS | | 0 | 5 | 95 | B | |
| CH | 2 | ← | OBM | 10YR 5/4 lgt. olive brown | ↓ | | ↓ | | | | | | | C | |
| | 3 | | | | | | | | | | | | | | |
| | 4 | | | | | | | | | | | | | | |
| | 5 | | | | | | | | | | | | | | |
| | 6 | | | | | | | | | | | | | | |
| | 7 | | | | | | | | | | | | | | |
| | 8 | | | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | |

observed pockets of OBM @ .6 to 1.1' - interspersed w/ pockets of YBM.

0-0.6' wet/to v.moist sandy silt-clay w/gravel
0.6-1.1 - decreasing sand + increasing gravel w/ depth, dk gray
1.1 start of OBM - firm to hard, fat clay/silt, w/trace sand, olive brown

* head tipped penetration overestimated

Sample Summary (check boxes for analysis):

| | Sample ID | | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | GS | TOC | HH, % solid, SP grain | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Y8RQ7 | SD13-13-0005 | FD | 4/3/13 | 0-0.5 | ✓ | ✓ | ✓ | | | Y8RQ8 = FD | | |
| B | Y8RQ9 | SD13-13-0520 | | 9:50 | 0.5-2 | ✓ | | ✓ | | | | | |
| C | Y8RR0 | SD13-13-2025 | FD | ↓ | 2-2.5 | ✓ | ✓ | ✓ | | | Y8RR1 = FD | | |
| D | | SD13-13-0025 | | ↓ | | | | | ✓ | | | | |
| E | | | | | | | | | | | | | |
| F | | | | | | | | | | | | | |

Reviewed by: Date:

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441 FI.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD13-14 | Northing: | 2164041.92 | | Attempt 1 Refusal? Y/N |
| Sampling | C.Cisneros/CH2M HILL | Easting: | 6023212.77 | Penetration (ft): | 6 ft 8 in |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft) | 6 ft 6 in |
| | | Depth (ft) | 20.2 ft | Date/Time: | 4/2/13 1405 |
| | | Pred Tide (ft): | 0.74 ft MLLW | | |
| | | St. Arrival | 1400 | | Attempt 2 Refusal? Y/N |
| Vessel: | Water-Marie | St.Depart | 1415 | Penetration (ft): | ∞ |
| Collection: | vibracore | Logged by: | T.Himmer/CH2M; T.Frank/E2 | Recovery (ft) | |
| Contact Information: | Theresa Himmer/CH2M HILL, theresa.himmer@ch2m.com, 781.378.2086 | | | Date/Time: | |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/Density | Cementation/Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample IDs (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4BM | 0.5 | | 10YR 2/1 | OH/OL w/ SF/SM | S. | N | H | wet | C.S. | MOD PHC | — | 80 | ~~60~~ 20 | A | 0-0.4' |
| | 1 | | | | | | | | | | — | 10 | 90 | B | Dk gray to |
| OBM | | | | CL | F | N | S | Dry | f.s. | None | | | | C | black sand m w/ clay & |
| | 2 | | 10YR 6/4 | | | | | | | | f | | | | silt, wet. |
| | 3 | | 5Y 6/2 & 4/1 | CH | S | slight plastic | | slight moist | | | — | — | 100 | D | 0.4 - 0.9 black clay/ silt, wet. |
| | 4 | | | CL | F | N | | Dry | ~~f.s.~~ | | — | - | 100 | | 1- BOC - OBM |
| | 6 | | 10YR 6/4 | CL | H | | | Dry | fs | | — | 15 | 85 | | 1-2' slightly moist clayey sand olive w/ pockets of orange. |
| | 6.4' | | | | | | | | | | | | | | |
| | 7 | | | | | | | | | | | | | | 2-3 orange-brown dry, sandy clay |
| | 8 | | | | | | | | | | | | | | 3-4.3 soft to slight firm gray clay (CL) ~~w/ slight odor~~ ~~to~~ large mottles - dk. gray & olive gray |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | |

4.3 - 5.4 orange brown clay, slight moist. (f),
5.4 to BOC - v. sandy hard, clay (CL)
possible burrows @ 5 - 5.3

Sample Summary (check boxes for analysis):

| | Sample ID | | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | GS | TOC | Alt. sp. gr. of solid |
|---|---|---|---|---|---|---|---|---|---|
| A | Y8RR3 | SD13-14-0005 | | 4/5/13 | 0-0.5 | ✓ | ✓ | ✓ | |
| B | Y8RR4 | SD13-14-0509 | | 1100 | 0.5-0.9 | ✓ | | ✓ | |
| C | Y8RR5 | SD13-14-1020 | | | 1.0-2.0 | ✓ | ✓ | ✓ | |
| D | Y8RR6 | SD13-14-2040 | MS/MSD | | 2.0-4.0 | ✓ | | ✓ | |
| E | | SD13-14-0009 | | 0 | 0-0.9 | | | | ✓ |
| F | | | | | | | | | |

Reviewed by: Date:

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441 FL01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

N: 2164034.84
E: 6023278.51

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD 13-15 | Northing: | ~~2164430.36~~ cc | Attempt 1 | Refusal? Y/N |
| Sampling | C.Cisneros/CH2M HILL | Easting: | ~~6023328.85~~ cc | Penetration (ft): | 6 ft 3 in |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft) | 60 inches |
| | | Depth (ft) | 14.3 | Date/Time: | 4/2/13 1332 |
| | | Pred Tide (ft): | 0.34 ft MLLW | | |
| | | St. Arrival: | 1330 | Attempt 2 | Refusal? Y/N |
| Vessel: | Walter Marie | St.Depart | 1350 | Penetration (ft): | |
| Collection: | vibracore | Logged by: | T.Himmer/CH2M; T.Frank/E2 | Recovery (ft) | |
| Contact Information: | Theresa Himmer/CH2M HILL; theresa.himmer@ch2m.com; 781.378.2086 | | | Date/Time: | |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/Density | Cementation/Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample IDs (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.5 | YBM + gravel | GM-GC | 10YR 2/1 | stiff | clay is plastic | H | WET-MOIST | MED GRAV. | SLIGHT PHC | 50-55 | 15 | 30 | A | flowable mud layer observed through liner @ sed/water interface |
| | 1 | | | | | | | | | | | | | B | |
| | 2 | SAND 2' OBM | SP-SM CH | 10YR 6/2 | v. stiff | plastic | | DRY | 2 | None | 0 | 0 | 100% | C | 0-1.6' Black v. stiff clayey gravel, w/ small cobbles |
| | 3 | | | 10YR 6/4 | hard | | | v. DRY | | | | | | D see below | 1.6-2 - dk gray to black med. sand. v. hard, drier than material above |
| | 4 | | | | | | | | | | | | | | |
| | 4.9 | | | | | | | | | MOD Diesel like odor @ 4-4.9 | | | | | 2-3.2 - v. stiff fat, olive or gray-brown gray clay - OBM, very distinct transition @ 3.2' |
| | 5 | | | | | | | | | | | | | | 3.2-4.9 - very stiff plastic light brown-yellow clay |
| | 6 | | | | | | | | | | | | | | |
| | 7 | | | | | | | | | | | | | | |
| | 8 | | | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | |

Sample Summary (check boxes for analysis):

| | Sample ID | | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | GS | TOC | % solids Atterberg Sp. grav | |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 48RR7 | SD13-15-0005 | N | 4/3/13 | 0-0.5 | ✓ | ✓ | ✓ | | |
| B | 48RR8 | SD13-15-0520 | | 15:40 | 0.5-2 | ✓ | | ✓ | | R9 split |
| C | 48RR9 | SD13-15-2040 | | | ~~2~~ 2-4 | ✓ | ✓ | ✓ | | |
| D | 48RS0 | SD13-15-4049 | | | 4-4.9 | ✓ | | ✓ | | |
| E | | SD13-15-0049 | | | 0-4.9 | ✓ | | ~~X~~ NA TRUE | ✓ | |
| F | | | | | | | | | | |

Reviewed by: Date:

Site Name: United Heckathorn
Project Number: 395441.FI.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD 13-1B | Northing: | 2163850.25 | | Attempt 1 Refusal? Y/N |
| Sampling | C Cisneros/CH2M HILL | Easting: | 6023087.22 | Penetration (ft): | 6' 5" |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft) | 6' 5" |
| | | Depth (ft) | 21.6 | Date/Time | 4/3/13 1616 |
| | | Pred Tide (ft): | 1.85 ft MLLW | | |
| | | St. Arrival: | 1610 | | Attempt 2 Refusal? Y/N |
| Vessel: | Walter Marie | St.Depart | 1620 | Penetration (ft): | |
| Collection: | vibracore | Logged by: | T.Hammer/CH2M F.Frank/EZ | Recovery (ft) | |
| Contact Information: | Theresa Hammer/CH2M HILL, therese.hammer@ch2m.com, 781.378.2666 | | | Date/Time: | |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/ Density | Cementation/ Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample ID: (letter corresponds to panel) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YBM SAND OBM | 0.5 | | OL/OH SP-SM CH | 10 YR 2/1; 2.5 YR 4/1 2.5 YR 6/4 to 6/6 | V.S F. H. | N plastic | H | wet moist dry | Z MS. Z vfs | ~~None~~ MOD PHC None | O | 0 90 ~5 | 100 ~10 100 95 | A B NS C | 0-1' wet, black clay/silt w/ trace sand. @ base of layer @ 1" of dark gray med sand. Very sharp change to stiff, tan clay w/ mottled iron oxide staining, light yellowish brown. massive. Sampled 1.5'. 3' of OBM over transition sharp, but sampled from slightly lower int. to avoid poss. assure we avoided cross-contamination |
| 6.5 | | | | | | | | | | | | | | | |
| | | | 0-1 - noted moderate PHC odor (diesel - like) after the samples were homogenized. | | | | | | | | | | | | |

Sample Summary (check boxes for analysis):

| Sample ID | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | TOC | RG | %Solid, Sp gr. |
|---|---|---|---|---|---|---|---|
| A YBRS1 | SD13-1B-0005 | | 0-0.5 | ✓ | ✓ | | |
| B YBRS2 | SD13-1B-0510 | | .5-1 | ✓ | ✓ | ✓ | |
| C YBRS3 | SD13-1B-1530 FD | | 1.5-3. | ✓ | ✓ | | FD=YBRS5 |
| D | SD13-1B-2010 | | | | | ✓ | |
| E | | | | | | | |
| F | | | | | | | |

Review: Date:

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441 FI.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD13-19 | Northing: | ~~2164049.90~~ 2163842.50 | Attempt 1 | Refusal? Y/N |
| Sampling | C.Cisneros/CH2M HILL | Easting: | ~~6023160.63~~ 6023185.28 | Penetration (ft): | 6ft |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft): | 6ft bin |
| | | Depth (ft): | 31.5 | Date/Time: | 4/2/13 1528 |
| | | Pred Tide (ft): | 0.25 ft MLLW | | |
| | | St. Arrival: | 1525 | Attempt 2 | Refusal? Y/N |
| Vessel: | | St.Depart: | 1545 | Penetration (ft): | |
| Collection: | vibracore | Logged by: | T.Himmer/CH2M, T.Frank/E2 | Recovery (ft): | |
| Contact Information: | Theresa Himmer/CH2M HILL, theresa.himmer@ch2m.com 731 378 2066 | | | Date/Time: | |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (dk/mstd) | Consistency/ Density | Cementation/ Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample IDs (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4BM | 0.5 | | OL/OH | 2.5 YR 2.5/1 | VS | N | H | wet | ~~MZ~~ MS. | MOD PHC | 0 | 3-5 | 95-97 | A | 0-1.8 black-dk gray clay/silt, v.soft wet, trace med. sand. |
| | 1 | | | | S | | | | ↓ | | ↓ | | | B | |
| | 2 | | w/ sand | | F | ↓ | | slight MS moist | | | | | | | |
| Transition | | | | | | | | | | | | 90 | 10 | | 1.8-2.7 transition to med dark gray, firm. |
| | 3 | | SP-SM | 2.5Y 4/2 | H | | ↓ | | ↓ | None | | | | C | |
| SAND | 4 | | | | | | | | | | | | | | |
| OBM | | | CL | 5Y 5/2 | H | slight H plastic | | Dry | Z | | — | — | 100 | X | slightly moist sand. decreasing fines w/ depth. |
| | 5 | | | | | | | | | | | | | D | 2.7 to 4' |
| | 6 | | | | | | | | | | | | | | |
| | 6.1 | | | | | | | | | | | | | | dk gray f-med sand, dry, hard. minor small shell hash 2.7 to 3' |
| | 7 | | | | | | | | | | | | | | |
| | 8 | | | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | | | piece of coke or charcoal @ 3.1' |
| | 10 | | | | | | | | | | | | | | |

Sample Summary (check boxes for analysis):

| | Sample ID | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth interval (ft) | Pesticides | GS | TOC | EPA | Sp gr/ 2.8 SD 4.9 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 48RS6 SD13-19-0005 | | 4/5/13 | 0-0.5 | ✓ | ✓ | ✓ | | | | | | |
| B | 48RS7 SD13-19-0520 | | 1225 | 0.5-2.0 | ✓ | | ✓ | | | | | | |
| C | 48RS8 SD13-19-2040 | | | 2.0-4.0 | ✓ | ✓ | ✓ | ✓ | | | | | |
| D | 48RS9 SD13-19-4560 | | | 4.5-6.0 | ✓ | | ✓ | | | | | | |
| E | SD13-19-0040 | | | 0.0-4.0 | | | | | ✓ | | | | |
| F | | | | | | | | | | | | | |

Reviewed by: Date:

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441 FI 01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD13-20 | Northing: | 2163837.61 | Attempt 1 Refusal? Y/N | 0 |
| Sampling | C Cisneros/CH2M HILL | Easting: | 6023255.11 | Penetration (ft): | 7ft 3in |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zo III | Recovery (ft) | 5ft 2in @ processing. settled over night |
| | | Depth (ft) | 28.1 | Date/Time: | 4/2/13 1502 |
| | | Pred Tide (ft): | 1.73 ft MLLW | | |
| | | St. Arrival: | 1500 | Attempt 2 Refusal? Y/N | |
| Vessel: | Walter Marie | SLDepart | 1525 | Penetration (ft): | |
| Collection: | vibracore | Logged by: | T Himmer/CH2M; T Frank/E2 | Recovery (ft) | |
| Contact Information: | Theresa Himmer/CH2M HILL, theresa.himmer@ch2m.com, 781 378.2086 | | | Date/Time: | |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/ Density | Cementation/ Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample ID's (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.5 | | OS 46M | Silty sandy gravel | 10YR 2/1 | MOD F. | N | H | WET | ES Ge. | MOD PHC | 80-90 | 5-10 | 5-10 | A | Top 1/2 - 3/4" very watery clay/silt. ontop of black gravel w/ silt fines + sand - observed pockets w/ less gravel but gravel pervasive throughout the core. Gravel is ranges from Subrounded to v. angular 3.3-4.0 pockets of olive grey clay 5.0-5.5 med sand trace to minor fines |
| 1 | | OH | OH | | F. | | | | | FAIR TO MOD PHC | | | | B | |
| 2 | | | | | | | | | | | | | | C | |
| 3 | | Some (CH) Pockets | | 10YR 2/1 and 5/4 | | | | | | | | | | D | |
| 4 | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | |

Sample Summary (check boxes for analysis):

| Sample ID | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth interval (ft) | Pesticides | GS | TOC | % Solid/Sp. gr. |
|---|---|---|---|---|---|---|---|
| A 48RT0 | SD13-20-0005 | 4/3/13 | 0 - 0.5 | ✓ | ✓ | ✓ | |
| B 48RT1 | SD13-20-0520 | | 0.5 - 2.0 | ✓ | | ✓ | |
| C 48RT2 | SD13-20-2040 | MS/MSD | 2.0 - 4.0 | ✓ | ✓ | ✓ | |
| D 48RT3 | SD13-20-4052 | | 4.0 - 5.2 | ✓ | | ✓ | |
| E | SD13-20-0052 | | 0 - 5.2 | | | | ✓ |
| F | | | | | | | |

Reviewed by: Date:

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441.FI.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD13-23 | Northing: | 2163651.19 | Attempt 1 | Refusal? Y/N |
| Sampling | C Cisneros/CH2M HILL | Easting: | 6023066.85 | Penetration (ft): | 4ft 4in |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft) | 3.7 ft |
| | | Depth (ft) | 21.4 ft | Date/Time: | 4/3/13 1535 |
| | | Pred Tide (ft): | 1.1 ft ft MLLW | | |
| | | St. Arrival: | 1526 | Attempt 2 | Refusal? Y/N |
| Vessel: | Walter Marie | St.Depart | 1540 | Penetration (ft): | |
| Collection: | vibracore | Logged by: | T.Himmer/CH2M; T.Frank/E2 | Recovery (ft) | |
| Contact Information: | Theresa Himmer/CH2M HILL, theresa.himmer@ch2m.com, 781 378 2086 | | | Date/Time: | |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/Density | Cementation/Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample IDs (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YBM | 0.5 | | SH/OL | 10YR 2/1 | V.S | N | H | wet | Z | NONE | - | 10 | 90 | A | 0-0.9 v. ~~stat~~ soft silt/clay, black wet, some med sand |
| SAND | 1 | | SP-SM + CH | BK 10YR 4/1 + ~~2.5~~ 10YR 2/1 | F | N | H | slight moist | CS SD | | - | 90 | 10 | B | 0.9-1.5 sand, med, trace shell hash, dk gray trace to minor fines. |
| OBM mixed w/ YBM see right | 2 | | | | | | | | f-m SD. | slight PHC | | 5 | 95 | | |
| | 3 | | CH | 2.5 YR 5/2 | F. | FAT/PLASTIC | | moist | MD. GR Z | ↓ | 5 | 5 | 90 | C | |
| | 3.7' | | | | | | | | | | | | | | 1.5 to boc → black silt/clay intermixed w/ hard fat. grey-brown clay, no clear transition - appears to be ~~intert~~ fingers of the ~~clay~~ silt/clay into the firmer/~~dry~~ drier clay the black clay/silt is moist & mod. firm |
| | 5 | | | | | | | | | | | | | | |
| | 6 | | | | | | | | | | | | | | |
| | 7 | | | | | | | | | | | | | | |
| | 8 | | | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | |

(TH) Slightly ~~hard/dry~~ moist, 3' to 3.7 predominantly firm clay, w/ some traces of the black silt/clay

some rounded med gravel @ top of 3-3.7. Slight PHC odor @ BOC (diesel-like)

Sample Summary (check boxes for analysis):

| | Sample ID | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | GS | TOC | PSD | [illegible] |
|---|---|---|---|---|---|---|---|---|---|
| A | Y8RT4 SD13-23-C005 | | 4/4/13 | | ✓ | ✓ | ✓ | ✓ | |
| B | Y8RT5 SD13-23-C520 | FD | 11:35 | | ✓ | | ✓ | | Y8RT4 = FD |
| C | Y8RT7 SD13-23-2037 | | | | ✓ | ✓ | ✓ | | |
| D | SD13-23-0037 | | | | | | | | ✓ |
| E | | | | | | | | | |
| F | | | | | | | | | |

Reviewed by: Date:

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441.FI.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD13-24 | Northing: | 2163642.13 | Attempt 1 | Refusal? Y/N |
| Sampling | C Cisneros/CH2M HILL | Easting: | 6023139.40 | Penetration (ft): | 6ft 11in |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft) | 6 ft |
| | | Depth (ft) | 32.5 ft | Date/Time: | 4/3/13 1515 |
| | | Pred Tide (ft): | 0.86 ft MLLW | | |
| | | St. Arrival: | 1511 | Attempt 2 | Refusal? Y/N |
| Vessel: | Walter Marie | St.Depart | 1518 | Penetration (ft): | |
| Collection: | vibracore | Logged by: | T Himmer/CH2M; T Frank/E2 | Recovery (ft) | |
| Contact Information: | Theresa Himmer/CH2M HILL, theresa.himmer@ch2m.com 781.378.2086 | | | Date/Time: | |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/Density | Cementation/Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample ID's (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YBM | 0.5 | | OL/OH | 10YR 2/1 | V.S | N | H | V. wet | vfg | none | tr. | 5 | 95 | on A | 0-0.7 v. wet, soft black silt/clay, loose |
| | 1 | | CH | 2.5 ~~10YR~~ 5/2 | H | plastic | | DRY | Z | slight PHC | 0 | 0 | 100 | B | |
| clast of OBM | 2 | | | | v. firm | plast | | moist | | | | | | | 0.7-2.0' dry, hard fat dark olive clay |
| | 3 | | | | | | | | | slight PHC | | | | C | 2-3.6 v. firm, ~~slightly~~ moist dark olive or grayish brown clay |
| | 4 | | CH-CL | | HARD MOD FIRM | | | | | | | | | | |
| | 5 | | | | | | | | cs. grav. | | | | | | 3.6-4.1-SAA, but hard. |
| YBM | 6 | | OL/OH | 10YR 2/1 and 2.5 YR 5/2 | S | N ↓ | | wet | ↓ | | 5 | tr. | 95 | D | 4.1-5.2 SAA, but wet, mod. firm w/ gravel @ bottom of interval |
| | 7 | | | | | | | | | | | | | | 5.2-6.0' soft clay-silt w/ gravel, wet see pockets of black material very sticky/cohesive - difficult to mix/homogenize during sampling |
| | 8 | | | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | |

→ silt/clay below clasts of OBM?

Sample Summary (check boxes for analysis):

| | Sample ID | | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | GS | TOC | % solid, Sp grav | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Y8RT9 | SD13-24-0005 | | 4/4/2013 | 0-0.5 | ✓ | ✓ | ✓ | | | | | | |
| B | Y8RU0 | SD13-24-0520 | | ~~10/1~~ | 0.5-2 | ✓ | | ✓ | | | | | | |
| C | Y8RU1 | SD13-24-2040 | | 10:15 | 2-4 | ✓ | ✓ | ✓ | | | | | | |
| D | Y8RU2 | SD13-24-4060 | | | 4-6 | ✓ | | ✓ | | | | | | |
| E | | SD13-24-0066 | | | | | | | ✓ | | | | | |
| F | | | | | | | | | | | | | | |

Reviewed by: Date:

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441.FI.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD13-25 | Northing: | 2163646.43 | | Attempt 1 Refusal? Y/N |
| Sampling | C.Cisneros/CH2M HILL | Easting: | 6023211.18 | Penetration (ft): | 6ft 10in |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft) | 5ft 9in |
| | | Depth (ft) | 33.9 | Date/Time: | 4/3/13 1556 |
| | | Pred Tide (ft): | 1.55 ft MLLW | | |
| | | St. Arrival: | 1552 | | Attempt 2 Refusal? Y/N |
| Vessel: | Walter Marie | St.Depart | 1600 | Penetration (ft): | |
| Collection: | vibracore | Logged by: | T.Himmer/CH2M T.Frank/E2 | Recovery (ft) | |
| Contact Information: | Therese Himmer/CH2M HILL therese.himmer@ch2m.com, 781.378.2086 | | | Date/Time: | |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/ Density | Cementation/ Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample IDs (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YBM | 0.5 | | OH/OL | 2.5 YR 2.5/1 w/ some 4/1 | VS. | N | H | wet | fs | MOD PHC throughout | 0 | tr | 100 | A | 0 - 5.3 v. soft wet, clay/silt dk gray + black, thin skin of light brown/oxidized layer @ top trace fine sand, increases firmness to "soft" @ 3' * |
| | 1 | | | | | | | | | | | | | B | |
| | 2 | | | | | | | | | | | | | | |
| | 3 | | | | S. | | | | | | | | | C | |
| | 4 | | | | | | | | | | | | | | |
| | 5 | | | | | | | | | | | | | | |
| SAND 5.9 | 5.3 | | SP-SM | 2.5 YR 4/1 | H | | | slight moist | MS | | - | 90 | 10 | D | 5.3 to BOC - Dk gray f-med sand, dense, hard, trace to minor fines Abrupt transition to sand. |
| | 6 | | | | | | | | | | | | | | |
| | 7 | | | | | | | | | | | | | | |
| | 8 | | | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | * mussel shell @ 2' 9 @ 45' |

Sample Summary (check boxes for analysis):

| | Sample ID | | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | GS | TOC | EPA pest | % solid spgr | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Y8RU3 | SD13-25-0005 | | 4/5/13 | 0-0.5 | ✓ | ✓ | ✓ | | | | | | |
| B | Y8RU4 | SD13-25-0520 | | 0745 | 0.5-2.0 | ✓ | | ✓ | | | | | | |
| C | Y8RU5 | SD13-25-2040 | FD | | 2.0-4.0 | ✓ | ✓ | ✓ | ✓ | | | FD=Y8RU6 | | |
| D | Y8RU7 | SD13-25-4059 | | | 4.0-5.9 | ✓ | | ✓ | | | | | | |
| E | | SD13-25-0059 | | | 0.0-5.9 | | | | | ✓ | | | | |
| F | | | | | | | | | | | | | | |

Reviewed by: Date:

Site Name: United Heckathorn
Project Number: 385441 FI 01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

CH2MHILL

Station ID: SD13-~~2927~~ CC
Sampling: C. Cisneros/CH2M HILL
Crew/Company: Dixon Marine
Vessel: Walter Marie
Collection: vibracore
Contact Information: Theresa Hinmer/CH2M HILL, theresa.hinmer@ch2m.com 781.378.3668

Northing: 2163456.36
Easting: 6022989.83
Datum: NAD83 CA State Plane Zn III
Depth (ft): 13.2 ft
Pred Tide (ft): 0.05 ft MLLW
St. Arrival: 1400
St.Depart: 1411
Logged by: T.Hinmer/CH2M, T.Frank/E2

Attempt 1 Refusal Y/N
Penetration (ft): 5 ft
Recovery (ft): ~~7.7~~ 4.0 ~~3.1~~
Date/Time: 4/3/13 1406
Attempt 2 Refusal Y/N
Penetration (ft):
Recovery (ft)
Date/Time:

processed

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/ Density | Cementation/ Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % shaven | % sand | % fines | Sample ID's (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | | ~~HBB~~ 4BM + sand & gravel | | | | | | | | | | | | |
| 0.5 | 0.5 | | loSW-SM | 10YR 5/1 | Hard | N | H | Moist | ~~C.Gr.~~ C.Gr. | N | 5-10 | 80 | ~~50~~ 10-15 | A | 0-0.5 loose, black silty/clayey poorly sorted sand md to cs grained. |
| 1 | 1 | | GM | 10YR 4/1 | | | | Dry | | | | | | | |
| 2 | 2 | | GC | 10YR 6/4 | | | | Moist | | | ~75 | ~~20~~ 15 | 10 | B | |
| | | | CH | | very Hard | | H | slight moist | | | 20 | 10 | 70 | | |
| | | | SW-SC | | | | | | | | | 30 | 50 | C | 0.5-0.9 SAA but drier, lighter |
| 3 | 3 | | CH | 10YR 5/4 | | | | Dry | | | | 10 | ~~85~~ 70 | | |
| | 3.1 | | SW-SC | | | | | | | | | 50 | 30 | | |
| 4 | 4 | | | | | | | | | | | | | | |
| 5 | 5 | | | | | | | | | | | | | | |
| 6 | 6 | | | | | | | | | | | | | | |
| 7 | 7 | | | | | | | | | | | | | | |
| 8 | 8 | | | | | | | | | | | | | | |
| 9 | 9 | | | | | | | | | | | | | | |
| 10 | 10 | | | | | | | | | | | | | | |

TH

3.0-2.9 2.7-~~BOC~~ v. hard, v. dry clay light brown

2.9-3.1 v. hard, ~~sandy clay w/~~ TH ~~gravel~~ clayey sand w/ gravel

coarse gravel obs. throughout core

no ~~clear~~ or abrubpt transitions in upper part of core, litho logic layers had gradual transition zones.

0.9-1.8 poorly sorted gravel w/ sand & clay. gravel sub rounded to sub angular

1.8-2.0 - v. hard dry, clay w/ gravel.

2-2.7 - hard, clayey sandy sand. md to cs. w/ some gravel

Transitions in lower part of core (below 2') more abrupt

Sample Summary (check boxes for analysis):

| Sample ID | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | TBT | TOC | EPH plus g/o SGT | SGT g/o | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A 08RU8 | SD13-27-0005 | MS/MSD 4/4/13 | 0-0.5 | X | X | X | | | | | | |
| B 08RU9 | SD13-27-0520 | 9:30 | .5-2 | X | | X | X | | | | | |
| C 08RV0 | SD13-27-2031 | | 2-3.1 | X | X | X | | | | | | |
| D | SD13-27-0031 | | 0-3.1 | | | | | X | | | | |
| E | | | | | | | | | | | | |
| F | | | | | | | | | | | | |

Reviewed by: Date:

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441.FI.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD13-28 | Northing: | 2163452.79 | Attempt 1 Refusal? Y/N | |
| Sampling | C Cisneros/CH2M HILL | Easting: | 6023091.65 | Penetration (ft): | 6.5ft+ |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft) | 69in |
| | | Depth (ft) | 34.3 | Date/Time: | 4/3/13 1445 |
| | | Pred Tide (ft): | 0.39ft ft MLLW | | |
| | | St. Arrival: | 1436 | Attempt 2 Refusal? Y/N | |
| Vessel: | Walter Marie | St.Depart | 1455 | Penetration (ft): | |
| Collection: | Vibracore | Logged by: | T Hemmer/CH2M; T Frank/EJ | Recovery (ft) | |
| Contact Information: | Theresa Hummer/CH2M HILL, theresa.hummer@ch2m.com, 781 376 2056 | | | Date/Time: | |

6' processed

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/ Density | Cementation/Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Samples (Dx, replicate, correspondence to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YBM | 0.5 | | MH-OL/OH | 10YR 2/1 mottled w/ lower 4/1 | VS. | N | H | wet | Z | NONE | 0 | 0 | 100 | A | 0-3' black, sticky clay silt, v. soft to soft |
| | 1 | | | | | | | | | | | | | B | increasing firmness & decreasing moisture @ 3' - abrupt transition observed |
| | 2 | | | | | | | | | | | | | C | |
| | 3 | | | | | | | moist | FAINT PHC | | | | | | |
| | 4 | | | | | | | | | | | | | | |
| | 5 | | | | | | | | | | | | | D | pockets of dark olive-brown to dk gray silt/clay bet. 4½-6' |
| | 6 | | | | | | | | | | | | | | |
| | 7 | | | | | | | | | | | | | | |
| | 8 | | | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | |

Sample Summary (check boxes for analysis):

| | Sample ID | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | PSDA | TOC | EPA pest | approx. % silt/clay | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | SB13-28-0005 | | 4/4/2013 | 0-.5' | ✓ | ✓ | ✓ | | | | | | |
| B | SB13-28-0520 | | 8:40 | .5-2 | ✓ | | ✓ | ✓ | | | | | |
| C | SB13-28-2040 | | | 2-4 | ✓ | ✓ | ✓ | | | | | | |
| D | SB13-28-4060 | | | 4-6 | ✓ | | ✓ | | | | | | |
| E | SD13-28-0060 | | | 0-6 | | | | | ✓ | | | | |
| F | | | | | | | | | | | | | |

Reviewed by: Date:

1 of 1

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441.FI.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD13-29 | Northing: | 2163438.66 | Attempt 1 Refusal? Y/N | |
| Sampling | C.Cisneros/CH2M HILL | Easting: | 6023189.47 | Penetration (ft): | 6ft 8in |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft) | 77in |
| | | Depth (ft) | 34.2ft | Date/Time: | 4/3/13 1422 |
| | | Pred Tide (ft): | 0.22 ft MLLW | | |
| | | St. Arrival: | 1420 | Attempt 2 Refusal? Y/N | |
| Vessel: | Walter Marie | St.Depart | 1430 | Penetration (ft): | |
| Collection: | vibracore | Logged by: | T.Hemmer/CH2M, T.Frank/E2 | Recovery (ft) | |
| Contact Information: | Theresa Hemmer/CH2M HILL, theresa.hemmer@ch2m.com, 781.878.2026 | | | Date/Time: | |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/ Density | Cementation/ Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample IDs (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MBM | 0.5 | | OH/ OL | 2.5 YR 2.5/1 + 3/1 | V.S. S. | N | H | v. wet wet | f.s | mod to strong PHC | 5 | 0-2 tr. | 98-100 | A | Entire core is v. wet to v. wet black to dk gray clay/silt w/ trace fine sand, organic PHC odor noted throughout - mod to strong. Notably stronger near the S.O.C. |
| | 1 | | | | | | | | | | | | | B | |
| | 2 | | | | | | | | | | | | | C | |
| | 3 | | | | | | | | | | | | | | |
| | 4 | | | | | | | | | | | | | | |
| | 5 | | | | | | | | cobble | | 5 | 10 | 85 | D | |
| E2 | 6 | | | | | | | | | | | | | | |
| | 7 | | | | | | | | | | | | | | |
| | 8 | | | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | |

@ 5.7 ft → SAA but w/ gravel + more sand content.

Sample Summary (check boxes for analysis):

| | Sample ID | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth (ft) | Pesticides | GSS | TOC | Spgr | No grav | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | y3RV6 SD13-29-0005 | | 4/5/13 | 0-0.5 | ✓ | ✓ | ✓ | | | | | | |
| B | y3RV7 SD13-29-0520 | MD | 950 | 0.5-2.0 | ✓ | | ✓ | | | FD=y3RV8 | | | |
| C | y3RV9 SD13-29-2040 | | | 2.0-4.0 | ✓ | ✓ | ✓ | | | | | | |
| D | y3RV10 SD13-29-4060 | | | 4.0-6.0 | ✓ | | ✓ | | | | | | |
| E | SD13-29-0000 | | | 0.0 6.0 | | | | ✓ | | | | | |
| F | | | | | | | | | | | | | |

Reviewed by: Date:

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441.FI.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD13-31 | Northing: | 2163263.24 | Attempt 1 | Refusal? Y/N |
| Sampling | C Cisneros/CH2M HILL | Easting: | 6022972.31 | Penetration (ft): | 1ft |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Z Attempt2 | Recovery (ft) | 1 inch |
| | | Depth (ft) | 14.6 15.2 | Date/Time: | 4/3/13 1325 |
| | | Pred Tide (ft): | -0.14 ft MLLW -0.11 | | |
| | | St. Arrival: | 1320 | Attempt 2 | Refusal? Y/N |
| Vessel: | Walter Marie | St Depart | 1355 | Penetration (ft): | 4ft 10in |
| Collection: | Vibracore | Logged by: | T Himmer/CH2M; T Frank/E2 | Recovery (ft) | 64in |
| Contact Information: | Theresa Himmer/CH2M HILL, theresa.himmer@ch2m.com, 781 378 2086 | | | Date/Time: | 4/3/13 1345 |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/ Density | Cementation/ Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample IDs (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Disturbed OBM | 0.5 | | CH w/ OH OH | 2.5 YR 5/6 and 5.1 | H | Plastic | H | wet DRY | CS | None | 0 | 5 | 95 | A | ~~0-2'~~ Entire core dominantly dry, hard, fat. |
| | | | | | | | | | | | | | | B | |
| OBM | | | CH | 2.5 YR 5/6 | | | H | | ~~C~~ Z | none | 0 | 0 | ~~Z~~ 100 | C (OBM) | light brownish yellow clay 0-2' has areas of mottled |
| | | | | | | | | | | | | | | NS | dark gray clay/ silt. upper ~~or~~ 2' of core appears disturbed compared to ~~lower~~ below 2' clay is massive Below 4' not sampled b/c 2-4 is OBM |

Sample Summary (check boxes for analysis):

| | Sample ID | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | GS | TOC | sp gr, % solids | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Y8RW1 SD13-31-0005 | | 4/4/13 | 0-0.5 | ✓ | ✓ | ✓ | | | | | | |
| B | Y8RW2 SD13-31-0520 | | 1500 | 0.5-2.0 | ✓ | | ✓ | | | | | | |
| C | Y8RW3 SD13-31-2040 | FD | | 2.0-4.0 | ✓ | ✓ | ✓ | | | FD-Y8RW5 | | | |
| D | SD13-31-0020 | | | 0.0-2.0 | | | | ✓ | | | | | |
| E | | | | | | | | | | | | | |
| F | | | | | | | | | | | | | |

Reviewed by: Date:

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441 FI.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD13-32 | Northing: | 2163251.79 | | Attempt 1 Refusal? Y/N |
| Sampling | C.Cisneros/CH2M HILL | Easting: | 6023070.70 | Penetration (ft): | 6 ft 9 in |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft) | 74 in |
| | | Depth (ft) | 33.5 | Date/Time: | 4/3/13 1251 |
| | | Pred Tide (ft): | -0.12 ft MLLW | | |
| | | St. Arrival: | 1245 | | Attempt 2 Refusal? Y/N |
| Vessel: | Walter Marie | St.Depart | 1300 | Penetration (ft) | |
| Collection: | vibracore | Logged by: | T.Himmer/CH2M, T.Frank/E2 | Recovery (ft) | |
| Contact information: | Theresa Himmer/CH2M HILL, theresa.himmer@ch2m.com, 781.378.2086 | | | Date/Time: | |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/Density | Cementation/Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample ID's (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YBM | 0.5 | | MH/OL | 2.5 YR 2.5/1 & 4.1/1 | V.S ↓ S | N | H | V. wet ↓ wet | Ps | st. PHC | 0 | tr. 0-3% | 97-100 | A | 0-BOC. Silt/clay w/ trace f. sand. |
| | 1 | | | | | | | | | | | | | B | |
| | 2 | | | | | | | | | | | | | | 0-1' v. soft + v. wet. |
| ↓ | 3 | | | w/ 2.5 YR 5.2 | | | | v. moist | | | | | | C | 2-3' wet + soft. |
| | 4 | | | | | | | | | | | | | | 0-3' very cohesive, sticky material below 3' material is |
| | 5 | | | | | | | | | | | | | D | |
| 6.1 | 6 | | | | | | | | | | | | | | still silt/clay & soft but, slightly less wet. |
| | 7 | | | | | | | | | | | | | | |
| | 8 | | | | | | | | | | | | | | @5.7' ~1/2" thin layer of black organic rich material |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | |

PHC odor noted throughout core.

@4.4 - clast of black, organic rich material

0-3 - core had to be sliced in half. below 3' sediment broke apart.

Sample Summary (check boxes for analysis):

| | Sample ID | | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth interval (ft) | Pesticides | GS | TOC | EPA | spg/90 solids | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Y8RW6 | SD13-32-0005 | | 4/5/13 | 0-0.5 | ✓ | ✓ | ✓ | ✓ | | | | | |
| B | Y8RW7 | SD13-32-0020 | | 0910 | 0.5-2.0 | ✓ | | ✓ | | | | | | |
| C | Y8RW8 | SD13-32-2040 | | | 2.0-4.0 | ✓ | ✓ | ✓ | | | | | | |
| D | Y8RN9 | SD13-32-4060 | | | 4.0-6.0 | ✓ | | ✓ | | | | | | |
| E | | SD13-32-0060 | | | 0.0-6.0 | | | | | ✓ | | | | |
| F | | | | | | | | | | | | | | |

Reviewed by: Date:

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441 FI 01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD13-33 | Northing: | 2163239.19 | Attempt 1 | Refusal? Y/N |
| Sampling | C Cisneros/CH2M HILL | Easting: | 6023168.50 | Penetration (ft): | 6ft 11in |
| Crew/Company: | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft) | 7ft 5in |
| | | Depth (ft) | 33.7 | Date/Time: | 4/3/13 1233 |
| | | Pred Tide (ft): | -0.06 ft MLLW | | |
| | | St. Arrival: | 1230 | Attempt 2 | Refusal? Y/N |
| Vessel: | Walter Marie | St.Depart | 1240 | Penetration (ft): | |
| Collection: | vibracore | Logged by: | T.Hammer/CH2M; T.Frank/E2 | Recovery (ft) | |
| Contact Information: | Theresa Hammer/CH2M HILL, theresa.hammer@ch2m.com, 731.378.2080 | | | Date/Time: | |

6.2' processed

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/ Density | Compositional Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % Gravel | % Sand | % Fines | Sample IDs (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YBM | 0 | ~~CL/OH~~ | ~~OL/OH~~ | 10YR 2/1 Blk. | VS | N | H | wet | Z | slight PHC | 0 | tr 0 | 100 | A | Entire core is black silt clay w/ pockets of gray-brown firmer clay |
| ↓ | 1 | | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | B | |
| | 2 | | | w/ 2.5YR 4/2 pockets below 2' | | | | | | | | | | C | All YBM |
| | 3 | | | | | | | | | | | | | | |
| | 4 | | | | | | | | | | | | | | |
| | 5 | | | | | | | | | | | | | D | |
| | 6 | | | | | | | | | | | | | | |
| | 6.2' | | | | | | | | | | | | | | |
| | 7 | | | | | | | | | | | | | | |
| | 8 | | | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | |

Sample Summary (check boxes for analysis):

| | Sample ID | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | GSS | TOC | %solids, specific gravity | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | YBRX0 SD13-33-0005 | | 4/4/13 | 0-0.5 | ✓ | ✓ | ✓ | | | | | | |
| B | YBRX1 SD13-33-0520 | MS/MSD | 1100 | 0.5-2.0 | ✓ | | ✓ | | | | | | |
| C | YBRX2 SD13-33-2040 | | | 2.0-4.0 | ✓ | ✓ | ✓ | | | | | | |
| D | YBRX3 SD13-33-4060 | | ↓ | 4.0-6.0 | ✓ | | ✓ | | | | | | |
| E | SD13-33-0060 | | | 0.0-6.0 | | | | ✓ | | | | | |
| F | | | | | | | | | | | | | |

Reviewed by: Date:

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441 FI 01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD13-35 | Northing: | 2163061.12 | | Attempt 1 Refusal? Y/N |
| Sampling | G Cisneros/CH2M HILL | Easting: | 6022947.27 | Penetration (ft): | 6ft 7in |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft) | 5ft 10in |
| | | Depth (ft) | 30.7 | Date/Time: | 4/3/13 1115 |
| | | Pred Tide (ft): | 0.82 ft MLLW | | |
| | | St. Arrival: | 1110 | | Attempt 2 Refusal? Y/N |
| Vessel: | Walter Marie | St.Depart | 1125 | Penetration (ft): | |
| Collection: | vibracore | Logged by: | T.Himmer/CH2M; T Frank/E2 | Recovery (ft) | |
| Contact information: | Theresa Himmer/CH2M HILL, theresa.himmer@ch2m.com, 781.378.2086 | | | Date/Time: | |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/Density | Cementation/Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample IDs (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YBM | 0.5 | | OH/OL | 5Y 2.5/1 to 3/2 | V.S. | N | H | Wet | ~~SC~~ CS. SND | None | tr. | 10 | 90 | A | 0-3.4 black to dark gray clay/silt w/angular cs. sand @ 1.2' (~1/2" thick. |
| | 1 | | | | | | | | | | | | | B | |
| | 2 | | | | | | | | | | | | | | |
| | 3 | -2.6 | | 5Y 4/1 | F S | | | | | slight PHC | | 80 10 | 20 90 | C | med, dk gray sand from 2.6 to 2.9' and from 3.4 to 4.6' (TH) |
| SAND | 3.4 | ~~S~~ | SP-SM | | F ~~S~~ | | H | Moist | CS | None | | 90 | 10 | | |
| | 4 | | | | | | | | | | | | | | |
| | 4.6 | | OH/OL | 5Y 2.5/1 to 3/2 | ~~S~~ S | | | WET | MS | | | 10 | 90 | D | ~~3.6'~~ trace shell hash in lower interval |
| YBM | 5 | | | | | | | | | | | | | | |
| plug at OBM | 6 5.8 | | CH | | F. ~~FAT~~ | FAT PLASTIC | | DRY | Z | None | | 0 | 100 | | 4.6 to BOC soft, wet black to dk gray clay/silt, wet, small plug at firm, drier plastic clay @ boc, olive brown |
| | 7 | | | | | | | | | | | | | | |
| | 8 | | | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | |

Sample Summary (check boxes for analysis):

| Sample ID | | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | GS | TOC | 8560d, SPGG, EPA Pest | |
|---|---|---|---|---|---|---|---|---|---|
| A y3Rx4 | SD13-35-0005 | FD | 4/4/13 | 0-0.5 | ✓ | ✓ | ✓ | | FD = y8RY5 |
| B y8Rx6 | SD13-35-0520 | | 1420 | 0.5-2.0 | ✓ | | ✓ | | |
| C y8Rx7 | SD13-35-2040 | | | 2.0-4.0 | ✓ | ✓ | ✓ | | |
| D y8Rx8 | SD13-35-4058 | | | 4.0-5.8 | ✓ | | ✓ | | ✓ |
| E | SD13-35-0058 | | | 0-5.8 | | | | ✓ | [illegible] |
| F | | | | | | | | | |

Reviewed by: Date:

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441 FL01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD13-36 | Northing: | 2163055.96 | Attempt 1 | Refusal? Y/N |
| Sampling | C.Cisneros/CH2M HILL | Easting: | 6023044.53 | Penetration (ft): | 6ft 7:10 |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft) | 6ft 4:10 |
| | | Depth (ft): | 36.5ft | Date/Time: | 4/3/13 1035 |
| | | Pred Tide (ft): | 6.53 ft MLLW | | |
| | | St. Arrival: | 1020 | Attempt 2 | Refusal? Y/N |
| Vessel: | Walter Marie | St.Depart | 1040 | Penetration (ft): | |
| Collection: | vibracore | Logged by: | T Hemmer/CH2M & T Frank/EA2 | Recovery (ft) | |
| Contact Information: | Theresa Hemmer/CH2M HILL, theresa.hemmer@ch2m.com, 781.378.2066 | | | Date/Time: | |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/ Density | Cementation/ Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample ID's (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YBM | 0 | | OH/OL | 10YR 5/4 | US | N | H | WET | t | Faint PHC | tr. | tr | 100 | A | Core almost entirely clay silt w/ varying degrees of firmness + moisture. Sand @ 4.3 to 4.5' and 5.2 - 5.4' |
| | 1 | | | 10YR 2.5 | S | | | | | | | | | B | |
| | 2 | | | 4R 2.5/1 | | | | | | | | | | | |
| | 3 | 2.8 | | 10YR 5/2 olive | | | | | | | | | | C | |
| | 4 | | | 2.5YR | | | | | | | | | | | |
| SAND | | | SP-SM | 4/1 | F | | | moist | MS | | | 90 | 10 | | Silt/clay v. sticky, v. difficult to split cores & mixing samples is difficult. |
| YBM | 5 | | OH/OL | to | S | | | wet | | | | 10 | 90 | | |
| SAND | | | SP-SM | 2.5/1 | F | | | moist | | | | 90 | 10 | D | |
| YBM | 6 | | OH/OL | | S | | | wet. | t | | | 5 | 95 | | |
| 6.5' | | | | | | | | | | | | | | | |
| | 7 | | | | | | | | | | | | | | 2 to 5' more olive gray 10YR 5/2 |
| | 8 | | | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | |

Sample Summary (check boxes for analysis):

| Sample ID | | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | TGS | TOC | Sp gr., % Solids | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | YBRX9 | SD13-36-0005 | 4/4/13 | 0.0-0.5 | ✓ | ✓ | ✓ | | | | | | |
| B | YBRY0 | SD13-36-0502 | 1300 | 0.5-2.0 | ✓ | | ✓ | | | | | | |
| C | YBRY1 | SD13-36-2040 | | 2.0-4.0 | ✓ | ✓ | ✓ | | | | | | |
| D | YBRY2 | SD13-36-4065 | | 4.0-6.5 | ✓ | | ✓ | | | | | | |
| E | | SD13-36-0006.5 | | 0.0-6.5 | | | | ✓ | | | | | |
| F | | | | | | | | | | | | | |

Reviewed by: Date:

CH2MHILL

Site Name: United Heckathorn
Project Number: 380441 FI.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD13-37 | Northing: | 2163043.31 | Attempt 1 Refusal? Y/N | |
| Sampling | C.Cisneros/CH2M HILL | Easting: | 6023145.91 | Penetration (ft): | 6ft 7:n |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft) | 5ft 11:n |
| | | Depth (ft): | 35.3 | Date/Time: | 4/2/13 1011 |
| | | Pred Tide (ft): | 2.02 ft MLLW | | |
| | | St. Arrival: | 1005 | Attempt 2 Refusal? Y/N | |
| Vessel: | Walter Marie | St.Depart | 1015 | Penetration (ft): | |
| Collection: | vibracore | Logged by: | T.Hammer/CH2M, T.Frank/EZ | Recovery (ft) | |
| Contact Information: | Theresa Hammer/CH2M HILL, theresa.hammer@ch2m.com, 781.378.2086 | | | Date/Time: | |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/ Density | Cementation/ Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample ID's (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4BM | 0 | | OH/OL | 2.5 YR 2.5/1 + 4/1 | V.S | N | H | V. wet | Z | Faint PHC | 0 | 0 | 100 | A | 0-4.8 Black-dark gray clay/silt. |
| ↓ | 1 | | | | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | B | soft to v.soft. v.wet.; shell (mussel @2.5) |
| | 2 | | | | | | | | | | | | | C | 4.8 to 5.2 - course, angular gravel w/ sand + silt |
| | 3 | | | | | | | | | | | | | | |
| | 4 | | | | | | | | | | | | | | |
| Gravel sand 4BM 6' | 5 | | | 2.5 YR 4/1 | S | | | wet | CS. GR Z | MOD ~~SD~~ PHC (X) | ~~5~~ 15 | ~~15~~ | 35 | D | ~~5.2~~ 5.2 to BOC wet, soft, dk gray clay |
| | 6 | | | | | | | | | | | | | | |
| | 7 | | | 2-4' interval - mainly dk gray w/ small inclusions 1/4 - 3/8" of darker, wetter clay/silt | | | | | | | | | | | Silt @ 5.6' there is layer ~3/8" thick - black, w/ (X) strong chemical-type ODOR |
| | 8 | | | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | |

Sample Summary (check boxes for analysis):

| Sample ID | | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth interval (ft) | Pesticides | TSS | TOC | %Solids, SPGV | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 4BRY3 | SD13-37-0005 | FD | 4/5/13 | 0-0.5 | ✓ | ✓ | ✓ | | | | FD 4BRY4 | |
| B | 4BRY5 | SD13-37-0520 | | 1030 | 0.5-2.0 | ✓ | | ✓ | | | | | |
| C | 4BRY6 | SD13-37-2040 | | | 2.0-4.0 | ✓ | ✓ | ✓ | | | | | |
| D | 4BRY7 | SD13-37-4060 | | | 4.0-6.0 | ✓ | | ✓ | | | | | |
| E | | SD13-37-0060 | | | 0.0-6.0 | | | | ✓ | | | | |
| F | | | | | | | | | | | | | |

Reviewed by: Date:

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441.FI.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD13-39 | Northing: | 2162979.33 | Attempt 1 Refusal? Y/N | |
| Sampling: | C.Cisneros/CH2M HILL | Easting: | 6022756.43 | Penetration (ft): | 5ft 7in |
| Crew/Company: | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft): | 5ft 3in |
| | | Depth (ft): | 40 | Date/Time: | 4/3/13 0821 |
| | | Pred Tide (ft): | 4.49 ft MLLW | | |
| | | St. Arrival: | 0808 | Attempt 2 Refusal? Y/N | |
| Vessel: | Walter Marie | St.Depart: | 0825 | Penetration (ft): | |
| Collection: | vibracore | Logged by: | T.Hammer/CH2M T.Frank@2 | Recovery (ft): | |
| Contact Information: | Theresa Hammer/CH2M HILL, theresa.hammer@ch2m.com, 781.378.2086 | | | Date/Time: | |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/ Density | Cementation/ Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample IDs (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MBM | 0-3.4 | | OL/OH | 10YR 2/1 and 5Y 4/1 | VS | N | H | wet | MS | None | 0 5 0 | 5-10 | 90-95 | A B C | 0-3.4 dark gray to black silt/clay stock, trace fine sand thin @ 0.4' layer of sand + gravel |
| 3.4 OBM | 3.4-4.9 | | CH | 5Y 4/1 | H | plastic | | Dry to slight moist | Z | Faint PHC | 0 | 5 | Z 100 | NS D | 3.4 to BOC hard, dry to slightly moist dk gray, fat clay. Did not sample 3.4 to 4 to avoid potential cross contam. some black flecks noted. |

Sample Summary (check boxes for analysis):

| Sample ID | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | GS | TOC | Sp grav/% solids |
|---|---|---|---|---|---|---|---|
| A ~~Y3RX8~~ | SD13-~~39~~-0005 | 4/4/13 | 0-0.5 | ✓ | ✓ | ✓ | |
| B ~~Y3RX9~~ | SD13-~~39~~-0520 | 1345 | 0.5-2 | ✓ | | ✓ | |
| C ~~Y3RY1~~ | SD13-~~39~~-~~2046~~ 2034 | | 2-3.4 | ✓ | ✓ | ✓ | |
| D ~~Y3RY2~~ | SD13-~~39~~-~~4045~~ 4049 | | 4-4.9 | ✓ | | ✓ | |
| E Y3RZ1 | SD13-39-0034 | | 0-3.4 | | | | ✓ |
| F | | | | | | | |

Reviewed by: Date:

CH2MHILL

Site Name: United Heckathorn
Project Number: 385441 FI.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD13-40 | Northing: | 2162662.19 | Attempt 1 | Refusal? Y/N |
| Sampling | C.Cisneros/CH2M HILL | Easting: | 6022921.50 | Penetration (ft): | 4ft 11in |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft) | ~~5ft 8in~~ * ~~a~~ 5' |
| | | Depth (ft) | 41.5 | Date/Time: | 4/3/13 0906 |
| | | Pred Tide (ft): | 3.54 ft MLLW | | |
| | | St. Arrival: | 0857 | Attempt 2 | Refusal? Y/N |
| Vessel: | Walter Marie | St.Depart | 0912 | Penetration (ft): | |
| Collection: | vibracore | Logged by: | T.Himmer/CH2M; T.Frank/E2 | Recovery (ft) | |
| Contact Information: | Theresa Himmer/CH2M HILL, theresa.himmer@ch2m.com, 781 378 2086 | | | Date/Time: | |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/ Density | Cementation/ Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample IDs (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.8m | 0.5 | | OH/OL | 10YR 2/1 to 4/1 | VS | N | H | wet | MS | ~~Non~~ | — | 0-5 | 95-100 | A | ost 2-3m of very fine clay, light tan, suspended in water ** |
| | 1 | | | | S | | | | | | | | | B | |
| | 2 | | | | | | | Moist | FS | | — | 1-3% | ~~99~~ 97-99 | | 0-2' dk gray to black clay/silk, v. sticky, wet, trace f-m sand 2-3.5 |
| 0.8m | 3 | | CL | 10YR 3/1 | H | | | | | | | | | C | |
| | | | | | | | | wet | CS. GR | | ≈5 | ~0 | 95 | | |
| ~~3.9~~ 4.0 | 4 | | | | | | | | | | | | | | 2-4' dry, dark gray clay. non plastic. 3.5-4 wet clay and some gravel - clay appears "fractured": eg - gravel sized clumps of clay w/in watery silt/clay. |
| | 5 | | | | | | | | | | | | | | |
| | 6 | | | | | | | | | | | | | | |
| | 7 | | | | | | | | | | | | | | |
| | 8 | | | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | |

ODOR -
0 - ~1.5 - None
1.5 - 2 moderate PHC
2 - 4 - none.

** 0.1' - 0.2' fine sand layer

Sample Summary (check boxes for analysis):

| | Sample ID | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | GS | TOC | EPA | spgr/% sand | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Y8RZ2 SD13-40-0005 | | 4/4/13 | 0-0.5 | ✓ | ✓ | ✓ | | | | | | |
| B | Y8RZ3 SD13-40-0520 | | 1540 | 0.5-2.0 | ✓ | | ✓ | | | | | | |
| C | Y8RZ4 SD13-40-2040 | | | 2.0-4.0 | ✓ | | ✓ | ✓ | | | | | |
| D | SD13-40-0040 | | | 0.0-4.0 | | | | | ✓ | | | | |
| E | | | | | | | | | | | | | |
| F | | | | | | | | | | | | | |

Reviewed by: Date:

* Note that from ~4ft 11in to 5ft 8in, sediment is very soft, and might not have been felt by driller taking water depth measurement. Penetration likely more than indicated, close to 5ft, 8in, sediment has continued to settle to 5ft.

CH2MHILL

Site Name: United Heckathorn
Project Number: 335441.FI.01
Project Location: Richmond, California
Survey Duration: April 1 - April 4, 2013

| | | | | | |
|---|---|---|---|---|---|
| Station ID: | SD13-41 | Northing: | 2162400.50 | Attempt 1 | Refusal? Y/N |
| Sampling | C. Cisneros/CH2M HILL | Easting: | 6023057.92 | Penetration (ft): | 6ft, 5in |
| Crew/Company | Dixon Marine | Datum: | NAD83 CA State Plane Zn III | Recovery (ft) | |
| | | Depth (ft) | 39.1 | Date/Time | 4/3/13 0945 |
| | | Pred Tide (ft): | 2.73 ft MLLW | | |
| | | St. Arrival: | 0932 | Attempt 2 | Refusal? Y/N |
| Vessel: | Walter Marie | St.Depart | 0948 | Penetration (ft): | |
| Collection: | vibracore | Logged by: | T. Himmer/CH2M; T. Frank/E2 | Recovery (ft) | |
| Contact Information: | Theresa Himmer/CH2M HILL, theresa.himmer@ch2m.com, 781.378.2088 | | | Date/Time | |

| Depth below water surface (ft) | Depth below mudline (ft) | Lithology | Type | Color (Munsell) | Consistency/Density | Cementation/Plasticity | Structure | Moisture Content | Maximum particle size | Odor | % gravel | % sand | % fines | Sample IDs (letter corresponds to below) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YBM | 0.5 | | ~~OH~~ OL ML/MH | 2.5 YR 3/2 | V.S | N | H | V. wet | Z | | 0 | 0 | 100 | A | V. soft to soft clay/ silt to 4' |
| | 1 | | | | | | | | CS. GR | slight PHC ODOR | tr. | | | B | Grayish brown w/ ~~shore~~ |
| | 2 | | | | | | | | Z | | 0 | | | | |
| | 3 | | | | | | | | | | | | | C | some black streaks. |
| | 4 | | | | MSD Firm | | | | | | | | | D | 4-5' wet, ~~angular~~ angular clumps |
| 5- OBM | 5 | | CL | 2.5YR 5/2 | H. | slight plastic | ~~Dry~~ | Dry | Z | none ~~Z~~ | 0 | 0 | 100 ~~Z~~ | X | of clay (CH) |
| | 6 | | | | | | | | | | | | | E | gravel-sized pieces. |
| 6.5 | 7 | | | | | | | | | | | | | | 4.9-5 transition to hard clay dk gray |
| | 8 | | | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | |

appears to be ~~fractured~~ ~~broken~~ clasts of OBM.

Angular ~~debris~~ rock @ 1' - cube @ 1" ~~m~~ square / gravel

Sample Summary (check boxes for analysis):

| | Sample ID | Sample Type (N/FD/MS/MSD) | Sample Date/Time | Depth Interval (ft) | Pesticides | GS | TOC | sp gr / % solids | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Y8RZ6 SD13-41-0005 | | 4/5/13 | 0.0-0.5 | ✓ | ✓ | ✓ | | | | | | |
| B | Y8RZ7 SD13-41-0520 | | 1100 | 0.5-5.0 | ✓ | | ✓ | | | | | | |
| C | Y8RZ8 SD13-41-0040 | | | 2.0-4.0 | ✓ | ✓ | ✓ | | | | | | |
| D | Y8RZ9 SD13-41-4049 | FD | | 4.0-4.9 | ✓ | | ✓ | | | | FD Y8RA0 | | |
| E | SD13-41-0049 | | | 0.0-4.9 | | | | ✓ | | | | | |
| F | | | | | | | | | | | | | |

Reviewed by: Date:

# Attachment 3
# Photograph Log

Photograph 1: Vibracore drilling team member holding the cable as the vibracore head was lowered in order to feel when the barrel hits the bottom.

Photograph 2: Rocky area surrounding SD13-06 and vessel tie off locations.

Photograph 3: Vibracore team members removing core catcher from barrel and capping bottom.

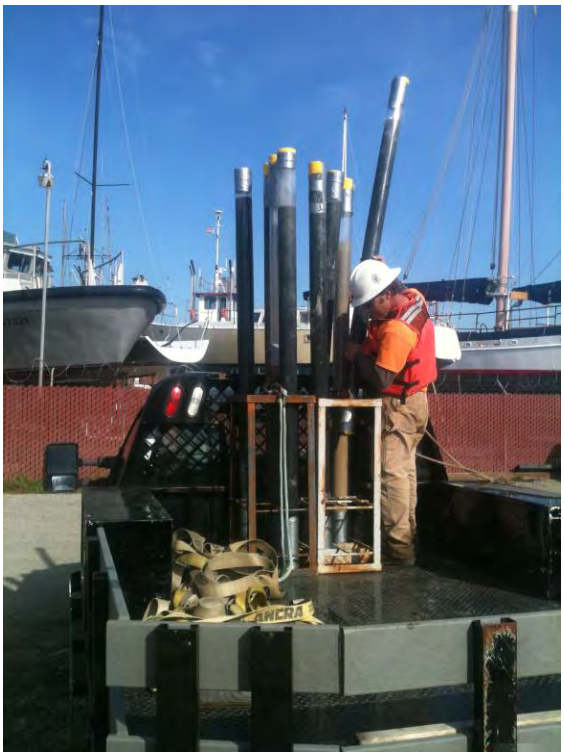
Photograph 4: Vibracore drill team members capping the fine-interval core from SD13-5.

Photograph 5: Vibracore sampling team members capping the fine-interval core from SD13-9.

Photograph 6: Vibracore team members coiling up hose on boat deck after rinsing off vibracore head.

Photograph 7: Vibracore team member decontaminating the core catcher.

Photograph 8: Completed cores and empty liners in the rack on the vessel.




Photograph 9: Vibracore team member loading completed cores into core rack on truck for transport to the laboratory.

# 2013 Groundwater Sampling and Hydrogeologic Investigation: Summary of Field Activities to Support Source Identification Study United Heckathorn Superfund Site, Richmond, California

| | |
|---|---|
| PREPARED FOR: | United States Environmental Protection Agency (USEPA) Region 9 |
| PREPARED BY: | CH2M HILL |
| DATE: | August 12, 2013 |
| PROJECT NUMBER: | USEPA CONTRACT NO. EP-S9-08-04<br>USEPA WORK ASSIGNMENT NO. 025-RIFS-09R3<br>CH2M HILL PROJECT NO. 385441 |

## Background

This technical memorandum summarizes the field activities in support of the groundwater investigation conducted between March 18 and March 28, 2013 at the United Heckathorn Superfund Site, in Richmond, California. CH2M HILL performed the groundwater investigation for the U.S. Environmental Protection Agency (USEPA) under Contract EP-S9-08-04 and Work Assignment No. 025-RIFS-09R3. The groundwater investigation was performed in accordance with the *Final Focused Feasibility Study Data Gaps Sampling and Analysis Plan (SAP) Addendum #2, Source Identification Study* (CH2M HILL, 2013) (SAP). Activities conducted at the site included collection of groundwater samples for analysis and a hydrogeologic investigation (tidal study and slug testing) to identify the source(s) of dichlorodiphenyltrichloroethane (DDT)[1] and Dieldrin that have been consistently measured in sediment and biota at the site since remediation was completed in 1997. Groundwater investigation activities were performed as one component of the Source Identification Study, which will include the full results of this groundwater investigation. The potential for contaminant transport to the Lauritzen Channel through leaching of pesticide-contaminated soils under the upland cap and groundwater transport to the channel will be evaluated and ruled in or out as a significant ongoing source of contamination. Groundwater seepage through contaminated embankment soils will also be evaluated. Results of the Source Identification Study will support the forthcoming Focused Feasibility Study (FFS) for the United Heckathorn Superfund Site.

[1] DDT is defined as the sum of 2,4'- and 4,4'-dichlorodiphenyltrichloroethane (DDT); 2,4'- and 4,4'-dichlorodiphenyldichloroethane (DDD); and 2,4'- and 4,4'-dichlorodiphenyldichloroethene (DDE)

# Overview of Field Activities

Groundwater samples were collected from ten soil borings (GW13-05 through GW13-14) and two newly installed monitoring wells (MW13-01 and MW13-03) for a total of 12 samples. All of the sampled locations were located along the northern and eastern shoreline of the Lauritzen Channel (Figure 1). Two additional monitoring wells (MW13-02 and MW13-04) were constructed approximately 130 feet from the shoreline in line with the two monitoring wells adjacent to the channel, to allow estimation of the groundwater gradients and seepage velocity (Figure 1).

The groundwater samples were analyzed for DDT and Dieldrin, volatile organic compounds (VOCs), and semivolatile organic compounds (SVOCs). Hydraulic testing, including a water-level evaluation and tidal study were also performed.

# Drilling Activities

Each soil boring location was marked with white paint. An Underground Safety Alert ticket was obtained for each boring (USA ticket numbers: 91876, 91892, 91900, 91907, 91914, 91927, 91936, 91945, 91951, 91958, 91984, 91990, 91992, and 91994). The locations were surveyed by a private utility locator, Subtronic Corp. (Martinez, CA), and each location was hand augered to clear the upper 5 feet. The concrete was cored by Osborne Concrete Coring & Cutting (Fremont, CA).

Drilling was completed by National Exploration, Wells, & Pumps, Inc. (Richmond, CA). Continuous soil cores were collected to confirm subsurface conditions, and allow the generation of continuous detailed lithological logs.

Boring and well construction applications were submitted to Contra Costa County (California) Department of Environmental Health; however, the county choose not to issue permits because they determined that issuance of permits would oblige them to conduct inspections of activities for which they had no legal enforcement jurisdiction based on the USEPA's Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) exemption. Soils were logged using Unified Soil Classification System (USCS) descriptions and are included in Attachment 1.

## Direct Push Groundwater Sampling Locations

At the 10 groundwater sampling locations, Direct Push Technology (DPT) was successfully used to advance borings. The SAP proposed drilling to at least 5 feet below the water table to allow sufficient borehole length to obtain the required volume of water for sampling. Due to the presence of a dry fill layer, very low permeability soil beneath the fill, and very poor groundwater yield the static water level (i.e., water table) could not be definitively determined at the time of drilling. As a result, the boreholes were extended approximately 10 or more feet below the estimated water table at some locations. The field geologist estimated the location of the water table using soil moisture and the relative elevation of the borehole compared with the water level in the Lauritzen Channel. Drill rods were removed and a ¾-inch diameter temporary polyvinyl chloride (PVC) well casing was installed in each boring with 10-foot long 0.01-inch slotted screen and a filter sock over the screened interval.

This method allowed accumulation of groundwater from the full length of the borehole resulting in sufficient groundwater volume for sample collection, which took from several hours to overnight.

After sampling was completed, all boring locations were abandoned by placing neat-Portland cement from the bottom of the boring using a tremie pipe. All displaced groundwater was contained for disposal. The top 2 feet of the boring was completed using concrete to restore the surface to its original condition.

A photograph log of field activities is provided in Attachment 2.

### Well Construction Locations

At the four well construction locations, drilling was completed using 6-inch diameter hollow-stem-augers. Drilling extended to 10 feet below the estimated water table based on soil moisture. Monitoring wells were constructed in each boring as described below.

### Waste Management

All concrete slurry, concrete cores, and soil cuttings were placed in United States Department of Transportation (DOT)-approved 55-gallon drums and labeled appropriately. All waste was characterized and removed from the site by Belshire Environmental Services (Foothill Ranch, CA), a licensed hazardous waste hauler. Waste soil, trash, and concrete were disposed of at US Ecology (Beatty, NV) and waste water was disposed of at DeMenno Kerdon (Compton, CA), both facilities approved under the USEPA "Off-Site Rule".

## Monitoring Well Construction

Monitoring wells were constructed using 2-inch diameter, Schedule 40 PVC casing and screen. All but one of the wells (MW13-03) had a 10-foot screen interval with 0.01-inch slot screen. Monitoring well MW13-03 had a 15-foot screen interval. Number 2/16 filter pack sand extended from the bottom of the boring to 1 to 2 feet above the top of the screen interval. Two feet of time-release bentonite pellets were placed on top of the filter pack sand. Neat-Portland cement was placed using a tremie pipe from the bentonite plug to within 2 feet of the ground surface. Wells were completed by placing a flush-mounted well box with a higher-than-standard traffic rating to protect them from crushing by the solid-tired, oversize vehicles used at the site.

The wells were developed by bailing with a bottom suction bailer to remove the fines from the bottom of the well. The wells were then surged using a close-fitting surge block, surging for a minimum of 3 minutes per saturated foot of well screen. The wells were then pumped until pH, temperature, electrical conductivity and turbidity parameters stabilized, as measured using an in-line water quality instrument. A minimum of 3 and a maximum of 10 saturated well volumes were removed from each well and placed in DOT-approved 55-gallon drums that were labeled appropriately.

# Monitoring Well Survey

The four wells and two points at the edge of the pier were surveyed. Each well location was surveyed at the ground surface, the edge of the rim, and the top of the north side of the casing. The two locations on the pier that were surveyed were marked with a survey nail to allow the surveyed location to be easily recognized. The two pier locations allowed for direct measurement of the water level in the channel using a free-hanging tape from a standard well water level meter at a location that remains flooded even during low tide. The survey results were reported horizontally to the nearest 0.01 feet in North American Datum (NAD) 1983 and the elevation to 0.01 feet in North American Vertical Datum (NAVD) 1988. Surveying was completed by Calvada Surveying (Corona, CA).

# Sample Collection Activities

Groundwater samples were collected from all temporary borings and monitoring wells MW13-1 and MW13-3 on March 21st and 22nd, 2013. Groundwater samples were collected using disposable tubing and a peristaltic pump. The depth to water was determined at each location to the nearest 0.01 foot. Table 1 presents a summary of the field parameters measured at each location. Field filtered samples for SVOCs (USEPA Method Contract Laboratory Program [CLP] Target Compound List [TCL} Semivolatiles) were filtered directly at the end of the tubing discharge point. Due to the elevated turbidity in the grab samples, multiple filters were necessary for samples GW13-08 and GW13-09. Unfiltered samples were then collected after the filter was removed. Samples were submitted to the laboratory as whole water samples for SVOC, VOC (USEPA Method CLP TCL Trace Volatiles), and organochlorine pesticides (USEPA Method E1699). Due to the low detection limit analyses required for organochlorine pesticides, samples were also submitted to the laboratory for filtering. All samples were pumped directly into pre-cleaned, pre-labeled containers which included the time and date of the sample collection. Field duplicates were collected at the rate of 1 field duplicate for every 10 field samples. Temperature, pH, and electrical conductivity were also measured for groundwater at each sampling location.

All samples for chemical analysis were collected in appropriate bottles as outlined in the SAP (CH2M HILL 2013), placed in a cooler at 4°C, and handled in accordance with chain-of-custody procedures. Characterization samples for VOC and SVOC analysis were sent to the CLP laboratory KAP Technologies (Spring, TX) and organochlorine pesticide samples were sent to Vista Analytical Laboratory (El Dorado Hills, CA). The laboratory chains of custody are provided in Attachment 3. All samples for waste characterization were sent to the EPA Region 9 laboratory (Richmond, CA).

# Water Level Evaluation – Tidal Study

A study of tidal fluctuation in the Lauritzen Channel and all four newly- constructed monitoring wells was conducted from 4:00 PM on March 26 to 4:00 PM on March 29, 2013 to estimate mean water levels and propagation of tidal influence through the aquifer. A stilling well was placed in the Lauritzen Channel by strapping a 1-inch diameter, Schedule 40 PVC well casing with a 5 foot screen interval and a 0.01-inch slot size screen to a piling. The

purpose of the stilling well was to secure and minimize the effect of wave action on the data logging transducer placed in the channel.

An In-Situ. Inc. Level TROLL® 700 data logging pressure transducer with vented cables was placed in each monitoring well and the stilling well. Only vented cable transducers were used to eliminate the effects of barometric pressure changes during the period of the study. A laptop computer with Win-Situ® 5 (software) was used to program the pressure transducers and synchronize the clock time in all the transducers.

At the end of the tidal study, the depth to groundwater in each well was measured along with the depth from one of the surveyed points on the pier to the depth of the water in the Lauritzen Channel. The tidal study was run for 72 hours. Data were downloaded from the transducers and trimmed to remove anomalous readings associated with placement and removal of the transducers.

# Slug Testing

Slug tests were conducted on all four of the newly- constructed monitoring wells on March 26th, 2013 (prior to the start of the tidal study) to estimate hydraulic conductivity of subsurface soils and allow estimation of groundwater flow velocities. Two "slug in" and two "slug out" tests were conducted on each well, with the extra test on each well as a backup in the event that mechanical or electronic problems resulted in unusable data from a particular test. Only one "slug in" and one "slug out" test were evaluated for each well because there were no technical anomalies and the two tests from each well provided substantially similar results.

Prior to conducting the slug test, the static water level in the well was measured to the nearest 0.01 foot. The "slug in" test was begun by starting the data recording on the Level TROLL® 700 data logging pressure transducers and then placing it in the monitoring well. The water level was then checked to ensure that only negligible displacement of water was caused by the transducer. A 1.5 inch diameter, 5-foot long displacement device was lowered rapidly (without allowing the device to free-fall) into the well until the top of the slug device was below the static water level. The test was allowed to run until the water level was static.

After completion of the "slug in" test, a "slug out" test conducted by rapidly removing the slug device and recording water levels until the water levels again were static. The "slug in" and "slug out" tests were repeated to ensure that data were available in the event that the first test did not provide useable data.

Although water level changes due to tidal influence occurred in all wells, the water level fluctuations during the test (typical several minutes) were not significant enough to impact the slug test analysis.

# Reference

*Final Focused Feasibility Study Data Gaps Sampling and Analysis Plan Addendum #2: Source Identification Study, United Heckathorn Superfund Site, Richmond, California.* Prepared by CH2M HILL, dated February 2013.

# Table

TABLE 1

**Groundwater Sampling - Field Water Quality Measurements and Elevations - March 2013**

*United Heckathorn Superfund Site, Richmond, California*

| | | | Well Constructionand Elevation Data | | | | | | Field Water Quality Parameters | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well ID | Groundwater Sample Collection Date & Time | | Well Depth (ft) | X | Y | Screen Interval (ft below surface) | Depth to Water (ft) | Tubing Intake Depth (ft) | Temperature ($^{o}$C) | Field pH | Specific Conductivity (mS) | Conductivity (mS) | Comment |
| MW13-01 | 3/25/2013 | 9:50 | 30 | 6023329.05 | 2163993.83 | 20-30 | 10.5 | 29 | 14.9 | 6.61 | 37.02 | 35.69 | Tan and cloudy |
| MW13-02 | NA | NA | 25 | 6023536.06 | 2163403.65 | 14.5-24.5 | NA | NA | NA | NA | NA | NA | |
| MW13-03 | 3/25/2013 | 15:30 | 33 | 6023282.26 | 2163398.94 | 18-33 | 11.5 | 32 | 15.1 | 6.65 | 34.96 | 34.62 | Tan and cloudy |
| MW13-04 | NA | NA | 30.0 | 6023392.09 | 2163360.93 | 20-30 | NA | NA | NA | NA | NA | NA | |
| GW13-05 | 3/21/2013 | 12:35 | 20 | 6023311.18 | 2164535.44 | 10-20 | 9.8 | NR | 21.6 | 6.66 | 43.50 | 43.5 | |
| GW13-06 | 3/21/2013 | 13:34 | 20 | 6023376.60 | 2164512.24 | 9-19 | 10.8 | NR | 26.2 | 6.61 | 27.67 | 24.07 | |
| GW13-07 | 3/22/2013 | 7:45 | 20 | 6023406.38 | 2164296.89 | 9-19 | 10.2 | NR | 15.06 | 6.54 | 21.54 | 17.67 | |
| GW13-08 | 3/22/2013 | 10:30 | 30 | 6023373.35 | 2164162.65 | 20-30 | 10.3 | NR | 19.7 | 6.36 | 28.96 | 26.01 | |
| GW13-09 | 3/22/2013 | 9:45 | 30 | 6023356.70 | 2164090.13 | 20-30 | 9.5 | NR | 17.2 | 6.45 | 35.32 | 30.07 | |
| GW13-10 | 3/22/2013 | 12:10 | 30 | 6023327.88 | 2163914.65 | 20-30 | 10.4 | 29 | 18.3 | 6.73 | 28.09 | 27.20 | Tan and cloudy |
| GW13-11 | 3/22/2013 | 12:45 | 30 | 6023340.97 | 2163840.06 | 20-30 | 7.5 | 29 | 17.9 | 6.71 | 32.23 | 31.61 | Tan and cloudy |
| GW13-12 | 3/22/2013 | 13:30 | 30 | 6023309.89 | 2163760.18 | 20-30 | 10.1 | 29 | 17.6 | 6.67 | 23.95 | 22.06 | Tan and very slightly cloudy |
| GW13-13 | 3/22/2013 | 11:15 | 30 | 6023310.98 | 2163700.38 | 20-30 | 9.6 | 29 | 17.9 | 6.72 | 27.09 | 24.62 | Tan and slightly cloudy |
| GW13-14 | 3/22/2013 | 10:30 | 30 | 6023250.84 | 2163063.34 | 20-30 | 8.0 | 29 | 16.9 | 6.51 | 32.61 | 30.02 | Tan and slightly cloudy |

**Notes:**

°C - degrees Celsius

ft - feet

mg/L - milligram per liter

mS - milliSiemens

mV - millivolts

NR - not recorded

NTU - nephelometric turbidity unit

# Figure

**LEGEND**

- Groundwater Sample Location
- Groundwater Monitoring Well - Sampled
- Groundwater Monitoring Well
- Removed Groundwater Well

B24 = Removed Groundwater Well Name
GW13-14 = Sample Location ID

N

0 62.5 125 250 Feet

Note:
Groundwater samples were collected at MW13-01 and MW13-03. These wells were also used for groundwater hydrogeologic evaluations. MW13-02 and MW13-04 were only used for groundwater hydrogeologic evaluations.

# FIGURE 1
# 2013 GROUNDWATER SAMPLING LOCATIONS

UNITED HECKATHORN SUPERFUND SITE
RICHMOND, CALIFORNIA

CH2MHILL

D:\Projects\EPA_UnitedHeckathorn\MapFiles\2013\GroundwaterSampling_July2013.mxd

# Attachment 1
# Soil Boring Logs

CH2MHILL

| PROJECT NUMBER: | BORING NUMBER: | |
|---|---|---|
| 385441.FI.01 | MW13-01 | SHEET 1 OF 1 |

# SOIL BORING LOG

PROJECT : March 2013 Groundwater Sampling and Hydraulic Evaluation LOCATION : United Heckathorn Superfund Site, Richmond, CA

ELEVATION : -- DRILLING CONTRACTOR : National Exploration, Wells and Pumps, Inc.

DRILLING EQUIPMENT AND METHOD : Geoprobe 7700, Direct Push - Dual Probe

WATER LEVELS : -- START : 3/19/2013 END : 3/19/2013 LOGGER : R. Lucich/J. Salinas

| DEPTH BELOW EXISTING GRADE (ft) | INTERVAL (ft) | RECOVERY (%) | LAB SAMPLE | USCS CODE/ LITHOLOGY | SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | WELL CONSTRUCTION DIAGRAM: WELL DIAMETER: 2" SCREENED INTERVAL: 20' - 30' BGS |
|---|---|---|---|---|---|---|
| | | | | | **Concrete** 0 - 8" | |
| | | | | SW | **Gravelly Sand (SW)** 8" - 7.5' - dark grayish brown, moist, loose, medium to coarse grained, subrounded, gravel is fine to coarse grained | |
| 5 | 5.0 | 50% | | | | |
| | | | | CL | **Clay (CL)** 7.5' - 9.5' - greenish gray, slightly moist, medium plasticity, medium hard | |
| 10 | 10.0 | 95% | | CH | **Clay (CH)** 9.5' - 15' - greenish black, moist, medium plasticity, slightly stiff | |
| 15 | 15.0 | 100% | | CL | **Clay (CL)** 15' - 22' - dark greenish gray, slightly moist, medium plasticity, stiff<br>17" - Color change to olive brown (2.5Y 4/3) | |
| 20 | 20.0 | 95% | | ML | **Clayey Silt (ML)** 22' - 23' - olive brown, moist, stiff | |
| | | | | CL | **Clay (CL)** 23' - 29' - olive brown, moist, very stiff | |
| 25 | 25.0 | 100% | | | 27' - 28' - wet | |
| 30 | 30.0 | | | SM | **Silty Sand (SM)** 29' - 30' - olive brown, moist, very fine grained, slightly dense<br>End Drilling on 3/19/2013<br>Total Borehole Depth: 30.0 ft bgs | |
| 35 | | | | | | |

| PROJECT NUMBER: | BORING NUMBER: |
|---|---|
| 385441.FI.01 | MW13-02 SHEET 1 OF 1 |

# SOIL BORING LOG

PROJECT : March 2013 Groundwater Sampling and Hydraulic Evaluation LOCATION : United Heckathorn Superfund Site, Richmond, CA

ELEVATION : -- DRILLING CONTRACTOR : National Exploration, Wells and Pumps, Inc.

DRILLING EQUIPMENT AND METHOD : Geoprobe 7700, Direct Push - Dual Probe

WATER LEVELS : -- START : 3/19/2013 END : 3/19/2013 LOGGER : R. Lucich/J. Salinas

| DEPTH BELOW EXISTING GRADE (ft) | INTERVAL (ft) | RECOVERY (%) | LAB SAMPLE | USCS CODE/ LITHOLOGY | SOIL DESCRIPTION<br>SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | WELL CONSTRUCTION DIAGRAM<br>WELL DIAMETER: 2"<br>SCREENED INTERVAL: 14.5' - 24.5' BGS |
|---|---|---|---|---|---|---|
| | | | | | **Concrete**<br>0 - 8" | |
| | | | | GW | **Sandy Gravel (GW)**<br>8" - 5" - yellowish brown, dry, loose, fine to coarse sand and gravel, subangular | |
| 5 | 5.0 | | | | | |
| | | 10% | | | 5' - 10' - No recovery | |
| 10 | 10.0 | | | | | |
| | | 100% | | CL | **Silty Clay (CL)**<br>10' - 14' - gray, moist to very moist, medium stiff | |
| | | | | CH | **Peaty Clay (CH)**<br>14' - 15' - dark grayish brown, very moist, slightly stiff, medium plasticity | |
| 15 | 15.0 | | | CL | 14.5' - Change to very dark gray (10YR 3/1), moist, medium plasticity, slightly stiff | |
| | | 100% | | ML | **Clay (CL)**<br>15' - 17' - dark greenish gray, moist, slightly stiff, medium plasticity | |
| 20 | 20.0 | | | | **Clayey Silt (ML)**<br>17' - 21' - dark greenish gray, very moist, slightly stiff<br>20' - Becomes brown | |
| | | 80% | | SM | **Silty Sand (SM)**<br>21' - 23.5' - grayish brown, wet, slightly dense, fine grained<br>22' - Becomes yellowish brown | |
| | | | | SM | **Silty Sand (SM)**<br>23.5' - 25' - brown, wet, slightly dense, fine to coarse grained, subangular to subrounded, with minor fine subangular gravel | |
| 25 | 25.0 | | | | End Drilling on 3/19/2013<br>Total Borehole Depth: 25.0 ft bgs | |
| 30 | | | | | | |
| 35 | | | | | | |

CH2MHILL

| PROJECT NUMBER: | BORING NUMBER: | |
|---|---|---|
| 385441.FI.01 | MW13-03 | SHEET 1 OF 1 |

# SOIL BORING LOG

PROJECT : March 2013 Groundwater Sampling and Hydraulic Evaluation LOCATION : United Heckathorn Superfund Site, Richmond, CA

ELEVATION : -- DRILLING CONTRACTOR : National Exploration, Wells and Pumps, Inc.

DRILLING EQUIPMENT AND METHOD : Geoprobe 7700, Direct Push - Dual Probe

WATER LEVELS : -- START : 3/20/2013 END : 3/20/2013 LOGGER : J. Salinas

| DEPTH BELOW EXISTING GRADE (ft) | INTERVAL (ft) | RECOVERY (%) | LAB SAMPLE | USCS CODE/ LITHOLOGY | SOIL DESCRIPTION<br>SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | WELL CONSTRUCTION DIAGRAM<br>WELL DIAMETER: 2"<br>SCREENED INTERVAL: 18' - 33' BGS |
|---|---|---|---|---|---|---|
| | | | | | **CONCRETE** | |
| | | | | GW | **Sandy Gravel (GW)**<br>8" - 5' - moist, loose, subangular clasts, fine to coarse sand and gravel | |
| 5 | 5.0 | | | | | |
| | | | | CL | **Clay (CL)**<br>5' - 7' - dark gray, moist, soft, medium plasticity | |
| | | 50% | | GW | **Gravel (GW)**<br>7' - 7.5' - very dark gray, loose, subangular, subangular clasts, some red clasts | |
| | | | | GW | **Sandy Gravel (GW)**<br>7.5' - 11.5' - grayish brown, moist, loose | |
| 10 | 10.0 | | | | | |
| | | 75% | | CL | **Clay (CL)**<br>11.5' - 16' - greenish black, moist, medium stiff, medium plasticity<br>14.5' - some rusting | |
| 15 | 15.0 | | | | | |
| | | 100% | | ML | **Clayey Silt (ML)**<br>16' - 23' - dark greenish gray, moist, medium stiff, medium plasticity<br>18' - subangular, Color change to light olive brown (2.5Y 5/4) | |
| 20 | 20.0 | | | | | |
| | | 100% | | GW | **Sandy Gravel (GW)**<br>23' - 25.5' - light olive brown, wet, loose, fine to coarse grained sand and gravel | |
| 25 | 25.0 | | | | | |
| | | 100% | | CL | **Clay (CL)**<br>25.5' - 27' - dark greenish gray, wet, soft, medium plasticity, subangular, some subangular clasts | |
| | | | | SW | **Sand (SW)**<br>27' - 27.5' - olive brown, wet, loose, subangular, fine to coarse grained | |
| | | | | GW | **Gravel (GW)**<br>27.5' - 29.5' - olive brown, wet, loose, subangular | |
| 30 | 30.0 | | | | | |
| | | | | SW | **Sand (SW)**<br>29.5' - 33' - olive brown, wet, loose, fine to coarse grained | |
| | | | | | End Drilling on 3/20/2013<br>Total Borehole Depth: 33.0 ft bgs | |
| 35 | | | | | | |

CH2MHILL

| PROJECT NUMBER: | BORING NUMBER: | |
|---|---|---|
| 385441.FI.01 | MW13-04 | SHEET 1 OF 1 |

# SOIL BORING LOG

PROJECT : March 2013 Groundwater Sampling and Hydraulic Evaluation LOCATION : United Heckathorn Superfund Site, Richmond, CA

ELEVATION : -- DRILLING CONTRACTOR : National Exploration, Wells and Pumps, Inc.

DRILLING EQUIPMENT AND METHOD : Geoprobe 7700, Direct Push - Dual Probe

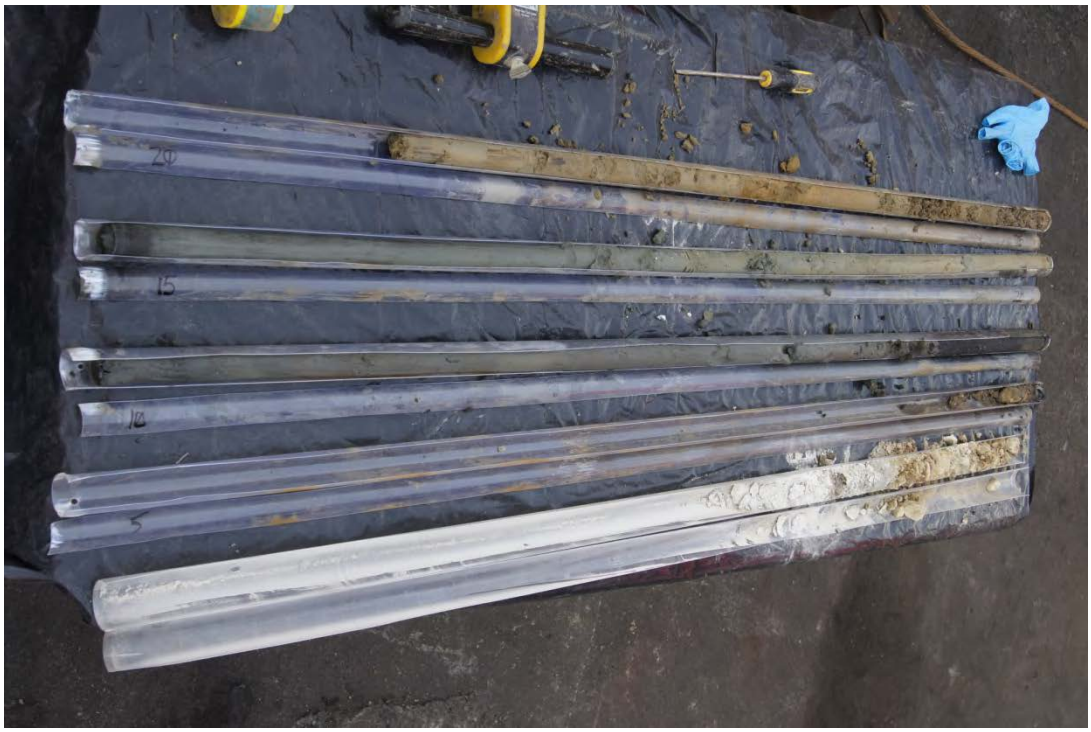
WATER LEVELS : -- START : 3/22/2013 END : 3/22/2013 LOGGER : R. Lucich

| DEPTH BELOW EXISTING GRADE (ft) | INTERVAL (ft) | RECOVERY (%) | LAB SAMPLE | USCS CODE/ LITHOLOGY | SOIL DESCRIPTION<br>SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | WELL CONSTRUCTION DIAGRAM<br>WELL DIAMETER: 2"<br>SCREENED INTERVAL: 20' - 30' BGS |
|---|---|---|---|---|---|---|
| | | | | | **Concrete**<br>0-8" | |
| | | | | SW | **Gravelly Sand (SW)**<br>8" - 6' - reddish brown, dry, loose, medium to coarse grained and subrounded gravel, fine to coarse grained, subrounded sand | |
| 5 | | | | ML | **Sandy Silt (ML)**<br>6' - 7' - gray, moist, soft | |
| | | | | SM | **Silty Sand (SM)**<br>7' - 8.5' - gray, wet, loose, very fine grained | |
| | | | | ML | **Sandy Silt (ML)**<br>8.5' - 9' - gray, moist, soft | |
| 10 | | | | SM | **Silty Sand (SM)**<br>9' - 12' - gray, wet, loose, very fine grained | |
| | | | | ML | **Sandy Silt (ML)**<br>12' - 13.5' - gray, moist, soft | |
| | | | | CH | **Peaty Clay (CH)**<br>13.5' -15' - very dark gray, moist, stiff, low plasticity | |
| 15 | | | | CL | **Silty Clay (CL)**<br>15' - 17' - greenish gray, moist, slightly stiff, medium plasticity | |
| | | | | SM | **Silty Sand (SM)**<br>17' - 20' - gray, very moist, slightly dense, very fine grained<br><br>19.5' - Becomes light olive brown (2.5Y 4/3) | |
| 20 | | | | ML | **Sandy Silt (ML)**<br>20' - 25' - olive brown, very moist, slightly stiff, medium plasticity | |
| 25 | | | | SM | **Silty Sand (SM)**<br>25' -30' - olive brown, wet, subrounded, slightly dense, very fine grained | |
| 30 | | | | | End Drilling on 3/22/2013<br>Total Borehole Depth: 30.0 ft bgs | |
| 35 | | | | | | |

# Attachment 2
# Photograph Log

Photograph 1: Concrete coring at GW13-10

Photograph 2: Installation of temporary well at grab groundwater location GW13-07.



Photograph 3: Soil cores in acetate liners for MW13-02.

Photograph 4: Example of a restored grab groundwater location.

Photograph 5:  Example of a completed groundwater monitoring well with lid.

# Attachment 3
# Laboratory Chains of Custody

**USEPA CLP Inorganics COC (LAB COPY)**

DateShipped:
CarrierName:
AirbillNo:

**CHAIN OF CUSTODY RECORD**

Case #: 43378
Cooler #:

**No: 9-031213-162429-0004 5**
Lab: KAP Technologies Inc.
Lab Contact: Rao Alsakani
Lab Phone: 281-367-0065

| Inorganic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Organic Sample # | For Lab Use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RJ5 | Ground Water/ | | CLP SVOA | 1025 (4C (+-2C)) (3) | MW13-03-0001F | | | |
| ~~Y8RJ7~~ | ~~Water/~~ | | ~~CLP TVOA, CLP SVOA~~ | ~~1042 (4C (+-2C) HCl)~~ 1043 (4C (+-2C)) (4) | ~~GW13-EB-02~~ | | | |
| ~~Y8RJ8~~ | ~~Water/~~ | | ~~CLP TVOA, CLP SVOA~~ | ~~1044 (4C (+-2C) HCl)~~ 1045 (4C (+-2C)) (4) | ~~GW13-EB-03~~ | Thank 3/22/13 | | |
| Y8RK0 ~~Y8RL4~~ | ~~Y8RK2~~ | Water | CLP TVOA | 1044 (4C (+-2C) HCL) | GW13-TB-04 | | | |
| Y8RK3 | water | | CLP TVOA, CLP SVOA | 4C (+-2C) HCl 4C (+-2C) (4) | GW13-EB-04 | 3.21.13/1700 | | |
| Y8RJ8 | water | | CLP TVOA, CLP SVOA | 4C (+-2C) HCl 4C (+-2C) (4) | GW13-EB-03 | 3.20.13/1700 | | |
| Y8RK1 | water | | CLP TVOA, CLP SVOA | 4C (+-2C) HCl 4C (+-2C) (4) | GW13-EB-05 | 3.22.13/1400/ | | |

| | |
|---|---|
| Sample(s) to be used for Lab QC: Y8RJ5 | **Shipment for Case Complete? N** |
| | **Samples Transferred From Chain of Custody #** |

Analysis Key: CLP SVOA=CLP TCL Semivolatiles, CLP TVOA=CLP TCL Trace Volatiles

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished By | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | [signature] | 3/22/13 | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

Generated by CamScanner from intsig.com

**USEPA CLP Organics COC (LAB COPY)**

DateShipped:

CarrierName: FedEx

AirbillNo:

**CHAIN OF CUSTODY RECORD**

Case #: 43378

Cooler #:

**No: 9-031512-115935-0002** 5

Lab: KAP Technologies Inc.

Lab Contact: Rao Alsakani

Lab Phone: 281-367-0065

| Organic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Inorganic Sample # | For Lab Use Only |
|---|---|---|---|---|---|---|---|---|
| ~~Y8RH0~~ | ~~Ground Water/~~ | | ~~CLP SVOA, CLP TVOA~~ | ~~1000 (4C (+-2C)), 1027 (4C (+-2C) HCl) (4)~~ | ~~GW13-05-0001~~ | | | |
| ~~Y8RH1~~ | ~~Ground Water/~~ | | ~~CLP SVOA~~ | ~~1001 (4C (+-2C)) (1)~~ | ~~GW13-05-0001F~~ | | | |
| ~~Y8RH2~~ | ~~Ground Water/~~ | | ~~CLP SVOA, CLP TVOA~~ | ~~1002 (4C (+-2C)), 1028 (4C (+-2C) HCl) (4)~~ | ~~GW13-06-0001~~ | [signature] 3/22/13 | | |
| ~~Y8RH3~~ | ~~Ground Water/~~ | | ~~CLP SVOA~~ | ~~1003 (4C (+-2C)) (1)~~ | ~~GW13-06-0001F~~ | | | |
| Y8RH4 | Ground Water/ | | CLP SVOA, CLP TVOA | 1004 (4C (+-2C)), 1029 (4C (+-2C) HCl) (4) | GW13-07-0001 | 3/22/13 0745 | | |
| Y8RH5 | Ground Water/ | | CLP SVOA | 1005 (4C (+-2C)) (1) | GW13-07-0001F | 3/22/13 0745 | | |
| Y8RH8 | Ground Water/ | | CLP SVOA, CLP TVOA | 1008 (4C (+-2C)), 1031 (4C (+-2C) HCl) (4) | GW13-08-0001 | 3/22/13 ~~0815~~ 1030 [initials] | | |
| Y8RH9 | Ground Water/ | | CLP SVOA | 1009 (4C (+-2C)) (1) | GW13-08-0001F | 3/22/13 ~~0815~~ 1030 [initials] | | |
| Y8RI0 | Ground Water/ | | CLP SVOA, CLP TVOA | 1010 (4C (+-2C)), 1032 (4C (+-2C) HCl) (4) | GW13-09-0001 | 3/22/13 0945 | | |
| Y8RI1 | Ground Water/ | | CLP SVOA | 1011 (4C (+-2C)) (1) | GW13-09-0001F | 3/22/13 0945 | | |
| Y8RI2 | Ground Water/ | | CLP SVOA, CLP TVOA | 1012 (4C (+-2C)), 1033 (4C (+-2C) HCl) (4) | GW13-10-0001 | 3/22/13 1210 | | |
| Y8RI3 | Ground Water/ | | CLP SVOA | 1013 (4C (+-2C)) (1) | GW13-10-0001F | 3/22/13 1210 | | |
| ~~Y8RJ6~~ | ~~Water/~~ | | ~~CLP TVOA, CLP SVOA~~ | ~~1040 (4C (+-2C) HCl), 1041 (4C (+-2C)) (4)~~ | ~~GW13-EB-01~~ | [signature] 3/22/13 | | |

| | |
|---|---|
| *Special Instructions:* | **Shipment for Case Complete? N** |
| | **Samples Transferred From Chain of Custody #** |

*Analysis Key:* CLP SVOA=CLP TCL Semivolatiles, CLP TVOA=CLP TCL Trace Volatiles

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished By | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | [signature] | 3/22/13 | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

Generated by CamScanner from intsig.com

**USEPA CLP Inorganics COC (LAB COPY)**

DateShipped:
CarrierName:
AirbillNo:

**CHAIN OF CUSTODY RECORD**

Case #: 43378
Cooler #:

**No: 9-031213-162429-0004 5**

Lab: KAP Technologies Inc.
Lab Contact: Rao Alsakani
Lab Phone: 281-367-0065

| Inorganic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Organic Sample # | For Lab Use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RH6 | Ground Water/ | | CLP SVOA, CLP TVOA | 1006 (4C (+-2C)), 1030 (4C (+-2C) HCl) (4) | GW13-93-0001 | 3/22/13 0815 | | |
| Y8RH7 | Ground Water/ | | CLP SVOA | 1007 (4C (+-2C)) (1) | GW13-93-0001F | 3/22/13 0815 | | |
| Y8RI4 | Ground Water/ | | CLP SVOA, CLP TVOA | 1014 (4C (+-2C)), 1034 (4C (+-2C) HCl) (4) | GW13-11-0001 | 3/22/13 1245 | | |
| Y8RI5 | Ground Water/ | | CLP SVOA | 1015 (4C (+-2C)) (1) | GW13-11-0001F | 3/22/13 1245 | | |
| Y8RI6 | Ground Water/ | | CLP SVOA, CLP TVOA | 1016 (4C (+-2C)), 1035 (4C (+-2C) HCl) (4) | GW13-12-0001 | 3/22/13 1330 | | |
| Y8RI7 | Ground Water/ | | CLP SVOA | 1017 (4C (+-2C)) (1) | GW13-12-0001F | 3/22/13 1330 | | |
| Y8RI8 | Ground Water/ | | CLP SVOA, CLP TVOA | 1018 (4C (+-2C)), 1036 (4C (+-2C) HCl) (4) | GW13-13-0001 | 3/22/13 1115 | | |
| Y8RI9 | Ground Water/ | | CLP SVOA | 1019 (4C (+-2C)) (1) | GW13-13-0001F | 3/22/13 1115 | | |
| Y8RJ0 | Ground Water/ | | CLP SVOA, CLP TVOA | 1020 (4C (+-2C)), 1037 (4C (+-2C) HCl) (4) | GW13-14-0001 | 3/22/13 1030 | | |
| Y8RJ1 | Ground Water/ | | CLP SVOA | 1021 (4C (+-2C)) (1) | GW13-14-0001F | 3/22/13 1030 | | |
| ~~Y8RJ2~~ | ~~Ground Water/~~ | | ~~CLP SVOA, CLP TVOA~~ | ~~1022 (4C (+-2C)), 1038 (4C (+-2C) HCl) (4)~~ | ~~MW13-01-0001~~ | | | RDL 3/22/13 |
| ~~Y8RJ3~~ | ~~Ground Water/~~ | | ~~CLP SVOA~~ | ~~1023 (4C (+-2C)) (1)~~ | ~~MW13-01-0001F~~ | | | RDL 3/22/13 |
| ~~Y8RJ4~~ | ~~Ground Water/~~ | | ~~CLP SVOA, CLP TVOA~~ | ~~1024 (4C (+-2C)), 1039 (4C (+-2C) HCl) (12)~~ | ~~MW13-03-0001~~ | | | RDL 3/22/13 |

*Sample(s) to be used for Lab QC: Y8RJ4, Y8RJ5*

**Shipment for Case Complete? N**

**Samples Transferred From Chain of Custody #**

*Analysis Key: CLP SVOA=CLP TCL Semivolatiles, CLP TVOA=CLP TCL Trace Volatiles*

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished By | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Roger Duid | 3/22/13 | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

Generated by CamScanner from intsig.com

**USEPA CLP Inorganics COC (LAB COPY)**

DateShipped:

CarrierName:

AirbillNo:

**CHAIN OF CUSTODY RECORD**

Case #: 43378

Cooler #:

**No: 9-031213-162429-0006**

Lab: KAP Technologies Inc.

Lab Contact: Rao Alsakani

Lab Phone: 281-367-0065

| Inorganic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Organic Sample # | For Lab Use Only |
|---|---|---|---|---|---|---|---|---|
| ~~Y8RH6~~ | ~~Ground Water/~~ | | ~~CLP SVOA, CLP TVOA~~ | ~~1006 (4C (+-2C)), 1030 (4C (+-2C) HCl) (4)~~ | ~~GW13-93-0001~~ | | | |
| ~~Y8RH7~~ | ~~Ground Water/~~ | | ~~CLP SVOA~~ | ~~1007 (4C (+-2C)) (1)~~ | ~~GW13-93-0001F~~ | | | |
| ~~Y8RI4~~ | ~~Ground Water/~~ | | ~~CLP SVOA, CLP TVOA~~ | ~~1014 (4C (+-2C)), 1034 (4C (+-2C) HCl) (4)~~ | ~~GW13-11-0001~~ | 3/26/13 | | |
| ~~Y8RI5~~ | ~~Ground Water/~~ | | ~~CLP SVOA~~ | ~~1015 (4C (+-2C)) (1)~~ | ~~GW13-11-0001F~~ | | | |
| ~~Y8RI6~~ | ~~Ground Water/~~ | | ~~CLP SVOA, CLP TVOA~~ | ~~1016 (4C (+-2C)), 1035 (4C (+-2C) HCl) (4)~~ | ~~GW13-12-0001~~ | | | |
| ~~Y8RI7~~ | ~~Ground Water/~~ | | ~~CLP SVOA~~ | ~~1017 (4C (+-2C)) (1)~~ | ~~GW13-12-0001F~~ | | | |
| ~~Y8RI8~~ | ~~Ground Water/~~ | | ~~CLP SVOA, CLP TVOA~~ | ~~1018 (4C (+-2C)), 1036 (4C (+-2C) HCl) (4)~~ | ~~GW13-13-0001~~ | | | |
| ~~Y8RI9~~ | ~~Ground Water/~~ | | ~~CLP SVOA~~ | ~~1019 (4C (+-2C)) (1)~~ | ~~GW13-13-0001F~~ | | | |
| ~~Y8RJ0~~ Y8RK4 | Ground Water/ | JTB 3/26/13 | ~~CLP SVOA,~~ CLP TVOA | ~~1020 (4C (+-2C)), 1037~~ (4C (+-2C) HCl) ~~(4)~~ (1) | ~~GW13-14-0001~~ GW13-TB-05 | 3/25/13 3/26/13 11 | 0800 | |
| ~~Y8RJ1~~ | ~~Ground Water/~~ | | ~~CLP SVOA~~ | ~~1021 (4C (+-2C)) (1)~~ | ~~GW13-14-0001F~~ | | | |
| Y8RJ2 | Ground Water/ | | CLP SVOA, CLP TVOA | 1022 (4C (+-2C)), 1038 (4C (+-2C) HCl) (4) | MW13-01-0001 | 3/25/13 0950 | | |
| Y8RJ3 | Ground Water/ | | CLP SVOA | 1023 (4C (+-2C)) (1) | MW13-01-0001F | 3/25/13 0950 | | |
| Y8RJ4 | Ground Water/ | | CLP SVOA, CLP TVOA | 1024 (4C (+-2C)), 1039 (4C (+-2C) HCl) (12) | MW13-03-0001 | 3/25/13 1530 | | |
| Y8RJ5 | Groundwater | | CLP SVOA | [4C (±2C)] (3) | MW13-03-0001F | 3/25/13 1530 | | |

Sample(s) to be used for Lab QC: Y8RJ4, Y8RJ5

**Shipment for Case Complete? N**

**Samples Transferred From Chain of Custody #**

Analysis Key: CLP SVOA=CLP TCL Semivolatiles, CLP TVOA=CLP TCL Trace Volatiles

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished By | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Roger Dlusey | 3.26.13 | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

Generated by CamScanner from intsig.com

**USEPA CLP Organics COC (LAB COPY)**

DateShipped:

CarrierName: FedEx

AirbillNo:

**CHAIN OF CUSTODY RECORD**

Case #: 43378

Cooler #:

**No: 9-031512-115935-0002**

Lab: KAP Technologies Inc.

Lab Contact: Rao Alsakani

Lab Phone: 281-367-0065

| Organic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Inorganic Sample # | For Lab Use Only |
|---|---|---|---|---|---|---|---|---|
| Y8RH0 | Ground Water/ | | CLP SVOA, CLP TVOA | 1000 (4C (+-2C)), 1027 (4C (+-2C) HCl) (4) | GW13-05-0001 | | | |
| Y8RH1 | Ground Water/ | | CLP SVOA | 1001 (4C (+-2C)) (1) | GW13-05-0001F | | | |
| Y8RH2 | Ground Water/ | | CLP SVOA, CLP TVOA | 1002 (4C (+-2C)), 1028 (4C (+-2C) HCl) (4) | GW13-06-0001 | | | |
| Y8RH3 | Ground Water/ | | CLP SVOA | 1003 (4C (+-2C)) (1) | GW13-06-0001F | | | |
| Y8RH4 | Ground Water/ | | CLP SVOA, CLP TVOA | 1004 (4C (+-2C)), 1029 (4C (+-2C) HCl) (4) | GW13-07-0001 | | | |
| Y8RH5 | Ground Water/ | | CLP SVOA | 1005 (4C (+-2C)) (1) | GW13-07-0001F | | | |
| Y8RH8 | Ground Water/ | | CLP SVOA, CLP TVOA | 1008 (4C (+-2C)), 1031 (4C (+-2C) HCl) (4) | GW13-08-0001 | | | |
| Y8RH9 | Ground Water/ | | CLP SVOA | 1009 (4C (+-2C)) (1) | GW13-08-0001F | TF 3/20/13 | | |
| Y8RI0 | Ground Water/ | | CLP SVOA, CLP TVOA | 1010 (4C (+-2C)), 1032 (4C (+-2C) HCl) (4) | GW13-09-0001 | | | |
| Y8RI1 | Ground Water/ | | CLP SVOA | 1011 (4C (+-2C)) (1) | GW13-09-0001F | | | |
| Y8RI2 | Ground Water/ | | CLP SVOA, CLP TVOA | 1012 (4C (+-2C)), 1033 (4C (+-2C) HCl) (4) | GW13-10-0001 | | | |
| Y8RI3 | Ground Water/ | | CLP SVOA | 1013 (4C (+-2C)) (1) | GW13-10-0001F | | | |
| Y8RJ6 | Water/ | | CLP TVOA, CLP SVOA | 1040 (4C (+-2C) HCl), 1041 (4C (+-2C)) (4) | GW13-EB-01 | 3/18/13 1630 | | |
| | | | | | | | | |

Special Instructions:

**Shipment for Case Complete? N**

**Samples Transferred From Chain of Custody #**

Analysis Key: CLP SVOA=CLP TCL Semivolatiles, CLP TVOA=CLP TCL Trace Volatiles

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished By | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tamara Jones 3/20/13 | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

**USEPA CLP Inorganics COC (LAB COPY)**

DateShipped:

CarrierName:

AirbillNo:

**CHAIN OF CUSTODY RECORD**

Case #: 43378

Cooler #:

**No: 9-031213-162429-0004**

Lab: KAP Technologies Inc.

Lab Contact: Rao Alsakani

Lab Phone: 281-367-0065

| Inorganic Sample # | Matrix/Sampler | Coll. Method | Analysis/Turnaround | Tag/Preservative/Bottles | Station Location | Collected | Organic Sample # | For Lab Use Only |
|---|---|---|---|---|---|---|---|---|
| ~~Y8RJ5~~ | ~~Ground Water/~~ | | CLP SVOA | 1025 (4C (+-2C)) (3) | MW13-03-0001F | ~~JF~~ 3/20/13 | | |
| Y8RJ7 | Water/ | | CLP TVOA, CLP SVOA | 1042 (4C (+-2C) HCl), 1043 (4C (+-2C)) (4) | GW13-EB-02 | 3/19/13 1700 | | |
| ~~Y8RJ8~~ | ~~Water/~~ | | ~~CLP TVOA, CLP SVOA~~ | ~~1044 (4C (+-2C) HCl), 1045 (4C (+-2C)) (4)~~ | ~~GW13-EB-03~~ | ~~JF~~ 3/20/13 | | |
| Y8RJ9 | Water/ | | CLP TVOA | 1044 (4C (+-2C) HCl) (1) | GW13-TB-01 | | | |

Sample(s) to be used for Lab QC: Y8RJ5

**Shipment for Case Complete? (N)**

**Samples Transferred From Chain of Custody #**

Analysis Key: CLP SVOA=CLP TCL Semivolatiles, CLP TVOA=CLP TCL Trace Volatiles

| Items/Reason | Relinquished by | Date | Received by | Date | Time | Items/Reason | Relinquished By | Date | Received by | Date | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jamare Jane | 3/20/13 | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

# E2 Consulting Engineers, Inc.

1300229

## CHAIN OF CUSTODY RECORD: UHGW_V001

2.1°C

2013 March Groundwater

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Project Name: United Heckathorn | | | Container: | 1 L Amber Glass | | | |
| | | | Preservatives: | 4C (+-2C) | | | |
| Project Number: 43378 | | | | | | | |
| Project Manager: | | | Filtered: | n | | | |
| Sample Manager: | | | Holding Time | 7 Days | | | |
| Cell Number: | | | | | | | |
| Fax/Email: | | | | Pesticides (E1699) | | Number of Containers | Ship To: Vista Analytical Laboratory 1104 Windfield Way El Dorado Hills, CA 95762 916-673-1520 Sample Receiving |
| SAMPLE ID | DATE | TIME | Matrix | | | | COMMENTS |
| ~~GW13-10-0001~~ | | | ~~GW~~ | ~~X~~ | | ~~1~~ | |
| ~~GW13-10-0001F~~ | | | ~~GW~~ | ~~X~~ | | 1 | ~~Filter on Receipt~~ |
| ~~GW13-11-0001~~ | | | ~~GW~~ | ~~X~~ | | ~~1~~ | |
| ~~GW13-11-0001F~~ | | | ~~GW~~ | ~~X~~ | | 1 | ~~Filter on Receipt~~ |
| ~~GW13-12-0001~~ | | | ~~GW~~ | ~~X~~ | | ~~1~~ | |
| ~~GW13-12-0001F~~ | | | ~~GW~~ | ~~X~~ | | ~~1~~ | ~~Filter on Receipt~~ |
| ~~GW13-13-0001~~ | | | ~~GW~~ | ~~X~~ | | ~~1~~ | |
| ~~GW13-13-0001F~~ | | | ~~GW~~ | ~~X~~ | | 1 | ~~Filter on Receipt~~ |
| ~~GW13-14-0001~~ | | | ~~GW~~ | ~~X~~ | | ~~1~~ | |
| ~~GW13-14-0001F~~ | | | ~~GW~~ | ~~X~~ | | ~~1~~ | ~~Filter on Receipt~~ |
| MW13-01-0001 | 3/25/13 | 0950 | GW | X | | ~~1~~ | 1 |
| MW13-01-0001F | 3/25/13 | 0950 | GW | X | | 1 | Filter on Receipt |
| | | | | | TOTAL NUMBER OF CONTAINERS | ~~33~~ 2 | |

JMS 3/26/13

| Signatures | | Date/Time | Shipping Details | Special Instructions: |
|---|---|---|---|---|
| Sampled by | | | Method of shipment: | |
| Relinquished by | Roger D Lovell | 3-26-13/1730 | Shipping Company: | Report Copy to: |
| Received by | Bobbi Benedict | 3/27/13 1050 | On ice: yes / no: | Ruth Siegmund |
| Relinquished by | | | Airbill No.: | ruth.siegmund@e2.com |
| Received by | | | Shipping Date: | |

E2 Consulting Engineers, Inc.

CHAIN OF CUSTODY RECORD: UHGW_V001 1300229

2013 March Groundwater

Project Name: United Heckathorn

Project Number: 43378

Project Manager:

Sample Manager:

Cell Number:

Fax/Email:

Container: 1 L Amber Glass

Preservatives: 4C (+-2C)

Filtered: n

Holding Time: 7 Days

Ship To:
Vista Analytical Laboratory
1104 Windfield Way
El Dorado Hills, CA 95762
916-673-1520
Sample Receiving

| SAMPLE ID | DATE | TIME | Matrix | Pesticides (E1699) | | Number of Containers | COMMENTS |
|---|---|---|---|---|---|---|---|
| MW13-03-0001 | 3/25/13 | 1530 | GW | X | | 3 | Additional volume for MS/MSD |
| MW13-03-0001F | 3/25/13 | 1530 | GW | X | | 3 | Filter on Receipt, Additional volume for MS/MSD |
| ~~GW13-EB-01~~ | | | ~~Water~~ | ~~X~~ | | ~~1~~ | |
| ~~GW13-EB-02~~ | | | ~~Water~~ | ~~X~~ | | ~~1~~ | |
| ~~GW13-EB-03~~ | | | ~~Water~~ | ~~X~~ | | ~~1~~ | |
| | | | | | | | |
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| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | TOTAL NUMBER OF CONTAINERS | ~~33~~ 6 | |

MS 3/26/13

| | Signatures | Date/Time |
|---|---|---|
| Sampled by | Roger D Lucid | 3-26-13/1730 |
| Relinquished by | | |
| Received by | Bettie Bonnaud | 3/27/13 1050 |
| Relinquished by | | |
| Received by | | |

Shipping Details

Method of shipment:

Shipping Company:

On ice: yes / no:

Airbill No.:

Shipping Date:

Special Instructions:

Report Copy to:
Ruth Siegmund
ruth.siegmund@e2.com

1300216

0.5°C

# E2 Consulting Engineers, Inc.

## CHAIN OF CUSTODY RECORD: UHGW_V001

2013 March Groundwater

Project Name: United Heckathorn
Project Number: 43378
Project Manager:
Sample Manager:
Cell Number:
Fax/Email:

| | |
|---|---|
| Container: | 1 L Amber Glass |
| Preservatives: | 4C (+-2C) |
| Filtered: | n |
| Holding Time | 7 Days |

| SAMPLE ID | DATE | TIME | Matrix | Pesticides (E1699) | Number of Containers | COMMENTS |
|---|---|---|---|---|---|---|
| GW13-05-0001 | 3/21/13 | 1200 | GW | X | 1 | |
| GW13-05-0001F | 3/21/13 | 1200 | GW | X | 1 | Filter on Receipt |
| GW13-06-0001 | 3/21/13 | 1334 | GW | X | 1 | |
| GW13-06-0001F | 3/21/13 | 1334 | GW | X | 1 | Filter on Receipt |
| GW13-07-0001 | | | GW | X | 1 | |
| GW13-07-0001F | | | GW | X | 1 | Filter on Receipt |
| GW13-93-0001 | | | GW | X | 1 | |
| GW13-93-0001F | | | GW | X | 1 | Filter on Receipt |
| GW13-08-0001 | | | GW | X | 1 | |
| GW13-08-0001F | | | GW | X | 1 | Filter on Receipt |
| GW13-09-0001 | | | GW | X | 1 | |
| GW13-09-0001F | | | GW | X | 1 | Filter on Receipt |
| | | | | TOTAL NUMBER OF CONTAINERS | 33 → 4 | |

J Frank 3/21/13

Ship To:
Vista Analytical Laboratory
1104 Windfield Way
El Dorado Hills, CA 95762
916-673-1520
Sample Receiving

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | Jannine Frank | 3/21/13 1700 |
| Received by | | |
| Relinquished by | Kathmar Benedict | 3/22/13 0935 |
| Received by | | |

**Shipping Details**

Method of shipment: fedex priority overnite
Shipping Company:
On ice: (yes) / no:
Airbill No.:
Shipping Date: 3/21/13

**Special Instructions:**

Report Copy to:
Ruth Siegmund
ruth.siegmund@e2.com

# 1300221 0.9°C 2.1°C 0.8°C

**E2 Consulting Engineers, Inc.**

## CHAIN OF CUSTODY RECORD: UHGW_V001

**2013 March Groundwater**

Project Name: United Heckathorn
Project Number: 43378
Project Manager:
Sample Manager:
Cell Number:
Fax/Email:

| SAMPLE ID | DATE | TIME | Matrix | Container: 1 L Amber Glass; Preservatives: 4C (+-2C); Filtered: n; Holding Time: 7 Days; Pesticides (E1699) | Number of Containers | COMMENTS |
|---|---|---|---|---|---|---|
| ~~GW13-05-0001~~ | | | GW | | 1 | |
| ~~GW13-05-0001F~~ | | | GW | X | 1 | Filter on Receipt |
| ~~GW13-06-0001~~ | | | GW | | 1 | |
| ~~GW13-06-0001F~~ | | | GW | X | 1 | Filter on Receipt |
| GW13-07-0001 | 3/22/13 | 0745 | GW | X | 1 | |
| GW13-07-0001F | 3/22/13 | 0745 | GW | X | 1 | Filter on Receipt |
| GW13-93-0001 | 3/22/13 | 0815 | GW | X | 1 | |
| GW13-93-0001F | 3/22/13 | 0815 | GW | X | 1 | Filter on Receipt |
| GW13-08-0001 | 3/22/13 | 1030 | GW | X | 1 | |
| GW13-08-0001F | 3/22/13 | 1030 | GW | X | 1 | Filter on Receipt |
| GW13-09-0001 | 3/22/13 | 0145 | GW | X | 1 | |
| GW13-09-0001F | 3/22/13 | 0145 | GW | X | 1 | Filter on Receipt |
| | | | | TOTAL NUMBER OF CONTAINERS | 33 / 8 | |

Ship To:
Vista Analytical Laboratory
1104 Windfield Way
El Dorado Hills, CA 95762
916-673-1520
Sample Receiving

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | Roger D Hunt | 3-22-13/1730 |
| Received by | | |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment:
Shipping Company:
On ice: yes / no:
Airbill No.:
Shipping Date:

**Special Instructions:**

Report Copy to:
Ruth Siegmund
ruth.siegmund@e2.com

#1300221 0.9°C 2.1°C 0.8°C

# E2 Consulting Engineers, Inc.

## CHAIN OF CUSTODY RECORD: UHGW_V001

2013 March Groundwater

Project Name: United Heckathorn
Project Number: 43378
Project Manager:
Sample Manager:
Cell Number:
Fax/Email:

Container: 1 L Amber Glass
Preservatives: 4C (+-2C)
Filtered: n
Holding Time: 7 Days

Ship To:
Vista Analytical Laboratory
1104 Windfield Way
El Dorado Hills, CA 95762
916-673-1520
Sample Receiving

| SAMPLE ID | DATE | TIME | Matrix | Pesticides (E1699) | Number of Containers | COMMENTS |
|---|---|---|---|---|---|---|
| GW13-10-0001 | 3/22/13 | 1210 | GW | X | 1 | |
| GW13-10-0001F | 3/22/13 | 1210 | GW | X | 1 | Filter on Receipt |
| GW13-11-0001 | 3/22/13 | 1245 | GW | X | 1 | |
| GW13-11-0001F | 3/22/13 | 1245 | GW | X | 1 | Filter on Receipt |
| GW13-12-0001 | 3/22/13 | 1330 | GW | X | 1 | |
| GW13-12-0001F | 3/22/13 | 1330 | GW | X | 1 | Filter on Receipt |
| GW13-13-0001 | 3/22/13 | 1115 | GW | X | 1 | |
| GW13-13-0001F | 3/22/13 | 1115 | GW | X | 1 | Filter on Receipt |
| GW13-14-0001 | 3/22/13 | 1030 | GW | X | 1 | |
| GW13-14-0001F | 3/22/13 | 1030 | GW | X | 1 | Filter on Receipt |
| ~~MW13-01-0001~~ | | | ~~GW~~ | ~~X~~ | 1 | |
| ~~MW13-01-0001F~~ | | | ~~GW~~ | ~~X~~ | 1 | Filter on Receipt |
| | | | | TOTAL NUMBER OF CONTAINERS | 33 10 | |

| | Signatures | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | [signature] | 3-22-13/1730 |
| Received by | | |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment:
Shipping Company:
On ice: yes / no:
Airbill No.:
Shipping Date:

**Special Instructions:**

Report Copy to:
Ruth Siegmund
ruth.siegmund@e2.com

# E2 Consulting Engineers, Inc.

**CHAIN OF CUSTODY RECORD: UHGW_V001**

**2013 March Groundwater**

1300209

0.6°C

| | |
|---|---|
| Project Name: United Heckathorn | Container: 1 L Amber Glass |
| | Preservatives: 4C (+-2C) |
| Project Number: 43378 | |
| Project Manager: | Filtered: n |
| Sample Manager: | Holding Time 7 Days |
| Cell Number: | |
| Fax/Email: | |

| SAMPLE ID | DATE | TIME | Matrix | Pesticides (E1699) | | Number of Containers | COMMENTS |
|---|---|---|---|---|---|---|---|
| ~~MW13-03-0001~~ | | | GW | X | TF 3/20/13 | 3 | Additional volume for MS/MSD |
| ~~MW13-03-0001F~~ | | | GW | X | | 3 | Filter on Receipt, Additional volume for MS/MSD |
| GW13-EB-01 | 3.18.13 | 1630 | Water | X | | 1 | |
| GW13-EB-02 | 3.19.13 | 1700 | Water | X | | 1 | |
| ~~GW13-EB-03~~ | | | Water | X | TF 3/20/13 | 1 | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
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| | | | | | | | |
| | | | | | | | |
| | | | | | TOTAL NUMBER OF CONTAINERS | 33 | |

Ship To:
Vista Analytical Laboratory
1104 Windfield Way
El Dorado Hills, CA 95762
916-673-1520
Sample Receiving

2

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | [signature] | 3/21/13 1600 |
| Received by | [signature] FedEx Priority | 3/21/13 0908 |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment: priority overnight
Shipping Company: fedex
On ice: (yes) / no:
Airbill No.:
Shipping Date:

**Special Instructions:**

Report Copy to:
Ruth Siegmund
ruth.siegmund@e2.com

#1300221 0.9°C 2.1°C 0.8°C

# E2 Consulting Engineers, Inc.

## CHAIN OF CUSTODY RECORD: UHGW_V001

2013 March Groundwater

Project Name: United Heckathorn
Project Number: 43378
Project Manager:
Sample Manager:
Cell Number:
Fax/Email:

Container: 1 L Amber Glass
Preservatives: 4C (+-2C)
Filtered: n
Holding Time: 7 Days

Ship To:
Vista Analytical Laboratory
1104 Windfield Way
El Dorado Hills, CA 95762
916-673-1520
Sample Receiving

| SAMPLE ID | DATE | TIME | Matrix | Pesticides (E1699) | Number of Containers | COMMENTS |
|---|---|---|---|---|---|---|
| ~~MW13-03-0001~~ | | | GW | X | ~~3~~ | Additional volume for MS/MSD |
| ~~MW13-03-0001F~~ | | | GW | X | ~~3~~ | Filter on Receipt, Additional volume for MS/MSD |
| ~~GW13-EB-01~~ | | | Water | X | ~~1~~ | |
| ~~GW13-EB-02~~ | | | Water | X | ~~1~~ | |
| GW13-EB-03 | | | Water | X | ~~1~~ | |
| GW13-EB-03 | 3-20-13 | 1730 | Water | X | 8 | |
| GW13-EB-04 | 3-21-13 | 1700 | Water | X | 1 | |
| GW13-EB-05 | 3-22-13 | 1400 | Water | X | 1 | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | TOTAL NUMBER OF CONTAINERS | 33 | |

3

| Signatures | | Date/Time |
|---|---|---|
| Sampled by | | |
| Relinquished by | [signature] | 3-22-13/1730 |
| Received by | | |
| Relinquished by | | |
| Received by | | |

**Shipping Details**

Method of shipment:
Shipping Company:
On ice: yes / no:
Airbill No.:
Shipping Date:

**Special Instructions:**

Report Copy to:
Ruth Siegmund
ruth.siegmund@e2.com

# Summary of Field Activities
# Tier 1 Sediment Transport Study
# United Heckathorn Superfund Site, Richmond, California

PREPARED FOR: United States Environmental Protection Agency
Region 9

PREPARED BY: CH2M HILL

DATE: January 4, 2013

PROJECT NUMBER: USEPA CONTRACT NO. EP-S9-08-04
USEPA WORK ASSIGNMENT NO. 025-RIFS-09R3
CH2M HILL PROJECT NO. 385441

## Background

In December 2012, high-resolution multibeam bathymetric and side-scan sonar surveys were performed at the United Heckathorn Site in Richmond, California in accordance with the *Preliminary Draft Tier 1 Sediment Transport Study Sampling and Analysis Plan* (SAP) (CH2M HILL, 2012). The results of the surveys will be incorporated into the Tier 1 Sediment Transport Study.

## Survey Activities

Bathymetric and side-scan sonar surveys were conducted in the Lauritzen Channel and a portion of the Santa Fe Channel (near the mouth of the Lauritzen Channel). Mr. Ken Israel and Mr. Mike Stecher of Sea Engineering, Inc. (SEI) mobilized to the site on December 3, 2012 to prepare the survey vessel and set up the real-time kinematic global positioning system (RTK GPS) base station for the survey. The base station was set up at the Auto Warehouse location (identified as BM1) following approval from Mr. Michael Williams at the Port of Richmond, and Mr. Jeremy Maxwell, the Operations Manager at the Auto Warehousing Company in Richmond, California. SEI met with CH2M HILL on December 4, 2012 to conduct the surveys. The weather on the day of the survey was overcast and the water within the Lauritzen Channel was calm. No vessels were present in any of the Levin-Richmond Terminal Corporation berths on the eastern side of the Lauritzen Channel. Additionally, Manson Construction Co. had moved all but a few barges from the western side of the Lauritzen Channel. A photographic log of the field activities is provided in Attachment 1.

The survey vessel was a 25-foot diesel, jet-propelled, aluminum-hulled boat owned by SEI. The survey equipment was pole-mounted on the survey vessel. Both surveys used high-accuracy, dual frequency, real-time kinematic GPS (RTK-GPS) for precise horizontal and vertical positioning (accuracy within a few centimeters, which is the current limit of the RTK-GPS positioning technology).

### *Bathymetric Survey*

The high-resolution multibeam bathymetric survey was conducted to define detailed bathymetric contours and morphology of the bed surface. The survey was run along the shore-parallel depth contours, progressing in an offshore to onshore direction with each pass.

Sonar equipment was comprised of a high-frequency, high-resolution multi-beam Reson 7125 sonar with wide swath width (approximately 160 degrees). The sonar was paired with a POS MV Wavemaster motion reference unit (MRU) which measured vessel motion (pitch, roll, heave) and heading, and an RTK-GPS. An Odom Digibar Pro sound velocitysensor was used to measure the speed of sound in the water column during the surveying for proper correction of acoustic signals. The surveys were performed in accordance with the U.S. Army Corps of Engineers Hydrographic Surveying manual, EM 1110-2-1003 (USACE, 2004). Bathymetric elevations were surveyed to accuracies of less than 0.2 feet in the vertical and horizontal.

### *Side-Scan Sonar Survey*

A dual-frequency side-scan sonar survey was performed to provide an aerial view of the channel bottom relief, and allow identification of flat bottom areas and debris. Transects provided 200 percent bottom coverage to ensure the best possible mosaic of all side scan imagery in the survey area.

A dual-frequency CMAX CM2 side-scan sonar was used to conduct the survey. The CM2 is a 325/780 kHz sonar with user-selectable swath ranges up to 150 meters per side. The towfish was pulled behind the vessel by a cable secured through an onboard davit.

## Findings

The results of the surveys will be presented in January 2013 as a supplement to this memo. The survey information will be used in the Tier 1 Sediment Transport study.

## References

CH2M HILL. 2012. *Preliminary Draft. Preliminary Draft Tier 1 Sediment Transport Study Sampling and Analysis Plan, United Heckathorn Superfund Site, Richmond, California.* November.

United States Army Corps of Engineers (USACE). 2004. Hydrographic Surveying. EM 1110 2-1003 31. April. Online: http://140.194.76.129/publications/eng-manuals/EM_1110-2-1003_pfl/toc.htm

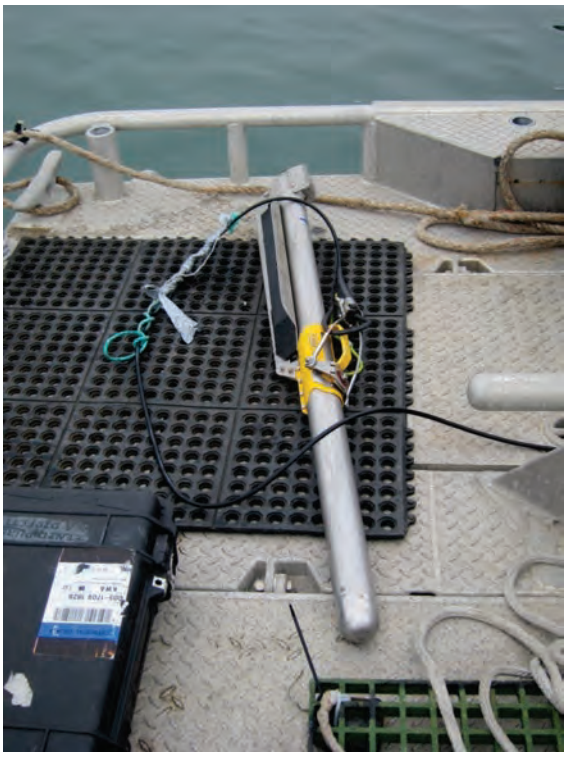
# Attachment 1
# Photograph Log

Photograph 1: View of SEI's survey boat.

Photograph 2: View of SEI attaching GPS unit to multibeam survey equipment.

Photograph 3: View of SEI lowering side-scan survey equipment into the channel.

Photograph 4: View of RTK-GPS unit on boat.



Photograph 4: View of side-scan survey equipment on boat.

Photograph 5: View of multibeam survey equipment in water

# Appendix D
# Tier 1 and Tier 2 Sediment Transport Studies

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D-1 United Heckathorn Superfund Site: Tier 1 Sediment Transport Study

D-2 United Heckathorn Superfund Site: Tier 2 Sediment Transport Study

# United Heckathorn Superfund Site:
# Tier 1 Sediment Transport Study

**April 2013**

Prepared for:
CH2M HILL

Prepared by:
Sea Engineering, Inc.
200 Washington Street, Suite 210
Santa Cruz, CA 95060
Tel: (831) 421-0871
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# *Introduction*

The United Heckathorn Superfund Site is located in Richmond Harbor on the east side of San Francisco Bay in Contra Costa County, California (Figure 1). From the mid-1940s to the mid-1960s, the site was used for processing, packaging and shipping pesticides. Although many types of pesticides were processed on the site, DDT[1] and Dieldrin are the primary contaminants of concern. The remedy selected for the marine portion of the site in the 1994 Record of Decision (USEPA, 1994) consisted of dredging sediment from the Lauritzen Channel and Parr Canal, followed by at least five years of post-remediation monitoring. The remedy for the upland part of the site included capping and institutional controls. The remedies for the marine and upland portions of the site were completed in 1997 and 1999, respectively. Post-remediation monitoring data indicate that sediments in the Lauritzen Channel have been recontaminated by DDT and Dieldrin (Antrim and Kohn, 2000; Anderson et al., 2000). A focused feasibility study (FFS) is planned to address residual contamination in the channel sediments.

A study of sediment dynamics in the Lauritzen Channel is being performed because (1) sediment has accumulated in the channel since the remedy was completed; (2) surface and subsurface sediment DDT concentrations are above the remediation goal; (3) the source(s) of the sediment and sediment-associated contamination have not been definitively identified; and (4) additional cleanup cannot occur until any active, ongoing source(s) are controlled.

It is not clear whether the sediments that have accumulated in the channel since 1997 were already contaminated (i.e., sediments from undredged areas that have been resuspended and redistributed throughout the channel), or whether they were transported into and deposited in the channel and subsequently contaminated by an ongoing local or far-field source, or whether both processes have occurred. Additionally, the amounts of sediment and sediment-associated DDT that are being transported into and out of the Lauritzen Channel and redistributed within the Lauritzen Channel are not known. A sediment transport analysis is necessary to understand the present distribution of contaminants in the channel.

The sediment transport analysis is being performed using a phased (tiered) approach as described in the U.S. Navy's *User's Guide for Assessing Sediment Transport at Navy Facilities* (Blake et al., 2007). In a Tier 1 study, sediment transport is assessed using basic site characterization data (e.g. bathymetric surveys, tidal ranges, sediment contaminant data) and analyses to address sediment management questions. A Tier 1 evaluation has relatively fewer data needs, a shorter time frame, and a higher level of uncertainty than a Tier 2 evaluation. A Tier 2 study focuses on collection of site-specific data and more refined data analyses, which may include use of analytical and numerical methods. Both Tier 1 and Tier 2 studies are being performed for the United Heckathorn site.

This document presents the results of the Tier 1 sediment transport study and the recommended scope and approach for the Tier 2 study. The results of the Tier 1 and Tier 2 studies will be evaluated in conjunction with the results of the source identification study and DDT fate and transport evaluation, long-term monitoring data, and data from previous investigations to refine the conceptual site model (CSM) for the site and support the development of remedial alternatives in the FFS.

[1] (dichlorodiphenyltrichloroethane; for the purposes of this report, "DDT" refers to the sum of all 4,4'- and 2,4'- isomers of DDT, DDD, and DDE. Dieldrin is present at lower concentrations but co-occurs with DDT; therefore, the report focuses on DDT.

The primary goals of the sediment transport study are to address the following sediment management questions:

- What is the source(s) of the sediment accumulating in the Lauritzen Channel?
- How does sediment transport lead to the redistribution of contamination within the Lauritzen Channel, or movement of contamination out of the channel?
- If part of the Lauritzen Channel is actively remediated, could sediment transport lead to the recontamination of the remediated area?

Due to the complexity of the processes affecting the sediment and contaminant transport in the Lauritzen Channel, multiple lines of evidence will be evaluated to fully address the management questions. The Tier 1 sediment transport study will characterize the sediment erosion/resuspension and transport processes in Lauritzen Channel as follows:

- Estimate the residence time of water within the Lauritzen Channel
- Determine tidal transport and tidal velocities
- Document the types of vessels that cause scour and determine the approximate area(s) affected by scour
- Determine whether outfall discharges are sufficient to scour sediments at the north end of the Lauritzen Channel
- Determine the relative significance of physical transport processes at the site (vessel activity, tidal currents, dredging, waves, stormwater discharge)
- Develop a conceptual sediment budget for the Lauritzen Channel.

The Tier 1 evaluation uses data from previous investigations at the United Heckathorn site and other publicly-available sources. Additionally, high resolution multibeam bathymetric and side scan sonar surveys were performed in accordance with the *Tier 1 Sediment Transport Sampling and Analysis Plan for the United Heckathorn Superfund Site* (CH2M HILL and Sea Engineering Inc., 2013). This report is organized as follows:

- Tier 1 evaluation
- Sediment transport CSM, including the relative significance of physical transport processes and a conceptual sediment budget
- Sediment management questions
- Conclusions and recommendations for the Tier 2 evaluation.

# *Tier 1 Evaluation*

## *Site Description*

The Lauritzen Channel is a tidal waterway inside the Richmond Harbor on the eastern shoreline of central San Francisco Bay. The Lauritzen Channel is a single spur inside the Richmond Harbor off of the Santa Fe Channel (Figure 2 and Figure 3). The harbor was originally intertidal marsh that was dredged and filled in the 1920s to provide a deepwater berthing area for commercial and private vessels (White et al., 1994). An extensive offshore breakwater provides protection from waves generated in the central San Francisco Bay and beyond. The tidal range in the harbor is approximately -0.6 to 2.1 m Mean Lower Low Water (MLLW). The shorelines of the harbor are generally armored with rip-rap, sandy gravel fill, or pile-supported structures (White et al., 1994). The upland regions surrounding the harbor are generally level and at heights of 2.1 to 3.3 m MLLW. The Lauritzen Channel is approximately 0.5 km long and 40 m wide at the head widening to over 100 m at the mouth. The depths in the channel range from 3 to 12 m MLLW (Figure 2). Presently Manson Construction Company occupies the western shoreline and the Levin Richmond Terminal occupies the eastern shoreline.

The most recent maintenance dredging of the Lauritzen Channel occurred in 1985. Between August 1996 and 1997, approximately 107,945 cubic yards of total sediment were removed from the Lauritzen Channel and the Parr Canal during remediation activities. Of the total amount, 105,325 cubic yards were removed from the Lauritzen Channel. The sediment was disposed of offsite at designated disposal facilities. Clean sand was placed to a nominal thickness of 6 inches over dredged portions of the Lauritzen Channel to facilitate colonization by benthic organisms (Chemical Waste Management Inc., 1997). A thicker layer of sand (approximately 18 inches) was reportedly placed in inaccessible areas that were impractical to dredge (i.e., areas with pilings). No sand was placed underneath the Levin pier because the slope was too steep to hold sand. The sand was hydraulically pumped from a barge into the channel. A bathymetric survey was performed after sand placement was completed; however, the distribution and thickness of the sand layer do not appear to have been verified. No other dredging activities have been conducted in the Lauritzen Channel since 1997 (EPA, 2012).

A recent site survey documented a number of small outfall pipes on the banks of the Lauritzen Channel (Figure 3). One 1.5 m diameter concrete culvert at the northern end of the channel is a City of Richmond municipal outfall that provides the primary storm drainage from the surrounding area into the channel (Figure 3) (CH2M HILL, 2012). Stormwater runoff from the upland remediated area of the United Heckathorn site is monitored and discharged to City of Richmond publicly-owned treatment works (POTW). In October 2012, EPA installed a flap gate on the municipal outfall at the head of the channel to prevent DDT-contaminated sediment from moving into the storm drain system during high tide.

## *Bathymetry and Bottom Features*

In 2012, Sea Engineering, Inc. conducted high resolution multibeam bathymetric surveys and sidescan sonar surveys to characterize the present state of the bottom sediment in the Lauritzen Channel. Figure 2 shows the results of the bathymetric survey. The survey clearly shows the extents of the dredged channel adjacent to the Levin terminal (Berths B and C), the shallower regions at the head of the channel, and the deeper dredged channels in the Santa Fe Channel with the deepest area on the south side of the Levin terminal (Berth A) to accommodate the largest ships in this portion of the Santa

Fe Channel. The side scan sonar survey map (Figure 4) shows acoustic imagery of the bottom, which shows hard structures, sediment characteristics, and other features.

The bathymetric and side scan sonar surveys reveal features that form in response to processes occurring at the channel bottom. For example, generally smooth, featureless sediment beds are indicative of a depositional environment where sediments are steadily accumulating in a pattern where sediment essentially "snows" down, creating a smooth surface. Alternatively, a rippled pattern at the bottom can be indicative of an active sediment transport environment.

The major features evident in the Lauritzen and Santa Fe Channels are the dredged channels and square regions reflecting different depths of dredging. Starting at the head of the Lauritzen Channel, the bottom appears generally smooth punctuated near the shorelines by some abnormal "hard" features that are likely due to shoreline debris, piers, and other structures. Of particular note in the upper channel is a single linear feature from north to south that resembles a furrow. This type of feature is typically the result of scour by a vessel propeller (i.e. prop scour) or the keel of a vessel dragging along the bottom. Further south in the channel, these linear furrow features become more evident, particularly in the deeper dredged channel. In the region of higher ship and associated tug activity near the Manson Construction and Levin facilities, there are more scour features. Of additional note are the "crater" features near the Manson facility. When Manson brings large crane barges into this area, the large vertical spuds are dropped into the sediment to anchor the barges in place. The craters are the bottom expression due to these spuds. Figure 5 provides delineation of these features by type. The effects of these processes on sediment fate and transport are discussed later in the report.

## *Sediment Properties*

In general, sedimentologists define two types of native sediments in the San Francisco Bay: Younger Bay Mud (YBM) and Older Bay Mud (OBM). YBM is more recent sediment that has been deposited since the onset of the industrial age and hydraulic mining in the 19th century that was responsible for a large influx of sediment to the entire San Francisco Bay. The YBM has a high water content (low consolidation) and a high clay and silt content. The OBM is older sediment often underlying the YBM. The OBM is highly consolidated, has a low water content, and is comprised of primarily silt, silty sand, and clay with some gravel. Generally, the OBM is not contaminated (White et al., 1994). Table 1 summarizes the physical properties of the YBM and OBM in the Richmond Harbor region as measured in the remedial investigation (RI) (White et al., 1994). Figure 6 shows the distribution of mud (combination of silt and clay size fractions) and sand in surface samples taken in 1999 and 2003, after the remedy was completed (Kohn and Gilmore, 2001; Kohn and Evans, 2004). The samples show that the surface sediment is mud-dominated with six samples containing over 50% sand. These data show that the overall composition of sediment in the Lauritzen Channel is similar to the pre-remedial conditions.

When assessing sediment properties in regions comprised primarily of fine sediment it is important to consider fluid mud. When a region has low density fine sediment, such as the YBM in the Lauritzen Channel, it is possible for fluid mud to exist. Fluid mud is unconsolidated material that can move with any movement of the overlying water, potentially leading to frequent high-volume sediment transport. Although fluid muds are not common in environments such as Richmond Harbor, the U.S. Army Corps of Engineers (USACE) conducted an investigation to verify that fluid mud was not present (Welp, 2005). This assessment indicated “soft” bottom conditions in several areas; however, no typical fluid mud characteristics were found. The USACE concluded that it is highly unlikely that fluid mud existed in the Lauritzen Channel during the study.

**Table 1. Sediment property summary (data from White et al., 1994).**

| Location | Mean %TOC | Mean %Solids | Mean %Gravel | Mean %Sand | Mean %Silt | Mean %Clay |
|---|---|---|---|---|---|---|
| Lauritzen Channel (YBM) | 1.91 | 49 | 6 | 26 | 25 | 42 |
| Santa Fe Channel (YBM) | 1.14 | 47 | 2 | 11 | 28 | 59 |
| Inner Harbor (YBM) | 1.14 | 45 | 0 | 5 | 32 | 62 |
| Parr Canal (YBM) | 5.19 | 45 | 4 | 24 | 27 | 34 |
| Lauritzen Channel (OBM) | 0.12 | 80 | 8 | 42 | 31 | 20 |
| Santa Fe Channel (OBM) | 0.23 | 77 | 1 | 30 | 37 | 32 |
| Inner Harbor (OBM) | 0.21 | 76 | 5 | 16 | 41 | 38 |

## *Sediment Accumulation*

The USACE conducted an extensive dual-frequency hydrographic survey in the Lauritzen Channel to map sediment density distributions (Welp, 2005). By means of this survey, maps of YBM thickness were developed (Figure 7). The thickness of the YBM varied from less than 0.3 m to 2.5 m, with an average of 1.5 m. The thickest YBM was in the deep dredged channel adjacent to the Levin terminal while the shallower regions of the channel had relatively thin YBM layers. As the YBM layer represents more recent deposits of sediment, the map of thicknesses suggests that the dredged channel adjacent to the Levin terminal is the region of highest sediment accumulation in the channel, followed by the head of the channel as the second highest area of accumulation, and the areas adjacent to Manson Construction as the areas of lowest sediment accumulation.

The sand layer that was placed in the channel after remedial dredging was completed in 1997 potentially could serve as a marker layer to determine the amount of sediment that has accumulated since 1997. However, the sand layer was evident in only 3 of 25 cores collected in 1999 and 12 of 21 cores collected in 2007 (Kohn and Gilmore, 2001; CH2M HILL, 2008). Figure 8 shows the thickness of YBM at the 2007 coring locations; a yellow bar indicates locations where sand was found in the sediment core profile. The patchy distribution of the sand layer suggests some combination of heterogeneous placement of the sand and other sediment bed processes that could be responsible for mixing the sediment bed both vertically and laterally. It should also be noted that the sand identified at some locations in the 2007 sampling was associated with shell hash and may not be a result of the remedial activities.

The most recent bathymetric survey conducted in the Lauritzen Channel prior to the 2012 survey was in 2007. These surveys were conducted using a lower resolution single beam surveying system, and supporting detailed information regarding the survey procedures (e.g. survey equipment, benchmarks) is not available. However, a gross comparison of bathymetric change was conducted to ascertain large changes in sediment bed elevation. Although the same vertical datum (MLLW) is referenced in both surveys, there is uncertainty regarding the benchmarks and accuracy of the 2007 survey compared to the 2012 survey. Therefore, there is unquantified uncertainty in the bathymetric comparison. Figure 9 shows the changes in the channel bed elevation. Overall sediment accumulation is seen in the deep dredged channel near the Levin terminal. The shallower regions adjacent to the Manson facility show apparent sediment erosion. The head of the channel generally exhibits sediment accumulation with

some regions of erosion. Given the lack of quantifiable uncertainty, this comparison should be considered qualitative only.

## *Tidal Hydrodynamics*

The Lauritzen and Santa Fe Channels are manmade features designed to provide low energy environments for vessel berthing. The region is further protected from San Francisco Bay by an extensive offshore breakwater designed to block any waves into the area. In low energy protected harbors such as this, regional sediments tend to accumulate in the dredged channels. The deeper dredged channels in Richmond Harbor overall have historically required periodic dredging due to the generally depositional environment.

The Lauritzen Channel is dominated by the tidal hydrodynamics of San Francisco Bay. The region experiences a semi-diurnal tide from the Pacific Ocean. The tide generally results in two high and two low tides per day with a dominant tidal period of 12.42 hours. Figure 10 shows an example of the local semi-diurnal tides. The average yearly tidal range in the harbor is approximately -0.6 to 2.1 m MLLW. Wave activity in the channel is negligible due to the offshore protection. Additionally, the narrow nature of the channels and relatively deep water negate the effects of any wave generation within the channels on hydrodynamics or sediment transport. The characteristics of the channels support the tidal dominance on circulation in the Channel.

### *Residence Time*

Determining the movement of water particles and their residence times in a tidal system can be calculated using a few characteristic values. The residence time is the most basic calculation. The residence time (τ) is the length of time that a water parcel in the system will remain in the system. This can be calculated as:

$$\tau = \frac{P + V}{P} * T$$

Where V is the total system volume, P is the tidal prism, and T is the tidal period. The total volume of water in the Lauritzen Channel at MLLW is 277,406 $m^3$. The tidal prism between MLLW and mean higher high water (MHHW) is 74,138 $m^3$. Given a tidal period of 12.42 hrs, the residence time in the Channel is 59 hrs. This indicates that a parcel of water could remain in the Channel for approximately 2.5 days before being exchanged. For a small channel such as the Lauritzen, this is a fairly long residence time and the Channel could be considered to have low circulation.

### *Tidal Transport and Tidal Velocities*

Given the cross sectional area at the mouth of the channel and the tidal prism, the maximum tidal velocity in the Lauritzen Channel can be calculated. Figure 11 shows the tidal flow rate at the Lauritzen Channel mouth required to transport the tidal prism during one tidal exchange. By dividing the maximum flow rate by the channel area, an average maximum velocity of approximately 1 cm/s can be calculated. Locally higher velocities can be driven by currents in the Santa Fe Channel and/or by abrupt changes in bathymetry; however, the basic analysis suggests that velocities are very low in the Lauritzen Channel.

The potential for sediment erosion and deposition can be evaluated using the velocities calculated above. To describe these processes, we use the shear stress in units of Pascals (Pa). The shear stress generated by water flowing over the sediment surface can be determined from the maximum water velocity. The critical shear stresses for erosion and deposition are the common parameters used to determine when the sediment particles are capable of eroding from or depositing to the sediment bed. When the critical shear stress for erosion is exceeded, particles erode and when the shear stress is lower than the critical shear stress for deposition, particles deposit.

For fine silt and clay such as the sediment in the Lauritzen Channel, a common screening value of 0.1 Pa is used for both the critical shear stress for erosion and deposition (Blake et al., 2007). A velocity of 1 cm/s generates a negligible shear stress; therefore, erosion due to the average tidal current is not expected. However, there is uncertainty on the potential for increased velocities in localized areas that can be investigated further in Tier 2 studies. Furthermore, the low tidal shear stresses would allow sediment particles transported into the region to settle out. The deposition rates would be particularly high in the deepest, lowest velocity areas. Combined with the long residence time (2.5 days) it is likely that particles transported into the Lauritzen Channel due to tides would have the opportunity to deposit in the channel. The low energy depositional environment is consistent with the need to periodically dredge other channelized regions in the Richmond Harbor.

## *Anthropogenic Processes*

The Lauritzen and Santa Fe Channels are active waterways with ship and barge berthing activities and therefore experience ongoing anthropogenic activities that have the potential to affect sediment transport patterns. Additionally, anecdotal information from local vessel operators suggests that tugs pushing on barges and ships in the Lauritzen Channel provide ample scouring to prevent sediment accumulation beyond navigable depths. The key processes that will be considered here are vessel operations and outfalls. These processes are evaluated qualitatively in this Tier 1 analysis, which will be used for the basis of the design for the Tier 2 study.

### *Propeller Scour*

The present description of vessel activity is based upon conversations with vessel and terminal operators in the area and anecdotal observations. The most common large bulk carrier vessels into the Lauritzen Channel are of the Handysize design between 40,000 and 55,000 Deadweight Tons (dwt) going to the Levin facility. The typical vessel docks and departs with two tugs. The tugs are characterized as tractor tugs. On average there are less than 12 ships per year into Levin Berth B in the Lauritzen Channel. The Levin Berth A, located in the Santa Fe Channel, is used for Panamax vessels of approximately 70,000 dwt. Approximately three of these vessels are in Berth A per year. Manson Construction Company has its main San Francisco Bay berthing and staging facility on the west side of the Lauritzen Channel. Manson generally has on the order of 6 to 10 unpowered crane and construction barges anchored with spuds in the channel. These barges are moved with tugs in the 1000 hp class. The values presented herein will be further investigated.

The high resolution survey of the navigable regions of the channel clearly shows that the vessel activities in the channels disturb the sediment in the system. Figure 12 is a satellite photo of tug and barge activity in the mouth of the channel showing a large suspended solids plume due to sediment resuspension. Figure 13 shows the regions of sediment disturbance due to both vessel scour and anchoring spuds. While these activities take place over a large region of the Lauritzen Channel and

extend throughout the Santa Fe Channel, it is important to note that the effects of both the scouring and anchoring spuds are discrete and localized. Figure 13 shows a number of profiles across some of the key features to provide some information about their dimensions. It is likely that the wide linear features are either direct scour from the large ship propellers or keel drags. A keel drag is possible for the largest scour features as the typical design draft of the Handysize ships (~ 11 m) is essentially equivalent to the scour depths. These features are on the order of 3 to 4.5 m in width and 30 cm or more in depth. There are only three to four distinct scour features, which is consistent with the relatively low ship traffic to the Levin Berth B. The smaller linear scar features often come in pairs consistent with two propellers on the typical tug used for these operations. These features are commonly less than a 1 m in width and on the order of 3 cm in depth. These observations are consistent with prop scour studies at other sites (Blake et al., 2007). The anchor spuds have a localized effect near the Manson facilities. The profiles through this area show that the zones of influence can be up to 2 m in diameter with a depth up to 0.5 m.

No evidence of scour features was seen in low tide shoreline visual surveys performed in December 2012 (CH2M HILL, 2012) or in the acoustic imagery. It is possible that the small amount of sediment present under the piers along the east shoreline and in the western shoreline areas could be resuspended by propeller scour; however, it is anticipated these volumes would be low in comparison to the sediment resuspended directly below the vessel activity.

It is evident that vessel scour and anchoring activities have a widespread and significant effect on the sediment in the Lauritzen Channel. The depths of the anthropogenically-induced mixing seen in the multibeam survey extend up to 1.4 m in depth and 5 m in width for individual events. With each individual event, the resuspended sediment over that depth has the potential to be transported before depositing. The low tidal circulation in the channel suggests that most of the sediment resuspended would disperse locally and likely settle within the channel; however, some dispersion and transport out of the Lauritzen Channel to the Santa Fe Channel is possible, particularly from the southern end of the Lauritzen Channel. The net effect of these activities is a high degree of vertical mixing of the sediment, high local dispersion, and low far-field dispersion of sediment resuspended during vessel activities.

This assessment of sediment disturbance does not take into account anecdotal accounts of intentional vessel operation to inhibit sediment accumulation through scouring which would necessarily be comprised of widespread scour and erosion. The qualitative bathymetric changes presented in Figure 9 would suggest that while the deeper east side of the channel and head of the channel is showing normal sediment accumulation, the west side of the channel could be undergoing a continuing scour due to the net effect of vessel activities.

## *Outfall Discharges*

Outfall discharges are another anthropogenic process that could potentially affect sediment transport. The outfalls located around the perimeter of the Lauritzen Channel are generally inactive and are anticipated to have low flow rates during wet weather (CH2M HILL, 2012). The City of Richmond municipal outfall at the head of the channel, which has the largest wet weather flow rate, is a potential source of localized scour. However, examination of the geophysical survey data showed no change in morphology that typically indicates scoured sediment near the outfall. Additionally, the side scan reveals no change in sediment texture that would be associated with ongoing, episodic scour.

# *Sediment Transport Conceptual Site Model*

A site characterization describes the physical, biological, and chemical processes at a site. The processes associated with the contaminant fate and transport are integrated and synthesized into a CSM. Development of a CSM is a fundamental step in developing a comprehensive understanding of contaminant fate and transport. At the Lauritzen Channel, where sediment-bound contaminants are the key risk factor, a sediment transport CSM is critical to addressing sediment management questions. The sediment transport CSM synthesizes all available data, describes a mass balance (i.e., a simple representation of all inputs and outputs to a system), and describes inferred sediment transport patterns (areas of deposition and erosion) based on grain size distribution, contaminant distribution, and geomorphology. The sediment transport CSM for the Lauritzen Channel presented below represents the Tier 1 CSM based on available data and provides a qualitative description that will be further quantified in the Tier 2 studies.

## *Sediment Transport Process Summary*

The information presented in the previous sections provides individual lines of evidence regarding the behavior of the sediment in the Lauritzen Channel. This section summarizes the key points and develops a description of the general patterns of sediment transport based on the multiple lines of evidence presented.

In the absence of anthropogenic activity, the Lauritzen Channel is a low energy, constructed channel that is dominated by tidal circulation. The low tidal velocities in the channel limit any potential for sediment resuspension due to tidal currents. Generally, with the continuation of the San Francisco Bay as a primary sediment source, the channel on the whole is a sediment sink with the highest sediment accumulation occurring in the deep channel along the east side of the waterway. In the absence of anthropogenic activity, the channel would continue to fill until a dynamic equilibrium between the tides and sediment sources is achieved (Bearman et al., 2010).

The geophysical surveys show that vessel scour and spud anchoring activities have a widespread effect on mixing sediments up to 0.5 m in depth over wide swaths. It is also possible that the small amount of sediment available in under-pier and shoreline areas could be resuspended; however, these volumes would be low in comparison to the sediment resuspended directly below vessel activity. The low tidal circulation in the channel indicates that most of the sediment resuspended would disperse locally and likely settle within the channel; however, some dispersion and transport out of the Lauritzen Channel to the Santa Fe Channel is possible. It is surmised that the net effect of these activities is a high vertical mixing of the sediment, high local dispersion, and low far-field dispersion of sediment resuspended during vessel activities. The contaminant distribution pattern seen in the RI, which was characterized by over an order of magnitude decline in sediment DDT concentration with increasing distance from the Lauritzen Channel, is consistent with low net contaminant transport out of the channel (White et al., 1994).

The net effect of the vessel activity in the low energy depositional channel can be examined through two lines of evidence describing the sediment bed. Both the maps of YBM thickness (Figure 7) and bathymetric change (Figure 9) show the general accumulation behavior of sediment in the Lauritzen Channel. Both lines of evidence reveal that the largest amount of sediment accumulation is in the deepest area on the east side of the channel. The accumulation is occurring in the region where currents are likely the lowest, causing the dredged channel to behave locally as a sediment trap. Conversely, the

west side of the channel, which experiences high vessel activity in shallow regions, exhibits low to no sediment accumulation of YBM and potential erosion in the bathymetric change (Figure 9). Finally, the head of the channel with low energy shallow water and moderate barge activity shows a moderate YBM accumulation and a mix of potential erosion and deposition. Although each line of evidence has uncertainty associated with it, they are completely independent of each other and all express similar trends, thereby increasing the confidence in the overall pattern.

Since the remedial dredging and sand placement in 1996 and 1997, no dredging activities have been conducted in the Lauritzen Channel. Follow-on sampling in the channel revealed that the sand layer was not present in the majority of cores, including those where the YBM and OBM interface was present. The sampling additionally revealed that the sand distribution was heterogeneous throughout the channel. The fact that the sand, where present, is often buried to a depth of 0.5 m or more shows that there has been either deposition or downward mixing of the sand at locations throughout the channel (or both) (Figure 14). The patchy distribution of the sand could be due to some combination of inconsistent sand placement and sediment disturbance.

Contaminants, particularly DDT, can also act as an indicator of sediment movement. Contaminant patterns in the Lauritzen Channel show heterogeneity similar to the sand distribution. Figure 14 illustrates the scatter in surface sediment DDT concentrations and the distribution of contamination between the surface layer and the bottom of the YBM layer. The highest DDT concentrations are in regions of sediment accumulation in the head of the channel and the deep area on the east side of the channel. Lower concentrations are present along the west side of the channel, consistent with the thin YBM layer and potential sediment erosion in this region.

It is important to note that bioturbation can mix sediments over an interval of a few mm to about 10 cm depending upon the resident species. However, given the large-scale mixing and heterogeneity in both the vertical and lateral distribution of sediment and DDT in the channel, it can generally be considered a secondary process with respect to sediment transport.

In summary, the Lauritzen Channel is a low-energy protected region with tidal velocities that are not likely to result in resuspension. The low energy coupled with sediment input from San Francisco Bay result in a net sediment accumulation in the channel. Ongoing vessel operations in the channel are responsible for localized mixing of the sediment bed, resuspension, and redistribution of sediment within the channel. A portion of the resuspended material may also be tidally dispersed into the Santa Fe Channel. Figure 15 graphically summarizes the key sediment transport processes. The net effect of these processes on sediment and contaminants in the channel are a heterogeneous distribution of contaminants with generally higher concentrations in areas of higher sediment accumulation.

## *Conceptual Sediment Budget*

A sediment budget is developed to account for the external inputs, outputs, and storage of sediment in a region due to the net effects of all of the sediment transport processes. The budget provides a useful tool for accounting for sediments and evaluating the effects of any changes to the system. Essentially the sediment budget is described by:

$$Sediment\ Input - Sediment\ Output = \Delta Sediment\ Storage$$

At a contaminated site in particular, the sediment budget provides the basis for accounting for contaminated sediment movement into and out of the system and storage within the system. The goal of the conceptual sediment budget here is to identify the external inputs and outputs of sediment to the system and identify potential methods for quantifying these processes. It is important to note that processes such as propeller scour can significantly alter deposition and erosion patterns within the system while the external exchange of sediment between the channel and the estuary remains unchanged.

The key external sediment inputs to the Lauritzen Channel are the tidal delivery of sediment from San Francisco Bay and upland runoff during wet weather (this will be verified as part of the Tier 2 study). The bay provides a constant delivery of silt and clay to the margins, including harbors. The sediment source is generally lowest in the summer and highest in the winter (Schoellhamer, 1996). Determining tidal fluxes of sediment into any water body is generally accomplished through some combination of field measurements of sediment flux, empirical modeling, and numerical modeling. The delivery of sediment from upland sources is primarily due to the municipal stormwater outfall at the head of the channel. Data are not readily available on the yearly flow and associated sediment load associated with the outfall; however, efforts will be made in Tier 2 to further assess the need for these data in the sediment budget and determine if the magnitude is significant. Figure 16 summarizes the key sources to be quantified as part of the Tier 2 sediment transport study. Qualitative indicators suggest the tidal delivery of sediment is the largest order of magnitude external sediment source to the region. Data from the Richmond Harbor suggest this external sediment source is below levels of concern for all contaminants of concern.

Indicators evaluated in this study show that the head of the Lauritzen Channel is a region of consistent sediment deposition; however, sediments in this region still have elevated levels of DDT and Dieldrin. While the San Francisco Bay does represent the largest external source of sediment, the persistence of high contamination in the channel is most likely due to a combination of incomplete removal during remedial activities, anthropogenic resuspension, and secondary sources (e.g. nearshore regions, outfalls). Ongoing sampling activities are being conducted to better characterize these processes.

The sediment outputs are the net result of suspended sediment in the channel that can be transported out by the tide. The key resuspension processes that have been identified are the vessel operations. As discussed, the props, keels, and anchor spuds of vessels may cause localized resuspension. Another source of suspended sediment in the system is suspended solids from outfalls during storm events. Although much of this material is likely to accumulate locally in the Lauritzen Channel, DDT contamination in the Santa Fe Channel suggests that tidal dispersion and transport of sediment resuspended in the channel occurs.

By summing the inputs and outputs of sediment over any given time, a change in sediment storage can be determined. A common method for accounting for the change in sediment volume in a harbor is through the dredging records. Often the average amount of sediment removed periodically for maintenance dredging can provide a direct measure of these volumes. Bathymetric change is another method of estimating the net volumetric change in sediment storage in a harbor. Although only sparse datasets are available at present for these types of analyses, these data sources are being thoroughly evaluated for quantitative analysis in the Tier 2 sediment transport analysis.

## *Sediment Management Questions*

This document developed a Tier 1 sediment transport CSM for the United Heckathorn Superfund Site. The Tier 1 CSM has been used address the following sediment management questions:

- What is the source(s) of the sediment accumulating in the Lauritzen Channel?

The tidal transport of San Francisco Bay sediment into the low energy Lauritzen Channel provides an ideal environment for deposition of bay sediment. The supply of sediment from the bay and the controlled nature of any other outfalls into the Lauritzen Channel indicate that the bay is the primary source of accumulating sediment.

- How does sediment transport lead to the redistribution of contamination within the Lauritzen Channel, or movement of contamination out of the channel?

Vessel activity is the primary source of resuspension in the Lauritzen Channel. The low energy environment of the channel allows this material to disperse and settle locally which can lead to redistribution of contamination within the channel. Some portion of the material resuspended, particularly during an ebb tide, can be transported out to the Santa Fe Channel and deposited.

- If part of the Lauritzen Channel is actively remediated, could sediment transport lead to the recontamination of the remediated area?

If high contaminant concentrations remain in locations that could be disturbed by anthropogenic activities, they could be redistributed to actively remediated areas.

## *Conclusions and Recommendations for Tier 2 Evaluation*

The Tier 1 sediment transport CSM for the United Heckathorn Superfund Site revealed several areas where improved data and analysis will provide more comprehensive answers to the sediment management questions. The goal of a Tier 2 evaluation is to address the management questions with a higher degree of certainty using targeted, site-specific data and more sophisticated data analysis methods guided by Tier 1 investigation. The following analyses are recommended to further describe the sediment transport processes identified in this report.

The magnitude and frequency of sediment resuspension and transport due to anthropogenic processes should be quantified to accurately determine the potential for sediment accumulation, contaminant redistribution, and potential for recontamination; and to support the development of effective remedial alternatives in the FFS.

The following field activities are recommended to provide the necessary data for the transport quantification:

- Deploy current meters with optical backscatter sensors to measure profiles of velocity and proxies for total suspended solids (TSS) at two locations.
    - Location one - central location in the mouth of the Lauritzen Channel to address net sediment transport into and out of the channel

    - Location two - the northern end of the channel in areas of no vessel activity to evaluate currents and suspended solids to determine sediment accumulation
- Collect channel velocity and TSS measurements during instrument deployment to determine sediment flux throughout the channel throughout the tidal cycle.
- Collect erosion rate measurements and develop a spatial picture of sediment erosion properties to better understand the potential for future sediment mixing, erosion, and transport. A series of sediment cores will be collected in areas of high, moderate, and low sediment accumulation for sediment erosion (Sedflume) analysis to characterize erosion potential of sediments as follows:
    - In areas of typical tug and barge movements
    - In the relatively undisturbed northern end of the channel
    - Under typical and storm conditions
- Deploy and monitor sediment tracers in an area of high vessel activity to assist in quantifying sediment transport due to the activity. The Tier 1 analysis hypothesized transport of sediment from high vessel activity areas to high accumulation areas within the Lauritzen Channel and potentially out of the channel.
- Collect sediment cores in the regions of high, moderate, and low sediment accumulation identified in the Tier 1 analysis and analyze samples for DDT to validate sediment contaminant distribution patterns and establish temporal trends in contaminant transport.
- A marker bed composed of feldspar or a similar material could be deployed in areas isolated from vessel activity (e.g. at the head of the Lauritzen Channel) to determine the magnitude of sediment accumulation and the quality of the sediment after the municipal storm drain system has been cleaned of residual sediment. A marker bed is not planned as part of the Tier 2 investigation because it could not be deployed until after the municipal storm drain system is cleaned, and it would need to be deployed for at least one year to capture seasonal variations.

In addition to the recommended field activities, further analytic activities are recommended as part of the Tier 2 analysis to support the quantification of the sediment and contaminant transport processes. The following analytic activities are recommended:

- Determine erosion potential using accepted models of propeller scour, and quantify sediment mixing depths and volumes during typical vessel operations using the bathymetric, sediment erosion, and suspended solids data for model calibration and validation.
- Develop a sediment flux analysis to determine offsite transport and potential recontamination within the Lauritzen Channel based on the field data. The flux analysis will provide a key input to a quantitative mass balance of sediment and contaminant transport (Wall et al., 2006).
- Modeling of resuspension, transport, and deposition in the area using the Environmental Fluid Dynamics Code (EFDC) will be performed determine spatial and temporal patterns of sediment and contaminant transport in the Lauritzen and Santa Fe Channels. The model will be used to:
    - Facilitate the extrapolation of long term tidal sediment fluxes to examine long term recovery impacts of various remedial scenarios
    - Examine natural deposition patterns to be expected from the estuary for future recovery

- Determine transport and deposition patterns of material resuspended during various anthropogenic events
- Conduct deeper examination of sediment and DDT mass balances
- Examination of spatial variation in residence time in channel in support of remedial evaluation

The quantitative model coupled with the analysis of the field data will be used to refine the CSM and answers to the sediment management questions. An updated quantitative sediment and contaminant fate and transport CSM will guide the remedial alternative development and analysis in the FFS.

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# *Figures*

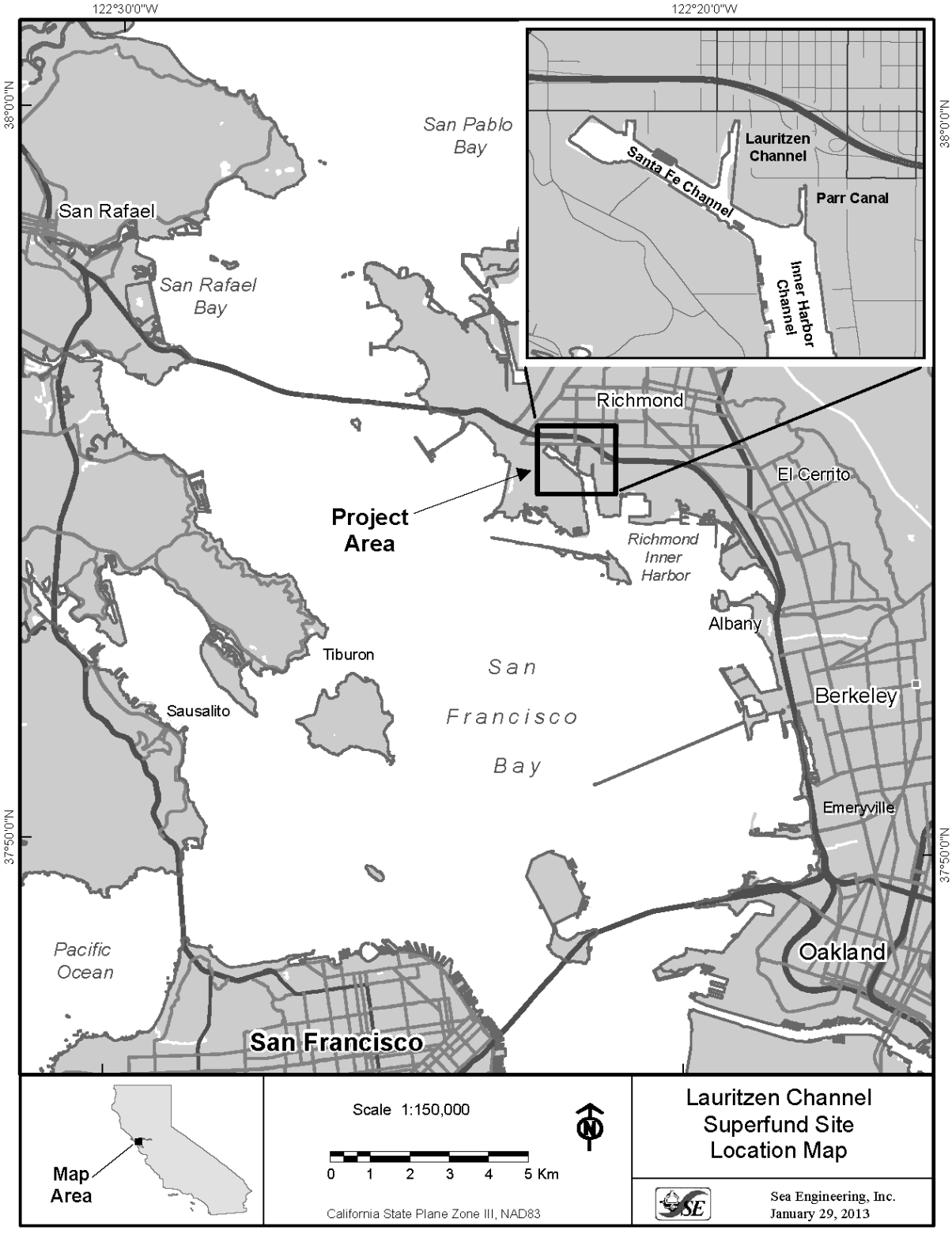


**Figure 1. Location of Richmond Harbor.**

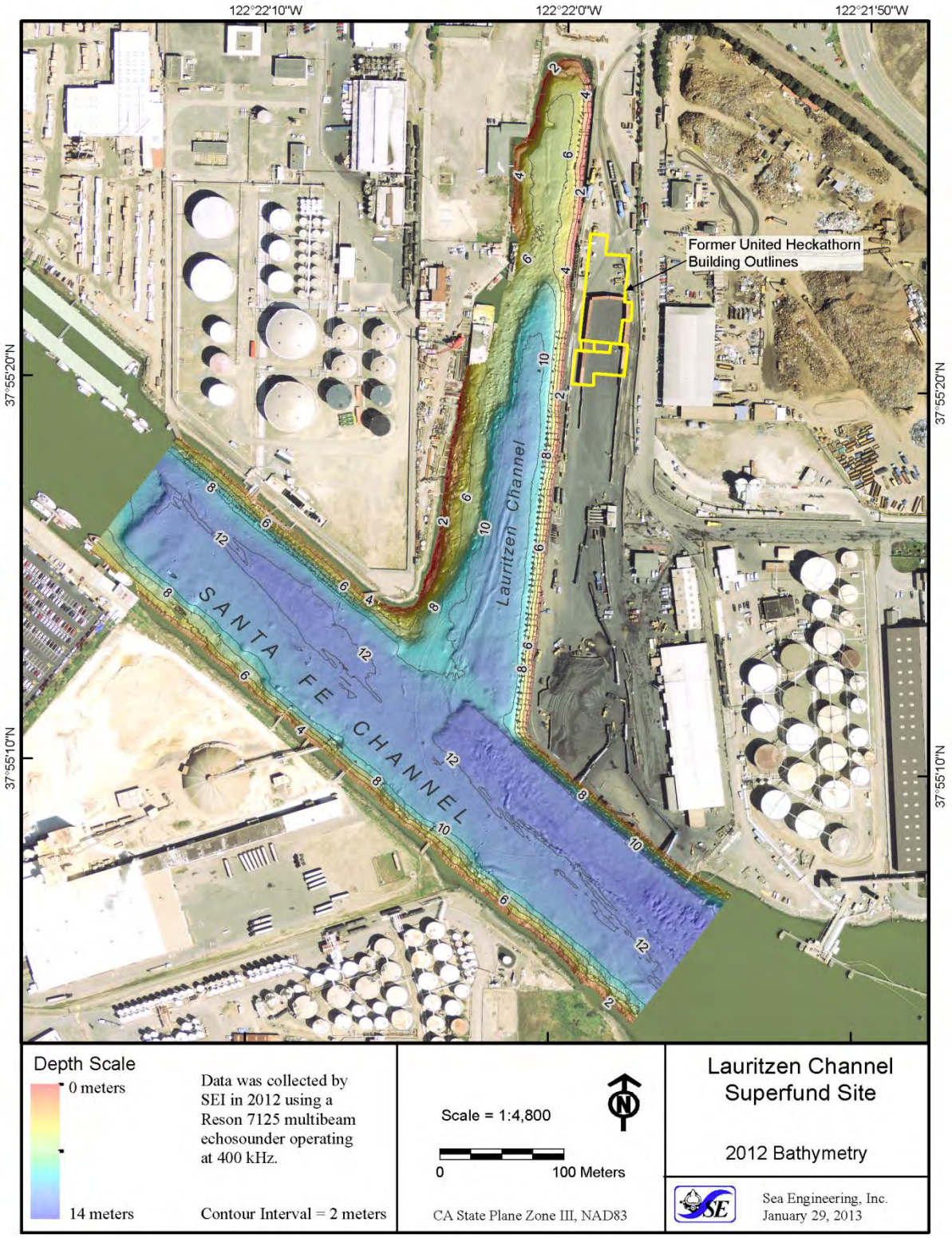


**Figure 2. Bathymetry map of the Lauritzen Channel and portions of the Santa Fe Channel.**

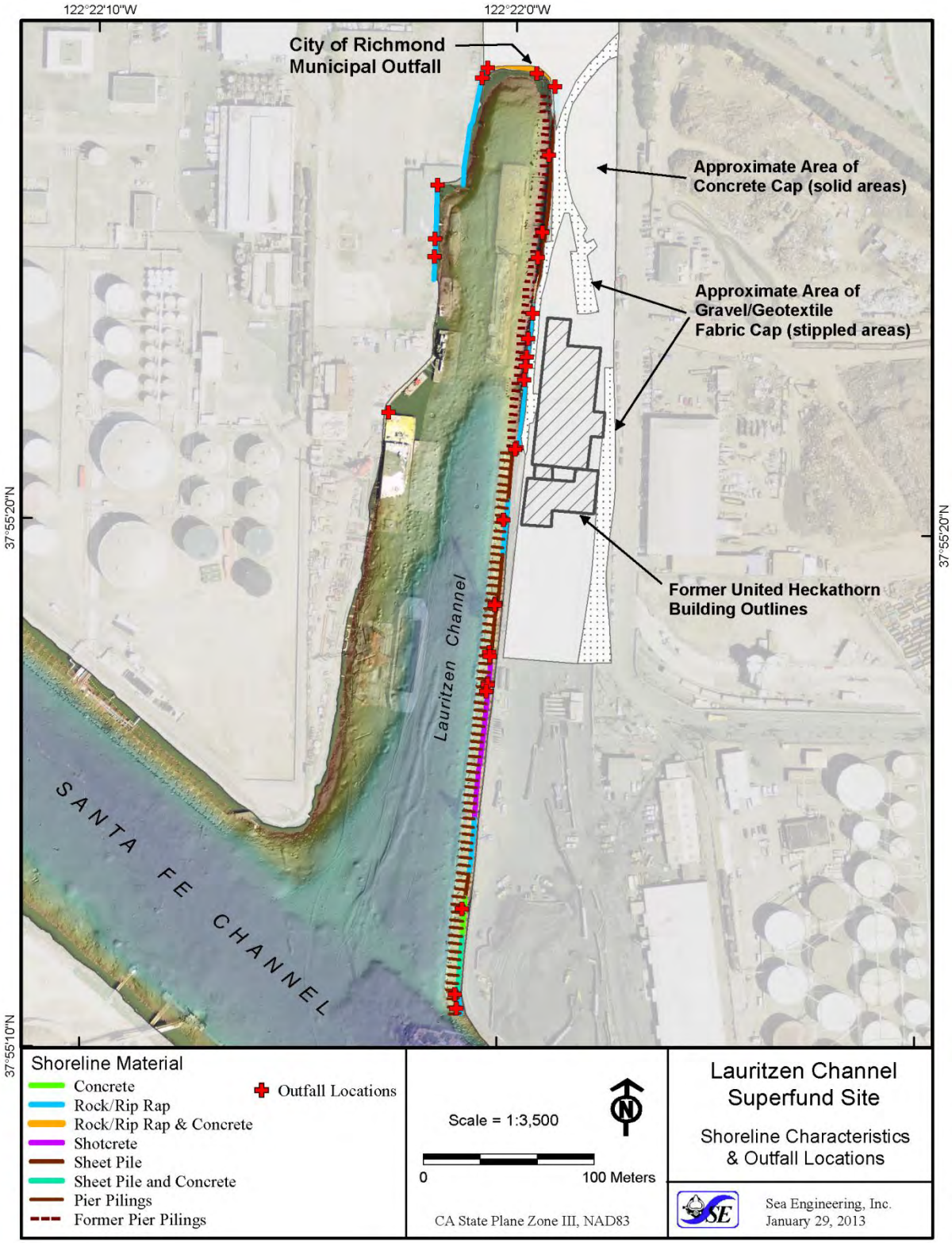


**Figure 3. Shoreline characteristics and outfall locations.**

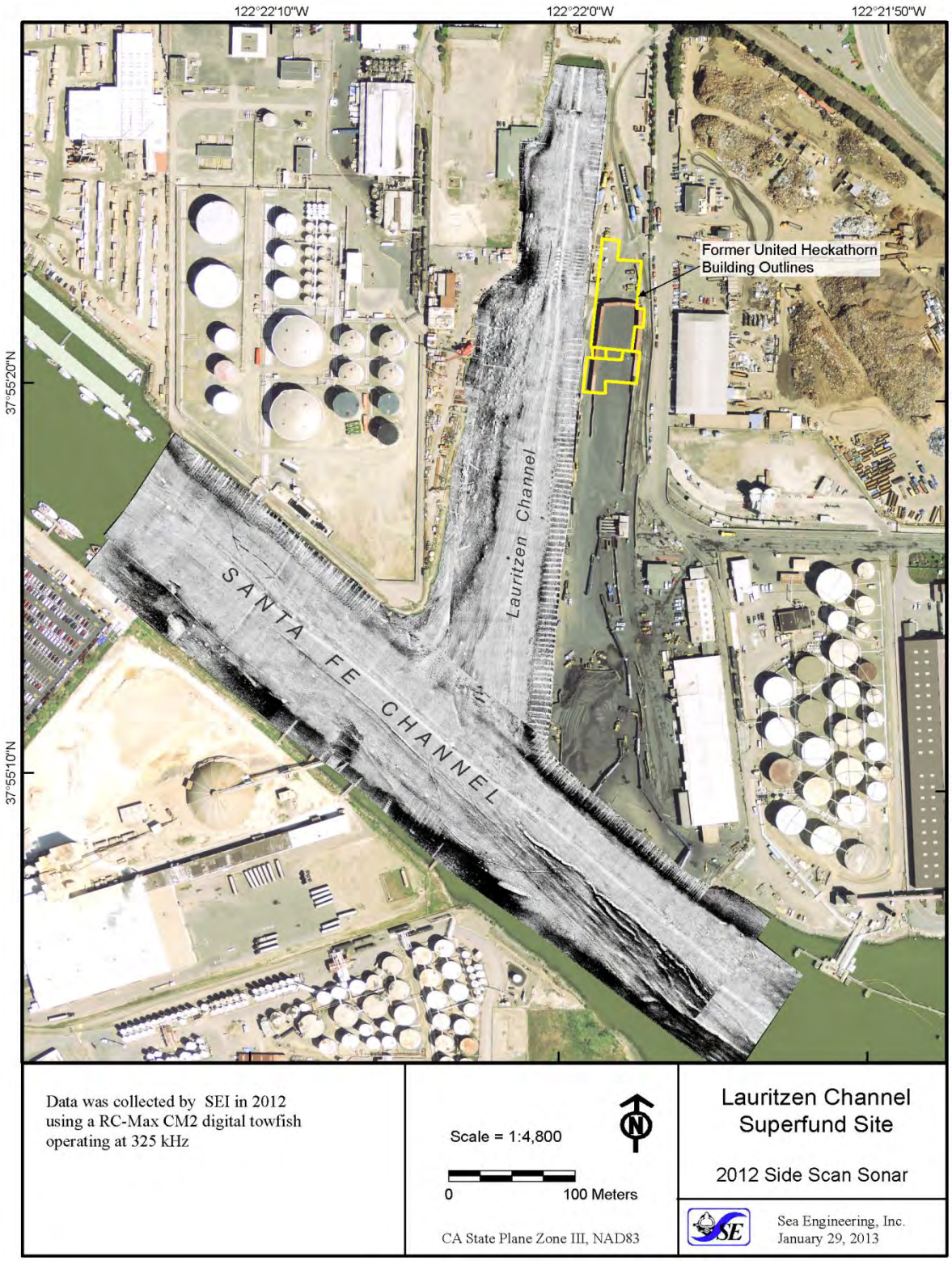


**Figure 4. Sidescan survey map of the Lauritzen Channel.**

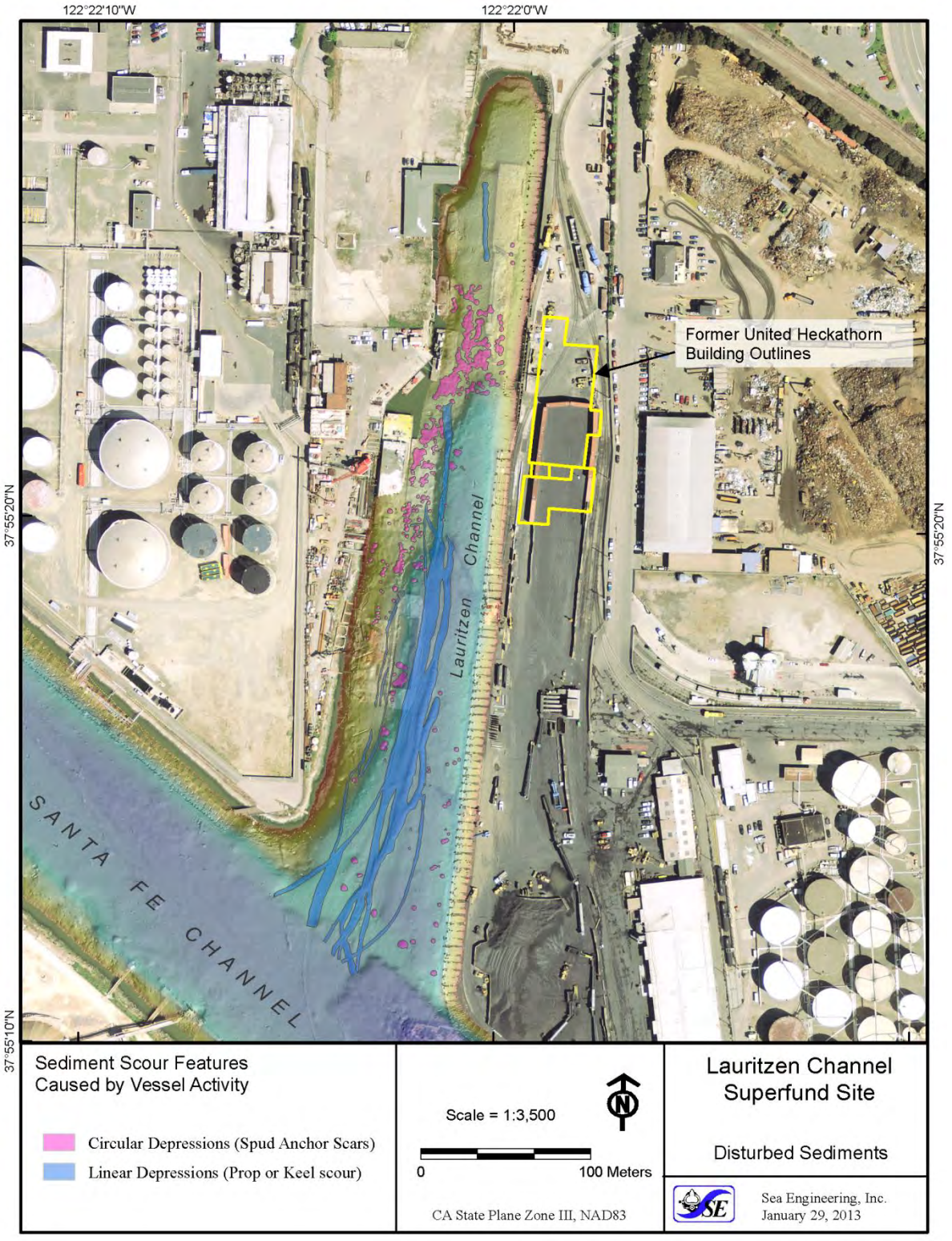


**Figure 5. Map of areas of sediment disturbance.**

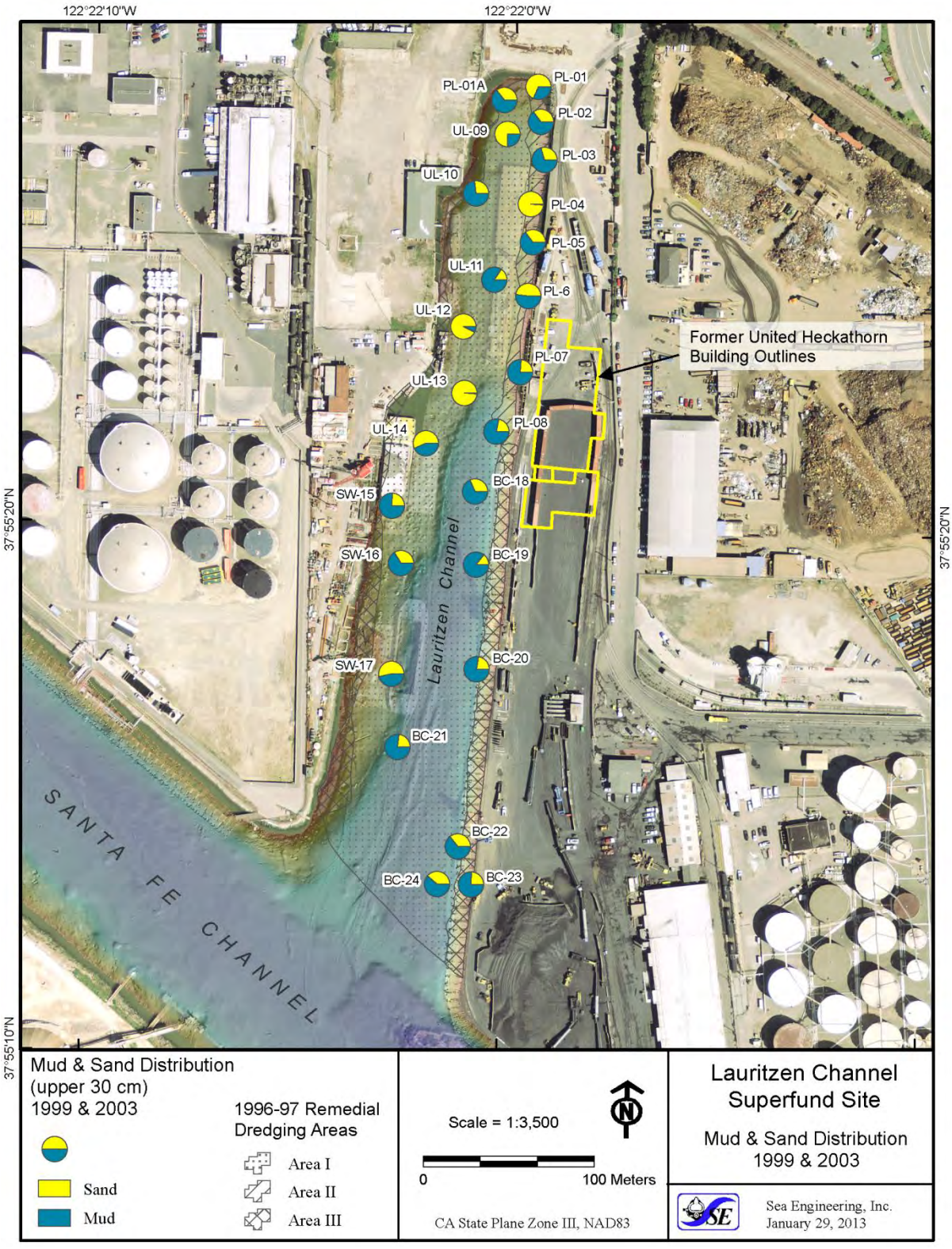


**Figure 6. Mud and sand distributions in surface samples of the Lauritzen Channel.**

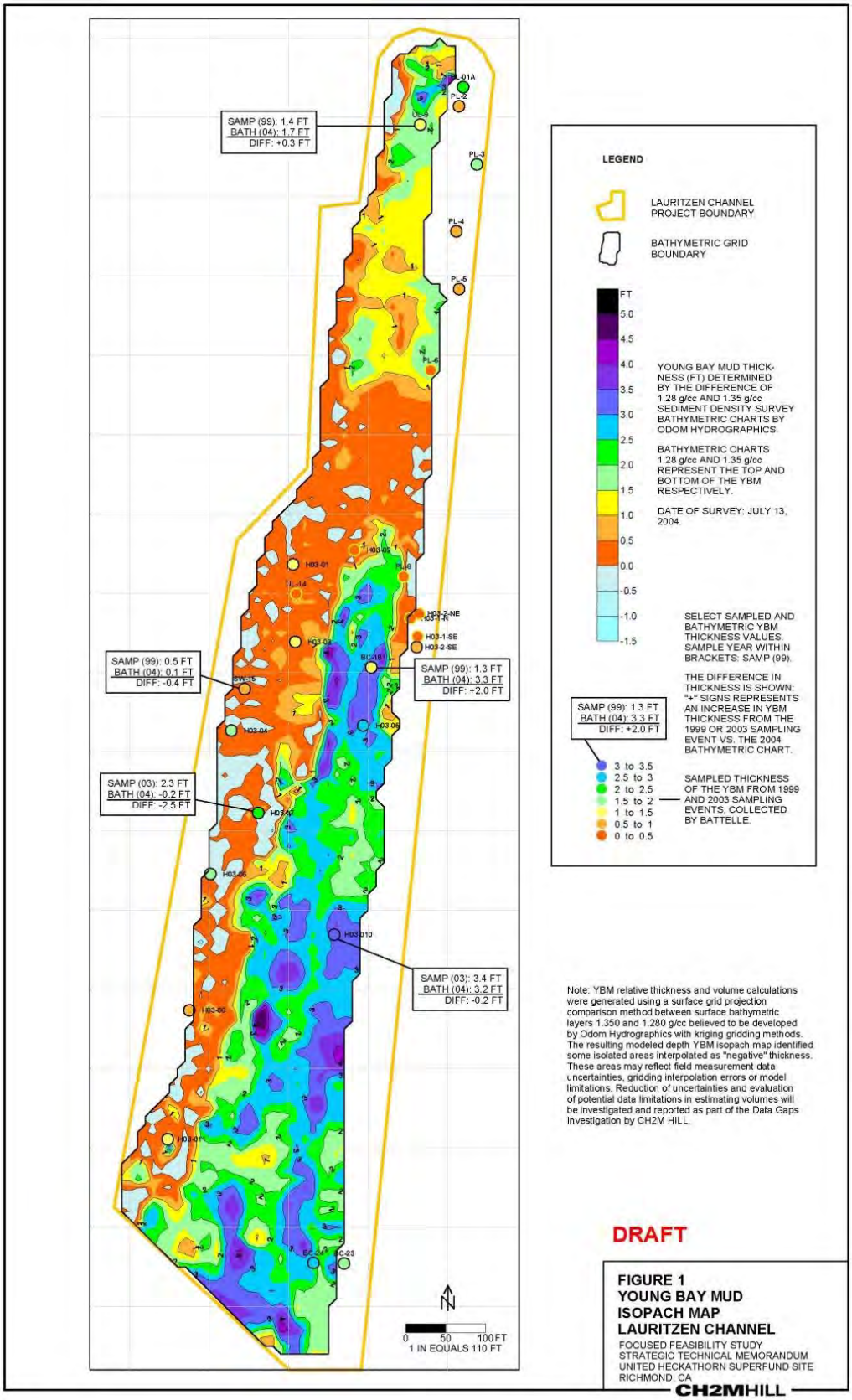


**Figure 7. Map of young bay mud thickness in the Lauritzen Channel (Welp, 2005; CH2MHILL, 2006).**

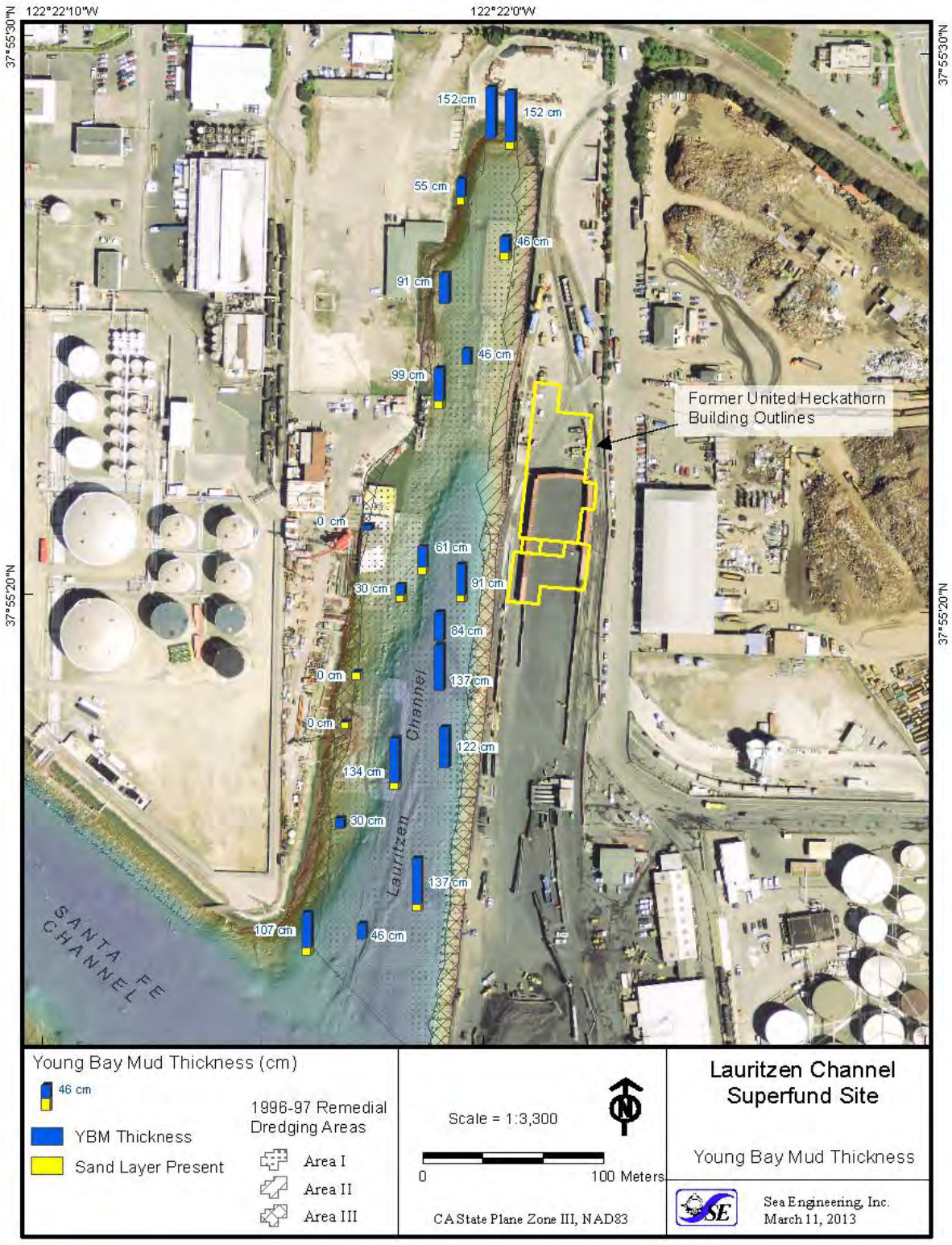


**Figure 8. Map of young bay mud thickness and sand where present in 2007 coring.**

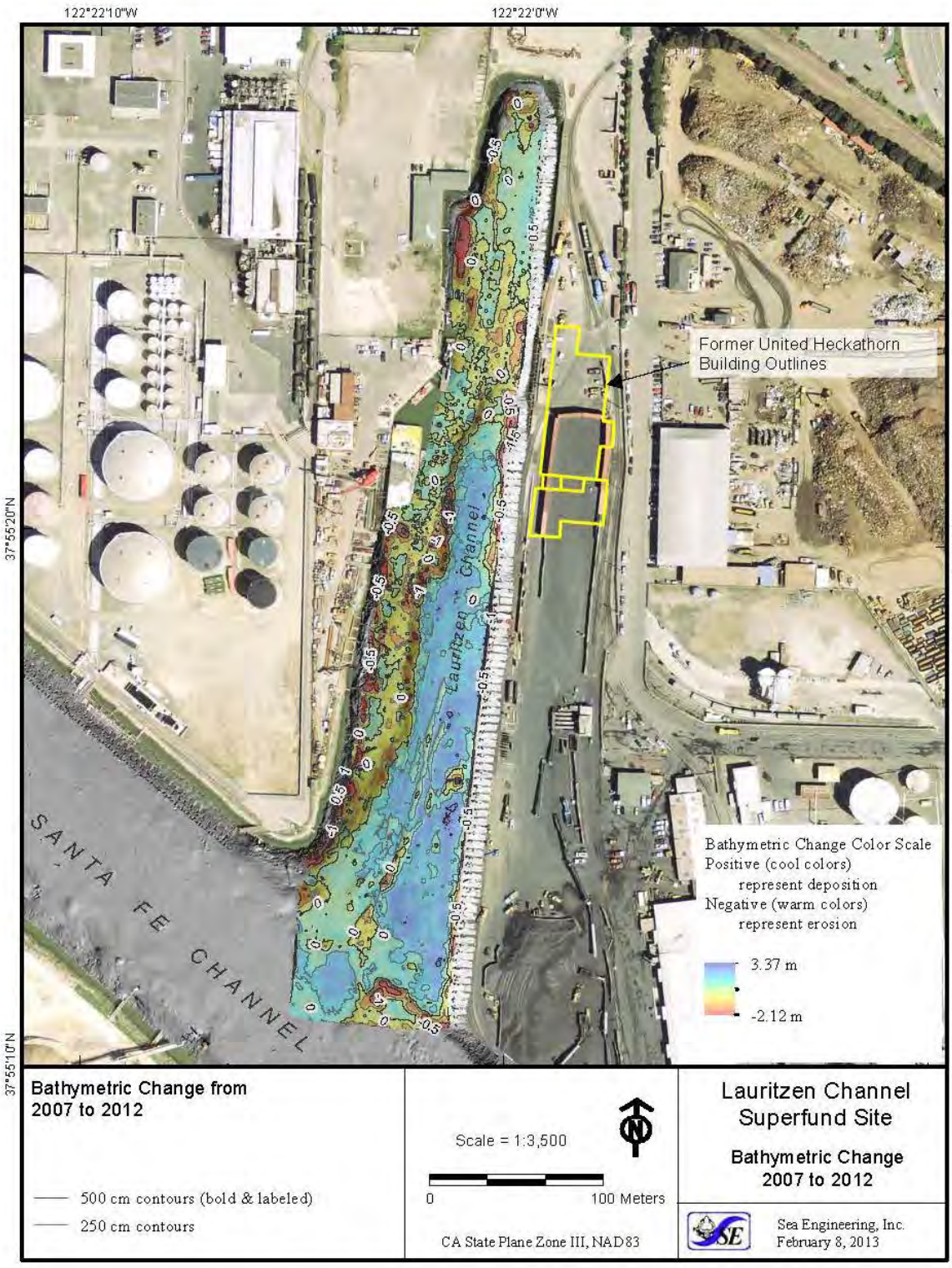


**Figure 9. Bathymetric change between the 2007 and 2012 surveys.**

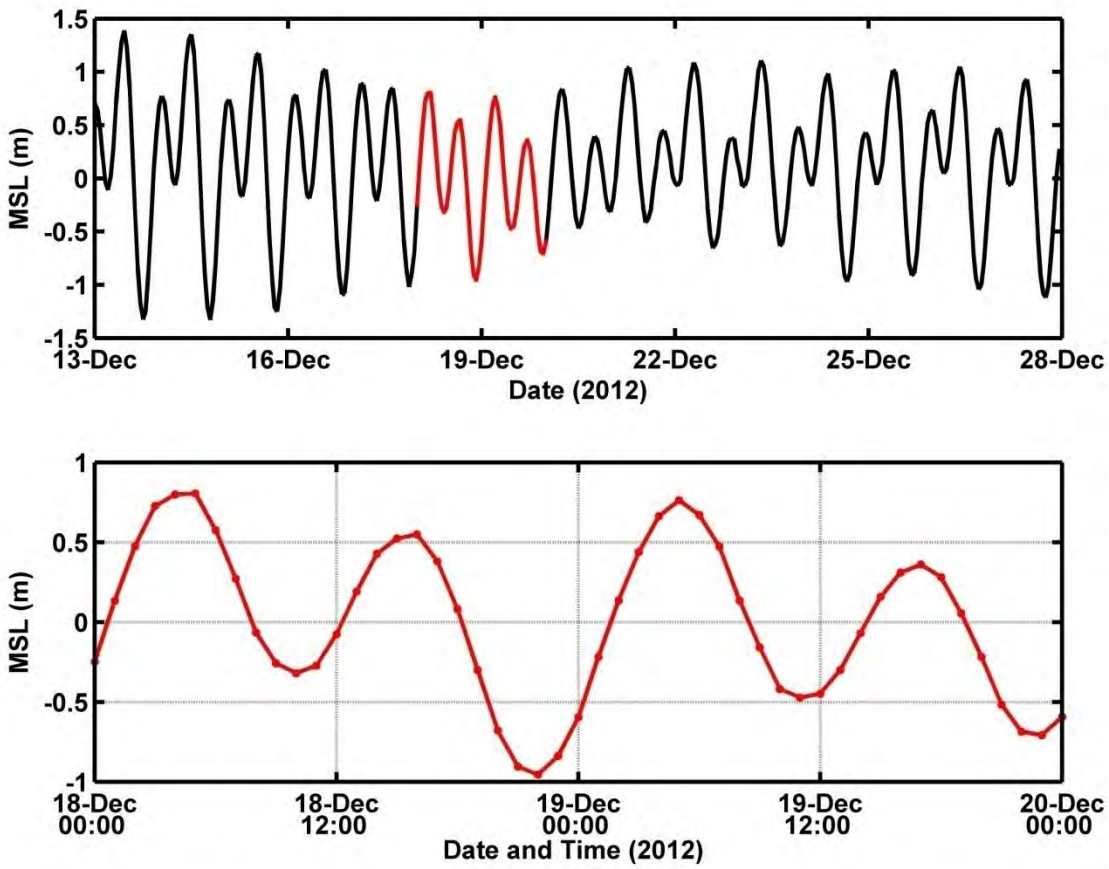


**Figure 10. Example tide for the outer Richmond Harbor.**

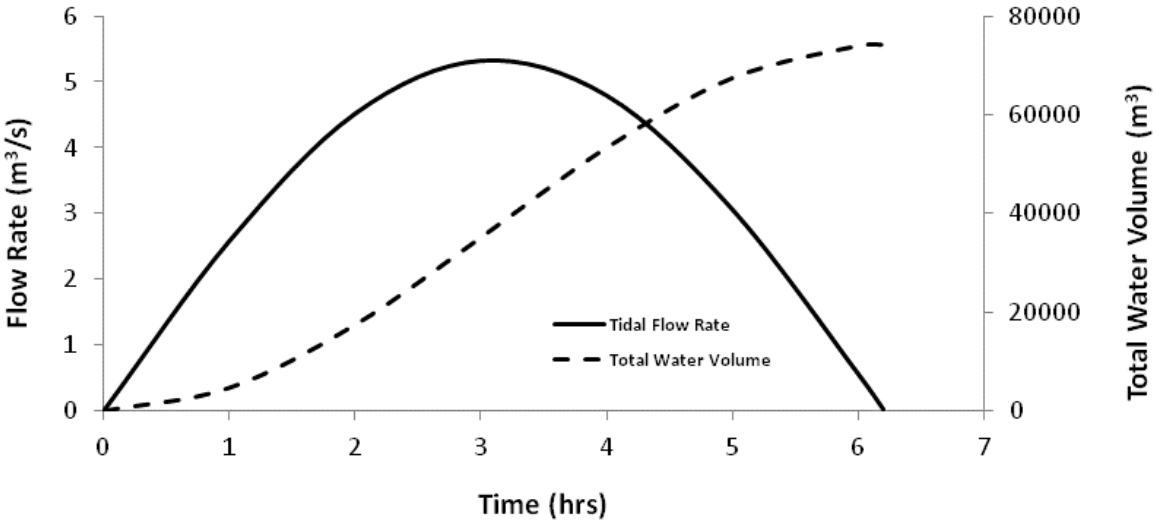


**Figure 11. Tidal flow rate and cumulative water volume exchanged during a tide change.**

**Figure 12. Satellite photo showing sediment plume during tug and barge activity (October 2011, Google Earth).**

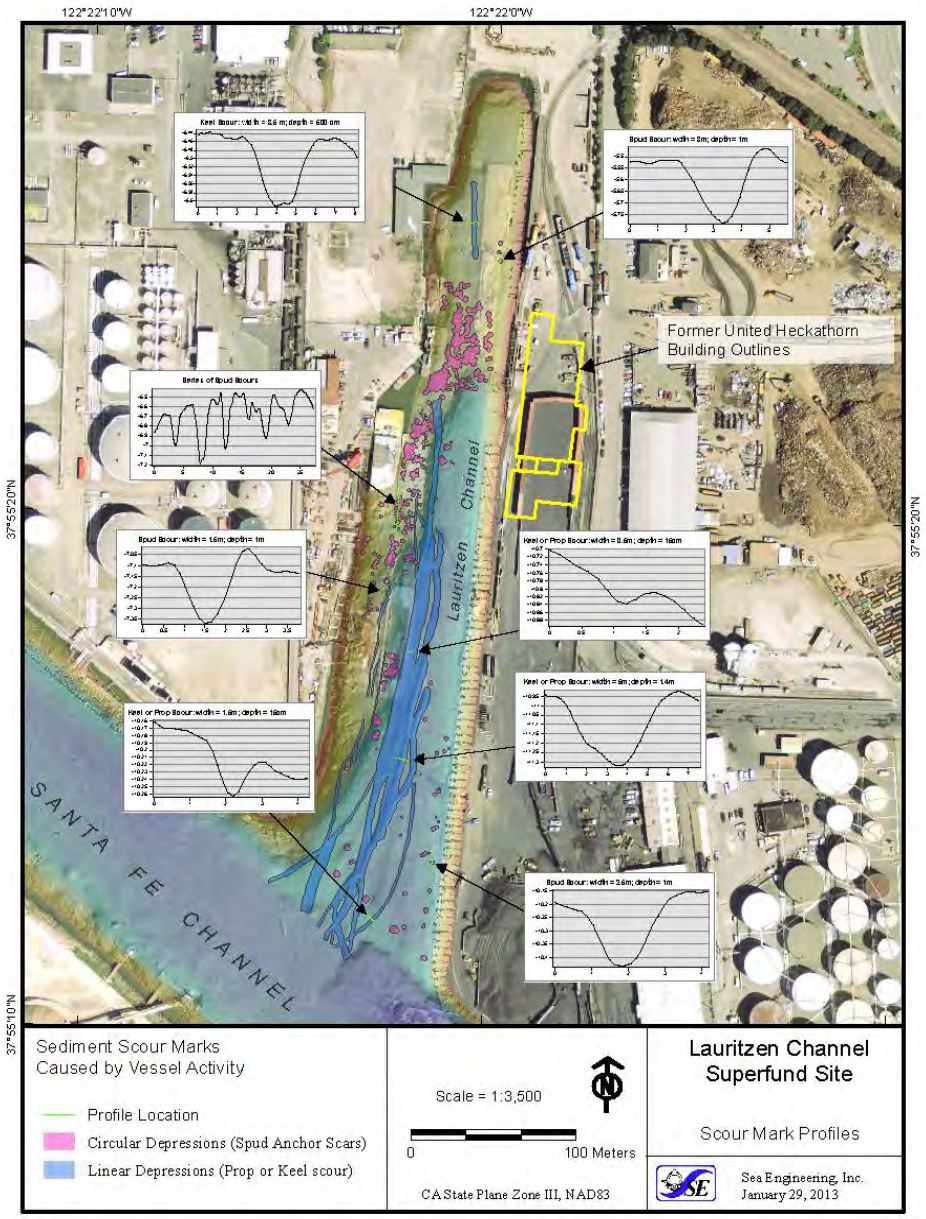


**Figure 13. Profiles of vessel and spud disturbance at the sediment bed.**

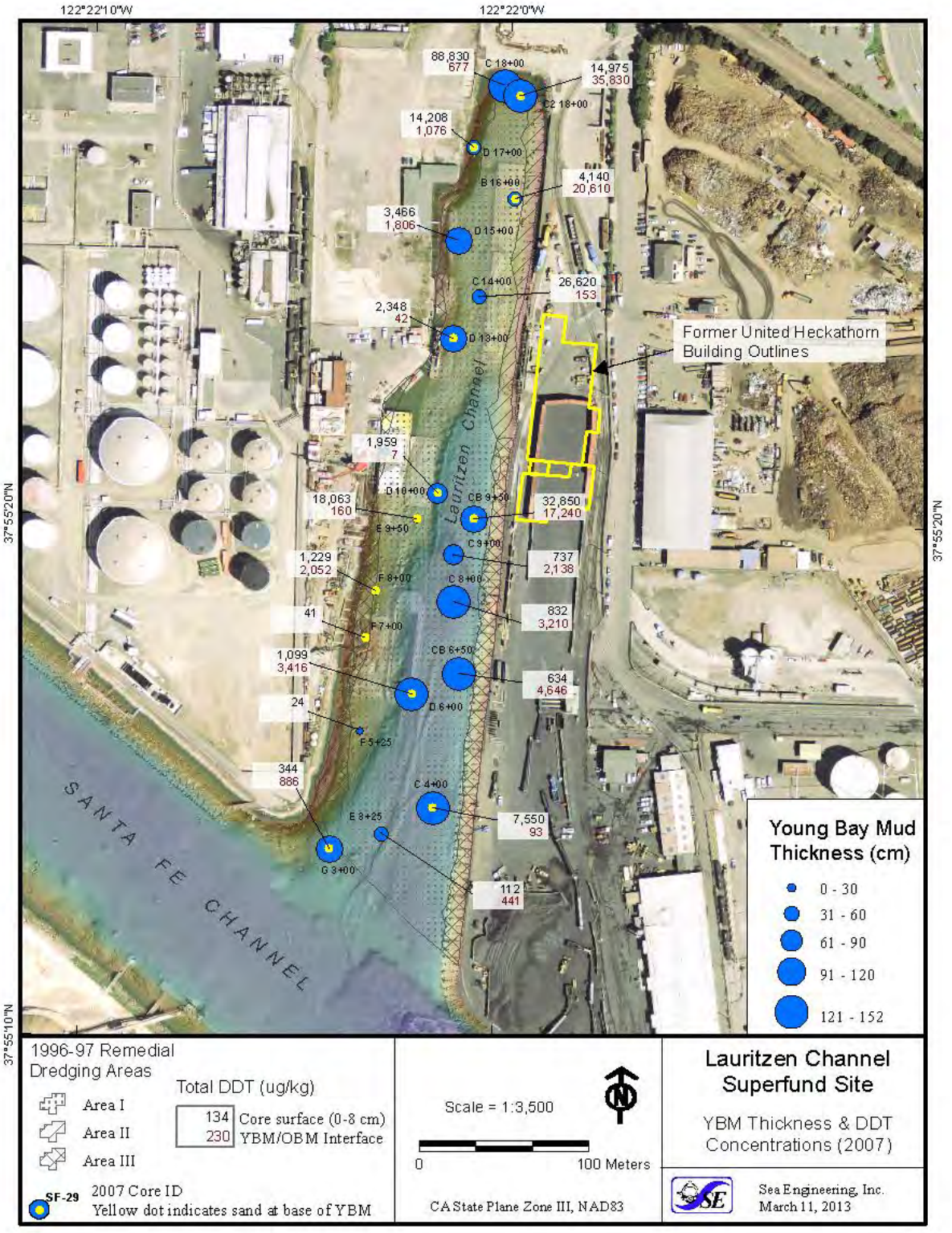


**Figure 14. Map of YBM surface and interface DDT concentrations, thickness of YBM, and sand presence.**

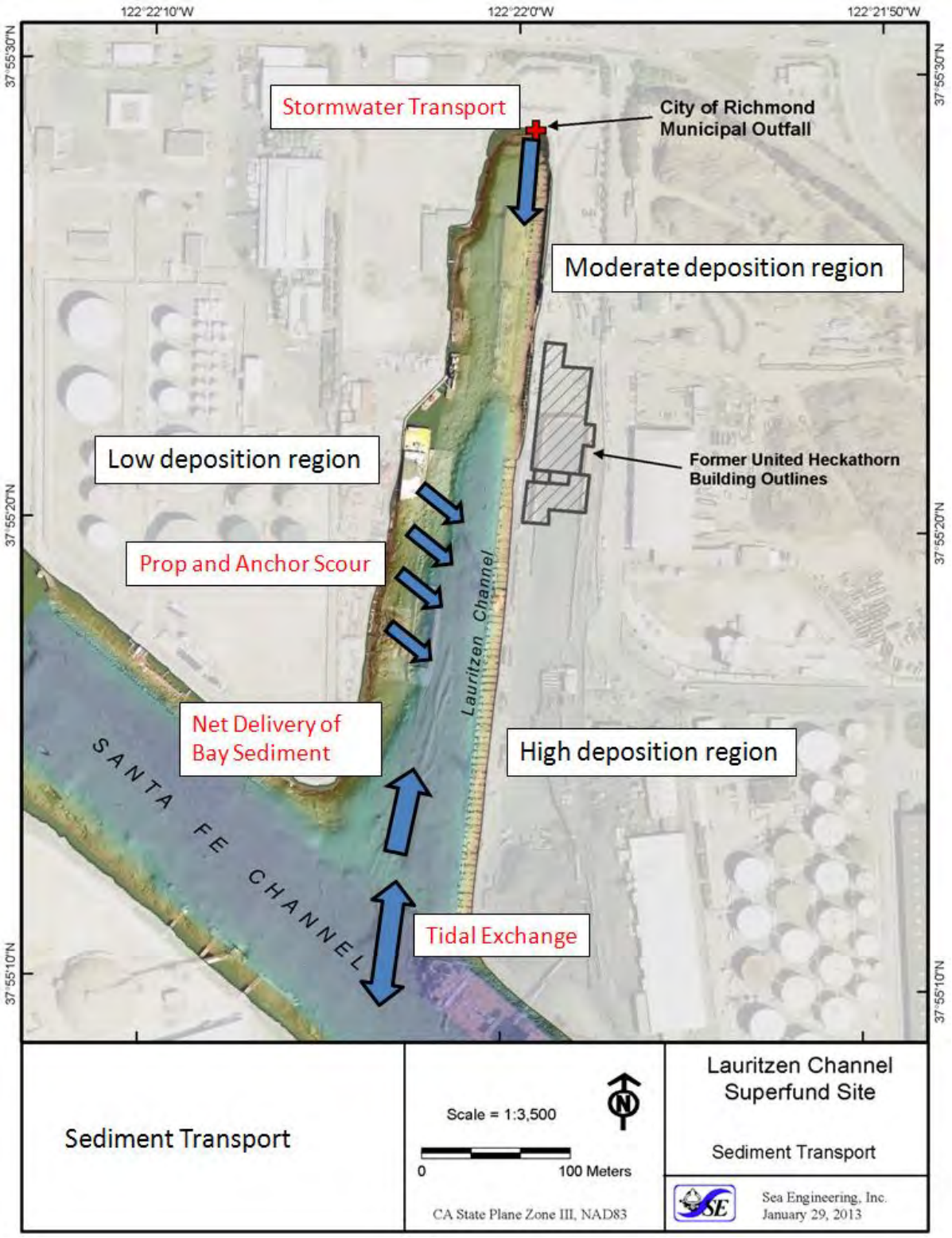


**Figure 15. Sediment transport process summary.**

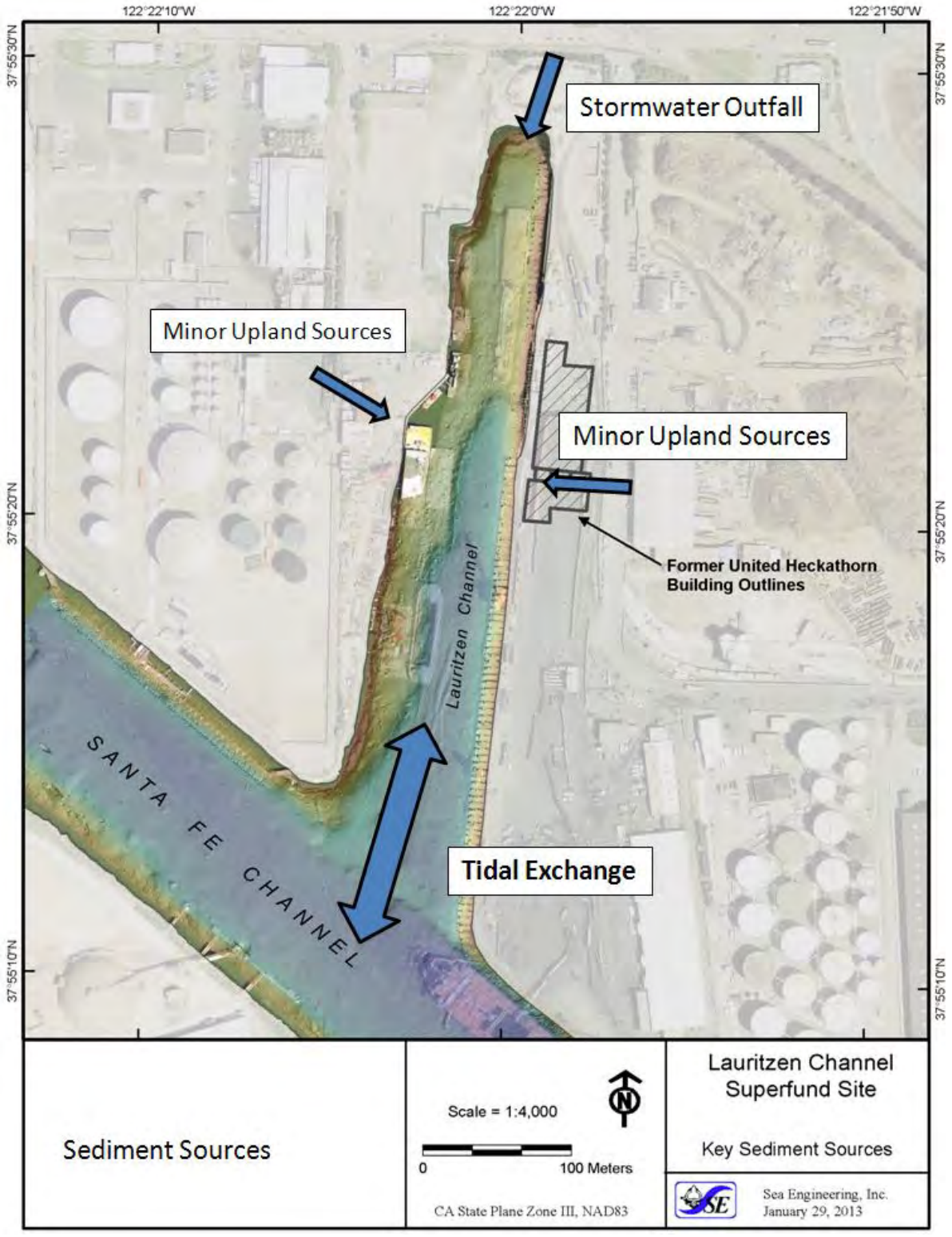


**Figure 16. Key sediment sources to the Lauritzen Channel.**

# United Heckathorn Superfund Site:
# Tier 2 Sediment Transport Study

**February 2014**

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CH2M HILL under contract to EPA Region 9

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Appendix C. Sedflume Analysis

## List of acronyms used in the report

ABS: Acoustic Backscatter

ADCP: Acoustic Doppler Current Profiler

BPH: Brake Horsepower

CSM: Conceptual Site Model

DDT: Dichlorodiphenyltrichloroethane

DGPS: Differential Global Positioning System

EFDC: Environmental Fluid Dynamics Code

FFS: Focused Feasibility Study

FSP: Field Sampling Plan

LISST: Laser in Situ Scattering and Transmissometry

LRTC: Levin Richmond Terminal Corporation

MLLW: Mean Lower Low Water

NOAA: National Oceanic and Atmospheric Administration

OBM: Older Bay Mud

POTW: Publicly Owned Treatment Works

PSD: Particle Size Distribution

REE: Rare Earth Element

SEI: Sea Engineering Inc.

TPE: Transport Pathway Evaluation

TSS: Total Suspended Solids

USDA: United States Department of Agriculture

USEPA: United States Environmental Protection Agency

YBM: Younger Bay Mud

YSI: Yellow Springs Inc.

# Executive Summary

Sea Engineering, Inc. (SEI) performed field and analytic activities to obtain hydrodynamic, water quality, and sediment data and to quantify sediment dynamics in the Lauritzen Channel of the United Heckathorn Superfund Site in Richmond, California. The field investigation involved measurements of system-wide current velocities, water quality, sediment characteristics and erosion rates, and a particle tracer study. Analytic activities included numerical modeling to elucidate the effects of ship wake and propeller scour and hydrodynamics on sediment transport processes.

A Tier 2 sediment transport conceptual site model (CSM) was developed from field and analytic results to address sediment management questions. The sediment management questions and findings are summarized below.

- What is the source(s) of the sediment accumulating in the Lauritzen Channel?

  The channel is low energy and provides an ideal environment for deposition of sediment. Results from the Tier 2 study indicate that the sediment accumulating in the Lauritzen Channel primarily originates from San Francisco Bay and that the local outfalls have minimal yearly averaged input.

- How does sediment transport lead to the redistribution of contamination within the Lauritzen Channel, or movement of contamination out of the channel?

  Vessel activity is the primary source of resuspension and redistribution in the Lauritzen Channel. The tidal velocities are very low throughout the channel, allowing for sediment deposition. The Tier 2 tracer study provided evidence of vessel resuspension and redistribution of sediment from the tracer locations to other areas throughout the channel. Vessel propeller scour analysis and numerical modeling showed that while a vessel can scour up to approximately 10 cm of sediment, greater than 90% of this sediment would settle locally. It can thus be inferred that redistribution of contamination would primarily be confined within the Lauritzen Channel. A portion of the material resuspended during an ebb tide could be transported out to the Santa Fe Channel; however, the study showed the mass to be limited (less than 7%).

- If part of the Lauritzen Channel is actively remediated, could sediment transport lead to the recontamination of the remediated area?

  Natural transport processes alone (e.g., tidal currents) would not lead to recontamination of remediated areas. However, high contaminant concentrations in locations with potential for disturbance by anthropogenic activities (e.g., vessel propeller or keel scour) could be redistributed to actively remediated areas.

This document presents the results of the Tier 2 sediment transport study. The results of the Tier 1 and Tier 2 studies will be evaluated in conjunction with the results of the source identification study, dichlorodiphenyltrichloroethane (DDT) fate and transport evaluation, long-

term monitoring data, and data from previous investigations to further refine the CSM for the site and support the development of remedial alternatives in the focused feasibility study.

# 1.0 Introduction

The United Heckathorn Superfund Site is located in Richmond Harbor on the east side of San Francisco Bay in Contra Costa County, California (Figure 1). From the mid-1940s to the mid-1960s, the site was used for processing, packaging and shipping pesticides. Although many types of pesticides were processed on the site, DDT[1] and Dieldrin are the primary contaminants of concern. The remedy selected for the marine portion of the site in the 1994 Record of Decision (United States Environmental Protection Agency (USEPA), 1994) consisted of dredging and offsite disposal of sediment from the Lauritzen Channel and Parr Canal, followed by at least five years of post-remediation monitoring. The remedy for the upland part of the site included capping and institutional controls. The remedies for the marine and upland portions of the site were completed in 1997 and 1999, respectively. Post-remediation monitoring data indicate that sediments in the Lauritzen Channel still have unacceptably high levels of DDT and Dieldrin (Anderson, et al., 2000; Antrim & Kohn, 2000). A focused feasibility study (FFS) is being performed to address residual contamination in the channel sediment.

The amounts of sediment and sediment-associated DDT that are being transported into and out of the Lauritzen Channel and redistributed within the Lauritzen Channel are not known. A study of sediment dynamics in the Lauritzen Channel has been performed because (1) sediment has accumulated in the channel since the remedy was completed; (2) surface and subsurface sediment DDT concentrations are above the remediation goal; (3) the source(s) of the sediment and sediment-associated contamination have not been definitively identified; and (4) additional cleanup cannot occur until any active, ongoing source(s) are controlled.

The sediment transport analysis was performed using a phased (tiered) approach as described in the U.S. Navy's *User's Guide for Assessing Sediment Transport at Navy Facilities* (Blake, Chadwick, White, & Jones, 2007). In a Tier 1 study, sediment transport is assessed using basic site characterization data (e.g. bathymetric surveys, tidal ranges, sediment contaminant data) and analyses to address sediment management questions. A Tier 1 Study was completed in April 2013 (Sea Engineering Inc, 2013).

This document presents the results of the Tier 2 sediment transport study developed from the results of the Tier 1 study. The Tier 2 study focused on collection of site-specific data and more refined data analyses, including the use of analytical and numerical methods as outlined in the Field Sampling Plan (FSP) for the Tier 2 sediment transport study (CH2M HILL; Sea Engineering Inc., 2013). The results of the Tier 1 and Tier 2 studies will be evaluated in conjunction with the results of the source identification study, DDT fate and transport evaluation, long-term

[1] Dichlorodiphenyltrichloroethane; for the purposes of this report, "DDT" refers to the sum of all 4,4'- and 2,4'- isomers of DDT, DDD, and DDE. Dieldrin is present at lower concentrations but co-occurs with DDT; therefore, the report focuses on DDT.

monitoring data, and data from previous investigations to refine the conceptual site model (CSM) for the site and support the development of remedial alternatives in the FFS.

The primary goals of the overall sediment transport study are to address the following sediment management questions:

- What is the source(s) of the sediment accumulating in the Lauritzen Channel?
- How does sediment transport lead to the redistribution of contamination within the Lauritzen Channel, or movement of contamination out of the channel?
- If part of the Lauritzen Channel is actively remediated, could sediment transport lead to the recontamination of the remediated area?

Due to the complexity of the processes affecting sediment and contaminant transport in the Lauritzen Channel, multiple lines of evidence were used to fully address the management questions. The Tier 2 sediment transport study characterizes the sediment erosion/resuspension and transport processes in Lauritzen Channel as follows:

- Hydrodynamic data, suspended solids, particle tracking, and sediment bed data were analyzed to determine transport and potential recontamination within the Lauritzen Channel. The analysis provided a key input to the FFS.
- Erosion potential was assessed using a propeller scour model to quantify sediment mixing depths and volumes during typical vessel operations. Model calibration and validation were accomplished using the bathymetric, sediment erosion, and suspended solids data.
- Sediment resuspension, transport, and deposition were modeled for the study site using the hydrodynamics model, Environmental Fluid Dynamics Code (EFDC). EFDC determined spatial and temporal patterns of resuspended sediment and associated contaminant transport in the Lauritzen and Santa Fe Channels. The primary goal of the modeling was to determine transport and deposition patterns of material resuspended during various anthropogenic events.
- The quantitative model was coupled with the analysis of the field data to refine the CSM and help provide answers to sediment management questions. The updated quantitative sediment and contaminant fate and transport CSM can guide the remedial alternative development and analysis in the FFS.

The Tier 2 evaluation uses data from previous investigations at the United Heckathorn site, field measurements from the summer of 2013 led by Sea Engineering, Inc. (SEI), and specific modeling analyses. This report is organized as follows:

- Site Description
- Tier 2 Field Efforts
- Sediment Transport Analysis
- Refined Sediment Transport CSM and Sediment Budget
- Summary and Sediment Management Questions

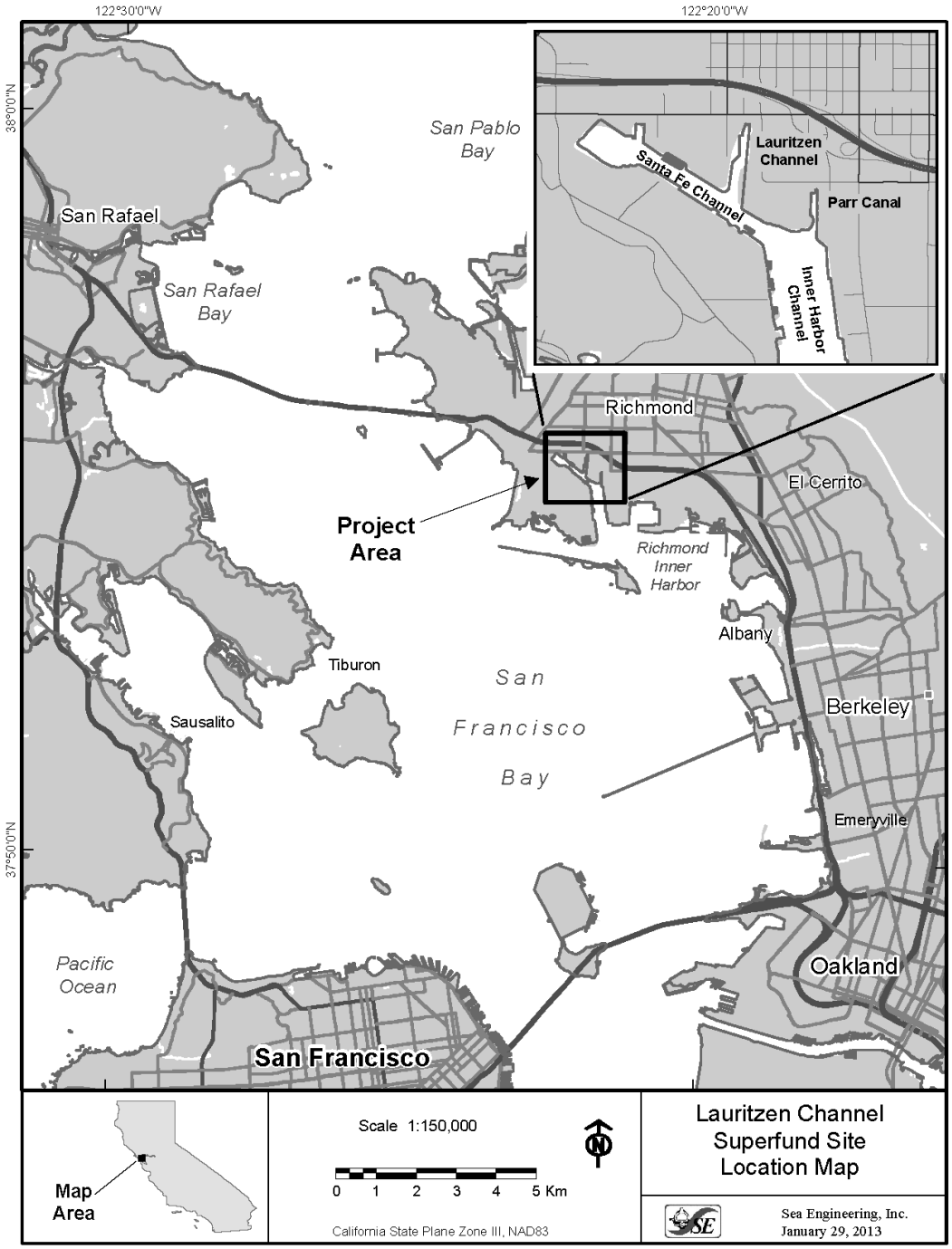


**Figure 1.Location of Richmond Harbor.**

## 2.0 Site Description

The Lauritzen Channel is a tidal waterway inside the Richmond Harbor on the eastern shoreline of central San Francisco Bay, California, USA. The Lauritzen Channel is a single spur inside the Richmond Harbor off of the Santa Fe Channel (Figure 1). The harbor was originally intertidal marsh that was dredged and filled in the 1920s to provide a deepwater berthing area for commercial and private vessels (White, Kohn, Gardiner, & Word, 1994). An extensive offshore breakwater provides protection from waves generated in the central San Francisco Bay and beyond. The tidal range in the harbor is approximately -0.6 to 2.1 m Mean Lower Low Water (MLLW). The shorelines of the harbor are generally armored with rip-rap, sandy gravel fill, or pile-supported structures (White, Kohn, Gardiner, & Word, 1994). The upland regions surrounding the harbor are generally level and at heights of 2.1 to 3.3 m MLLW. The Lauritzen Channel is approximately 0.5 km long and 40 m wide at the head widening to over 100 m at the mouth. The depths in the channel range from 3 to 12 m MLLW (Figure 2). Presently, Manson Construction Company occupies the western shoreline and the Levin Richmond Terminal occupies the eastern shoreline.

The most recent maintenance dredging of the Lauritzen Channel occurred in 1985. Between August 1996 and 1997, approximately 107,945 cubic yards of total sediment were removed from the Lauritzen Channel and the Parr Canal during remediation activities. Of the total amount, 105,325 cubic yards were removed from the Lauritzen Channel. The sediment was disposed of offsite at designated disposal facilities. Clean sand was placed to a nominal thickness of 6 inches over dredged portions of the Lauritzen Channel to facilitate colonization by benthic organisms (Chemical Waste Management Inc, 1997). A thicker layer of sand (approximately 18 inches) was reportedly placed in inaccessible areas that were impractical to dredge (i.e., areas with pilings). No sand was placed underneath the Levin pier because the slope was too steep to hold sand. The sand was hydraulically pumped from a barge into the channel. A bathymetric survey was performed after sand placement was completed; however, the distribution and thickness of the sand layer do not appear to have been verified. No other dredging activities have been conducted in the Lauritzen Channel since 1997.

A December 2012 site survey documented a number of small outfall pipes on the banks of the Lauritzen Channel (CH2M HILL, 2013(a)). One 1.5 m diameter concrete culvert at the northern end of the channel is a City of Richmond municipal outfall that provides the primary storm drainage from the surrounding area into the channel. Storm water runoff from the upland remediated area of the United Heckathorn site is monitored and discharged to City of Richmond publicly-owned treatment works (POTW). In October 2012, EPA installed a flap gate on the municipal outfall at the head of the channel to prevent DDT-contaminated sediment from moving into the storm drain system during high tide. The outfalls are described in detail in the *Source Identification Study Report* (CH2M HILL, 2013(b)).

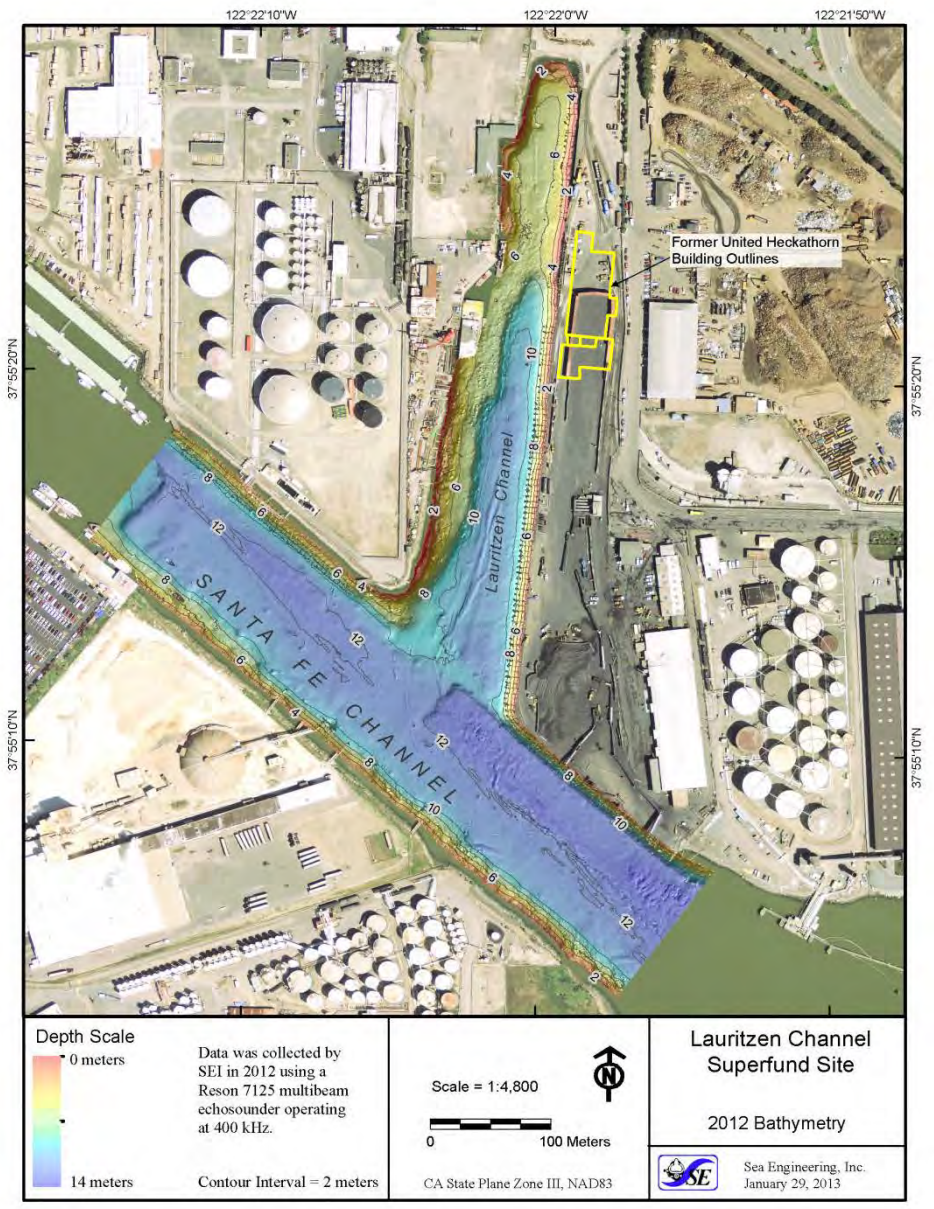


**Figure 2. Bathymetric map of the Lauritzen Channel and surrounding Santa Fe Channel.**

## 2.1 Sediment Bed

In 2012, SEI conducted high resolution multibeam bathymetric and sidescan sonar surveys to characterize the present state of the bottom sediment in the Lauritzen Channel. Figure 2 shows the results of the bathymetric survey. The survey clearly shows the extents of the dredged channel adjacent to the Levin terminal (Berths B and C), the shallower regions at the head of the channel, and the deeper dredged channels in the Santa Fe Channel with the deepest area on the south side of the Levin terminal (Berth A) to accommodate the largest ships in this portion of the Santa Fe Channel.

The bathymetric and side scan sonar surveys reveal features that form in response to processes occurring at the channel bottom. Features typical of scour by a vessel propeller or the keel of a vessel dragging along the bottom (i.e. linear furrowing) are evident in the survey. Further south in the channel, these linear furrow features become more evident, particularly in the deeper dredged channel. In the region of higher ship and associated tug activity near the Manson Construction and Levin facilities, there are more scour features. Of additional note are the "crater" features near the Manson facility. When Manson brings large crane barges into this area, the large vertical spuds are dropped into the sediment to anchor the barges in place. The craters are the bottom expression due to these spuds. Figure 3 provides delineation of these features by type developed as part of the Tier 1 analysis. The effects of these processes on sediment fate and transport are discussed later in this report.

Bathymetric survey data were used to characterize sediment accumulation in the Lauritzen Channel after remedial dredging was completed in 1997. Multiple partial bathymetric surveys were conducted between 1998 and 2007. These surveys were conducted using a lower resolution single beam surveying system and supporting detailed information regarding the survey procedures (e.g. survey equipment, benchmarks) is not available. However, comparison of bathymetric change was conducted to ascertain large changes in sediment bed elevation. Figure 4 shows the changes in the channel bed elevation between the 2007 and 2012 surveys. Overall, sediment accumulation is seen in the deep dredged berth near the Levin terminal. The shallower regions adjacent to the Manson facility show apparent sediment erosion. The northern portion of the channel generally exhibits sediment accumulation with some regions of erosion. While useful in visualizing general trends in accumulation, the uncertainty in the absolute elevations of these surveys does not allow for direct calculation of volume of sediment accumulated in the Channel.

Accumulation rates can be determined from the Younger Bay Mud (YBM) thickness identified in individual cores from coring efforts in 1999, 2003, 2007, and 2013[2]. The accumulated YBM volume is assumed to be representative of the new sediment accumulation since dredging for the datasets after the 2001 period. It is unknown what portion of the YBM represents new deposition prior to 2001. Multiplying the YBM thicknesses in the individual cores by the average solids densities of those cores provides a mass per unit area. By generating spatially-interpolated surfaces of thickness and density, sediment mass can be determined for each time period. The calculated sediment volumes and masses are shown in Table 1. On average, between 2001 and 2013, the channel experienced approximately 3,600 cy/year (2,752 $m^3$/yr) of sediment accumulation. Figure 5 shows the YBM mass interpolated over the channel. The northern end of the Levin berth has experienced the highest accumulation. One region near the shore of the Manson facility shows high YBM accumulation and the northern end of the channel shows moderate YBM accumulation. The northern shoreline of the Manson facility

[2] The 1999/2003 data were combined for analysis because the 2003 cores were intended to fill spatial data gaps in the 1999 core locations. The combined data set is referred to as 2001.

shows the lowest YBM accumulation consistent with the highest regions of disturbance (Figure 3).

**Table 1. YBM accumulation volume and mass in the Lauritzen Channel.**

| Year | YBM Volume (cy) | YBM Volume ($m^3$) | YBM Mass (kg) |
|---|---|---|---|
| **2001** | 22,862 | 17,467 | 15,731,336 |
| **2007** | 38,292 | 29,255 | 26,319,230 |
| **2013** | 66,163 | 50,549 | 45,478,880 |

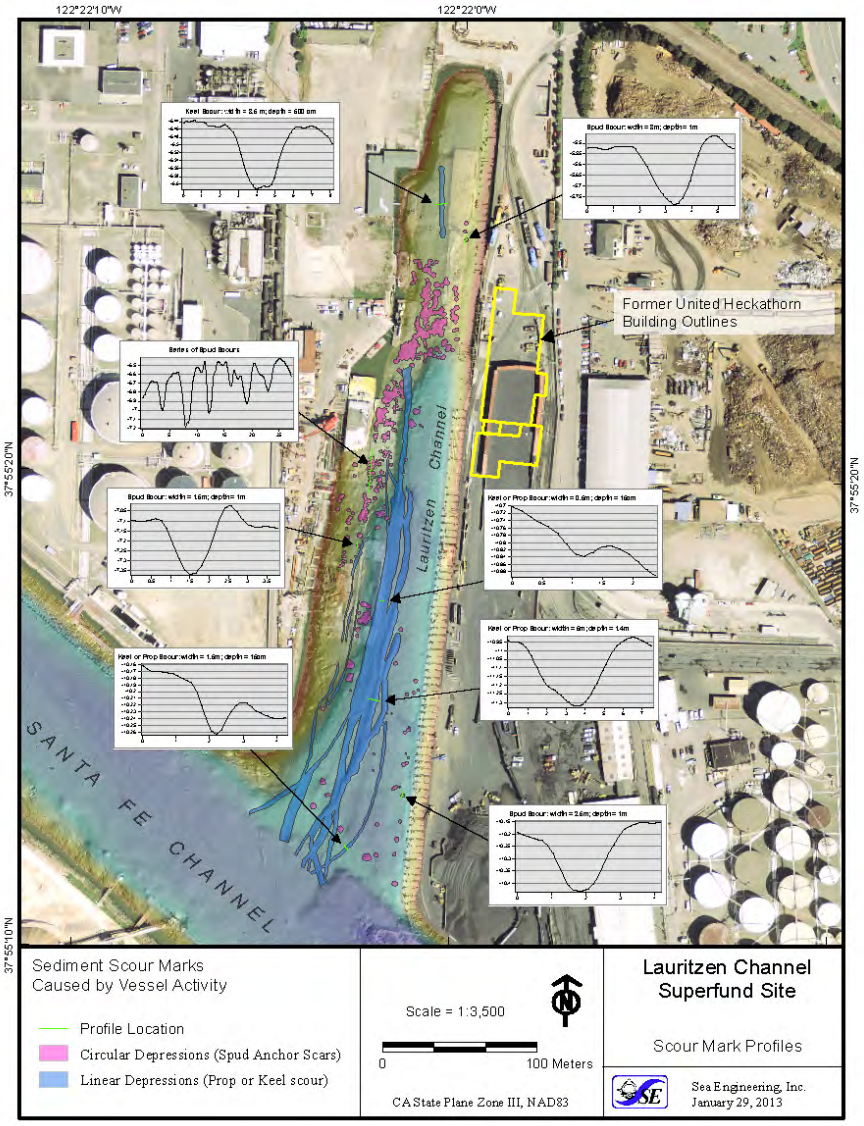


**Figure 3. Sediment disturbance due to vessel activity.**

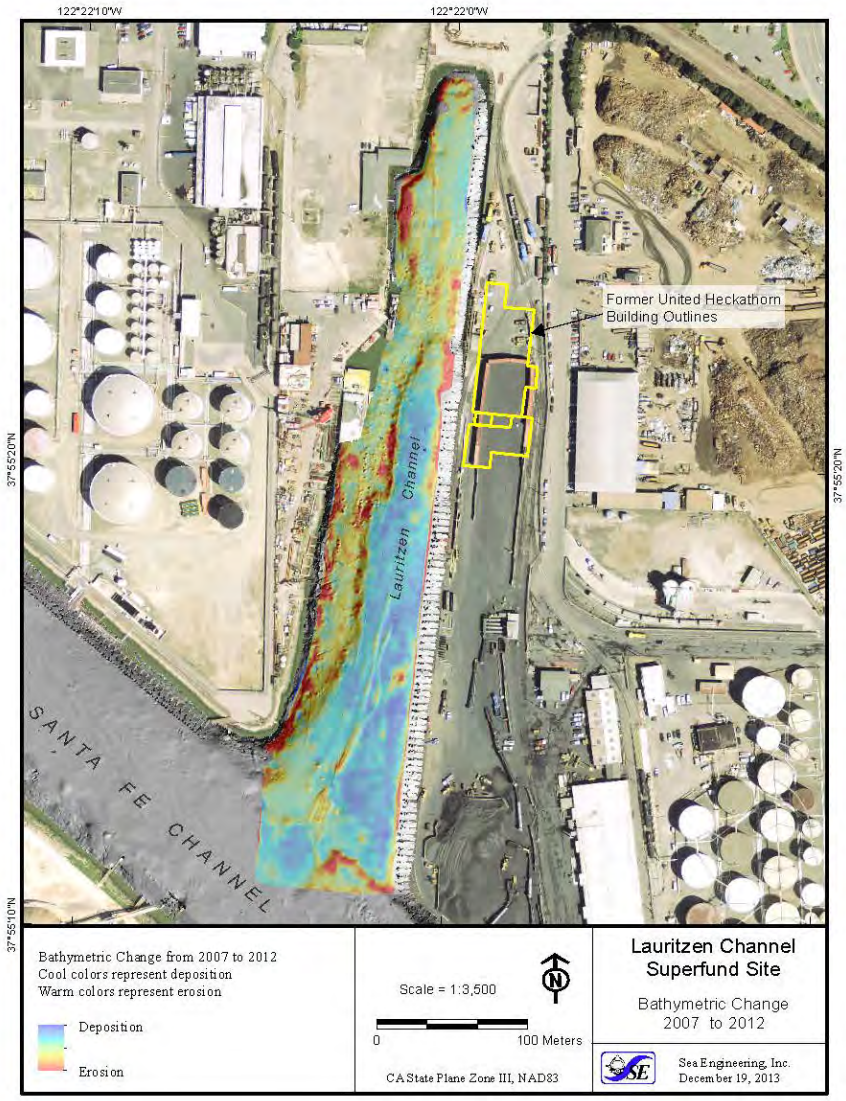


**Figure 4. Bathymetric Change from 2007 to 2012.**

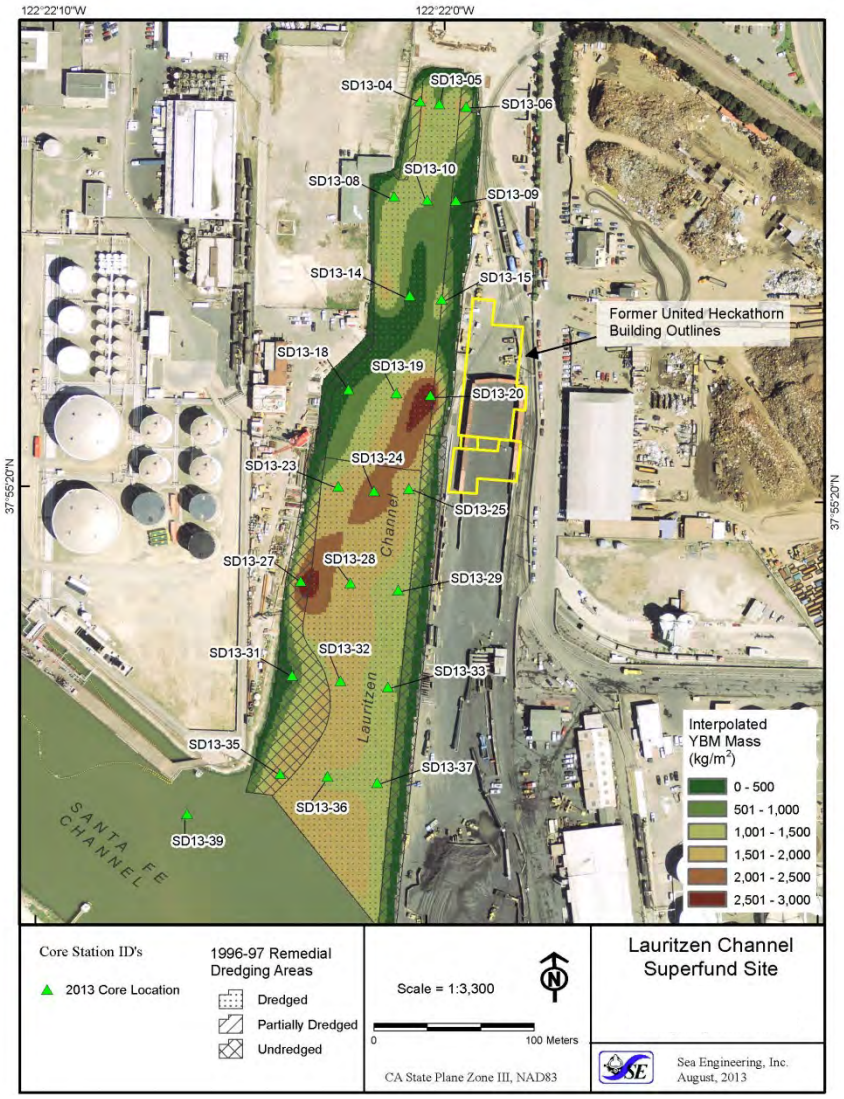


**Figure 5. Younger Bay Mud Mass in 2013.**

## 2.2 Tidal Hydrodynamics

The Lauritzen and Santa Fe Channels are manmade features designed to provide low energy environments for vessel berthing. The region is further protected from San Francisco Bay by an extensive offshore breakwater designed to block any waves into the area. In low energy protected harbors such as these channels, regional sediments tend to accumulate in the dredged channels. The deeper dredged channels in Richmond Harbor overall have historically required periodic dredging due to the generally depositional environment.

The Lauritzen Channel is dominated by the tidal hydrodynamics of San Francisco Bay. The region experiences a semi-diurnal tide from the Pacific Ocean. The tide generally results in two high and two low tides per day with a dominant tidal period of 12.42 hours (M2 semi-diurnal tidal constituent). Figure 6 shows an example of the local semi-diurnal tides. The average yearly tidal range in the harbor is approximately -0.6 to 2.1 m MLLW. Wave activity in the channel is negligible due to the offshore protection. Additionally, the narrow nature of the channels and relatively deep water negate the effects of any wave generation within the channels on hydrodynamics or sediment transport. The characteristics of the channels support the tidal dominance on circulation in the Lauritzen Channel.

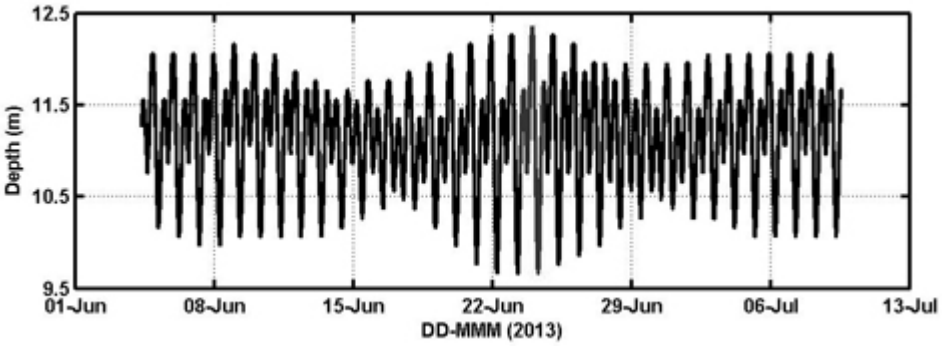


**Figure 6. Example pressure data illustrating semi-diurnal tidal variability.**

Determining the movement of water particles and their residence times in a tidal system can be calculated using a few characteristic values. The residence time is the most basic calculation. The Tier 1 analysis indicated that a parcel of water could remain in the Channel for approximately 2.5 days before being exchanged. For a small channel such as the Lauritzen, this is a fairly long residence time and the Channel could be considered to have low circulation.

Given the cross sectional area at the mouth of the channel and the tidal prism, the maximum tidal velocity in the Lauritzen Channel can be calculated. In the Tier 1 analysis, an average maximum velocity of approximately 1 cm/s was calculated as the depth-averaged velocity over the cross-section. Locally higher velocities can be driven by currents in the Santa Fe Channel, winds, and/or by abrupt changes in bathymetry; however, the basic analysis suggests that velocities are very low in the Lauritzen Channel.

For fine silt and clay such as the sediment in the Lauritzen Channel, a screening value of 0.1 Pa is commonly used for both the critical shear stress for erosion and deposition (Blake et al., 2007). A velocity of 1 cm/s generates a negligible shear stress; therefore, erosion due to the average tidal current is not expected. Furthermore, the low tidal shear stresses would allow sediment particles transported into the region to settle out. The deposition rates would be particularly high in the deepest, lowest velocity areas. Section 3 provides further details of the Tier 2 field studies developed to address sediment resuspension potential.

## 2.3 Anthropogenic Processes

The Lauritzen and Santa Fe Channels are active waterways with ship and barge berthing activities that have the potential to affect sediment transport patterns. In general, both transiting vessels and stationary vessels pushing against an object (pier or barge) can mobilize sediment. The potential for sediment transport in the Lauritzen Channel due to propeller scour is evaluated in Section 4.2.2.

# 3.0 Tier 2 Field Efforts

The purpose of the Tier 2 Sediment Transport Study field efforts was to further quantify the key processes involved in sediment transport in the Lauritzen Channel as informed by the Tier 1 analysis and with particular emphasis on the management questions. Specific project objectives and studies to address these objectives are listed below.

- Erosion potential of sediment due to natural and anthropogenic processes.
    - Tracer Study
    - Sedflume Analysis
- Magnitude and frequency of sediment resuspension and the magnitude and direction of net sediment flux.
    - Hydrodynamic and Water Quality Data Collection
    - Tracer Study
- Quantity of sediment transport in areas of high vessel activity.
    - Hydrodynamic and Water Quality Data Collection
    - Tracer Study

These studies are outlined in the following sections.

## 3.1 Hydrodynamic and Water Quality Data Collection

The primary objective of the hydrodynamic data collection was to determine the magnitude of tidal velocities in the system, identify sediment resuspension events, and determine the magnitude and direction of sediment flux. The following section outlines the field measurements.

### 3.1.1 Methods

SEI deployed two bottom-mounted mooring platforms, each equipped with a Teledyne RDI 1200 kHz Workhorse Sentinel Acoustic Doppler Current Profiler (ADCP) and a Yellow Springs, Inc. (YSI) water quality sonde with temperature, pressure, and optical turbidity probes (Figure 7). The ADCPs were mounted "uplooking" on bottom-mount platforms and programmed to collect data every 10 minutes at a vertical cell spacing of 0.25 m. The water quality sondes were fixed to the bottom-mount platforms. Water quality data were collected every 15 minutes at a height of 0.5 m above the seabed. The two instrumented platforms were deployed at the mouth and near the head of the Lauritzen Channel in approximately 11 m and 7 m mean water depth between 4 June and 9 July 2013 (Figure 8).

**Figure 7. Bottom-mount platform with ADCP and YSI water quality sonde indicated.**

**Figure 8 Location of ADCP Platforms and Transects**

Water samples for analysis of total suspended solids (TSS) were collected for the purpose of relating moored backscatter time series data to analytical TSS data over a range of tidal conditions. Water column profiles of particle size distribution (PSD) from surface to about 0.5 m above the bed were also collected near the two bottom-mounted platforms using a LISST-100X, type C. PSDs were measured between approximately 3 μm and 280 μm. The median particle diameter ($D_{50}$), 10$^{th}$ percentile ($D_{10}$), 90$^{th}$ percentile ($D_{90}$), and cumulative volume particle size distributions were computed from Laser in situ Scattering and Transmissometry (LISST) data.

A "downlooking" ADCP was mounted on the port side of the vessel and measured the spatial distribution of the vertical current profile in the system concurrently with a differential global positioning system (DGPS) for sub-meter scale location accuracy. The vessel-mounted ADCP was programmed to collect data at 0.25 m vertical bins. ADCP surveys were conducted on 4 and 5 June and 8 and 9 July 2013 following the three transect lines indicated in Figure 8. The ADCP transects were conducted in both directions (i.e. back and forth) across each transect line to reduce directional bias in the data.

Current meter and acoustic backscatter (ABS) data from the moored and mobile (i.e. vessel-mounted) ADCPs were used to calculate sediment flux at the mouth and head of the Lauritzen Channel. Sediment flux is generally defined as the product of flow rate, Q (units of volume per time), and TSS (units of mass per volume):

$$F = Q * TSS \qquad \text{Eq. 1}$$

where flux is represented by F and is in units of mass per time. TSS as a function of time and depth was derived from ADCP measured ABS (Downing, Thorne, & Vincent, 1995; Shulkin & Marsh, 1962; Thorne, Vincent, Hardcastle, Rehman, & Pearson, 1991; Gartner, 2004)). Briefly, ABS was computed from the ADCP-measured echo intensity (EI) following:

$$ABS = 10 \log_{10}(EI) + BS + WA \qquad \text{Eq.2}$$

where BS is the two-way transmission loss due to beam spreading and WA is the correction for the acoustic absorption of water. ABS was related to TSS determined in the laboratory from collected water samples, collocated with the ADCP.

Flow rate as a function of time and depth was obtained by correlating cross-channel flow rate measured by the vessel-mounted ADCP with current velocity measured by the moored, bottom-mounted ADCP at specific times of data collection. Least-squares linear regression analysis was employed to quantify the depth-dependent relationship between cross-channel flow rate, Q(z), and moored current velocity, U(z) for each of the 18 transects:

$$Q(z) = m(z) * U(z) + b(z) \qquad \text{Eq.3}$$

where m(z) and b(z) are the depth-dependent slope and y-intercept of the best-fit lines between Q(z) and U(z) at each bin, z. The slopes and intercepts, m(z) and b(z), were then applied to moored current velocity signals to derive time series of flow rate as a function of depth, Q(z). Sediment flux was computed as the product of Q and TSS.

More details regarding hydrodynamic and water quality data collection and results can be found in Appendix A.

### 3.1.2 Results

Measured current velocities were generally very low and varied with tidal oscillations (Figure 9). Current velocities were typically higher near the surface. Infrequent increases in current velocity were observed near the sediment bed. These maximal peaks in velocity extended from the bottom throughout the water column. Similar patterns were observed at both moored platform locations. The time-averaged depth-averaged velocity magnitude over the period of deployment was near 0.01 m/s at both the mouth and the head of the Lauritzen Channel (Table 2).

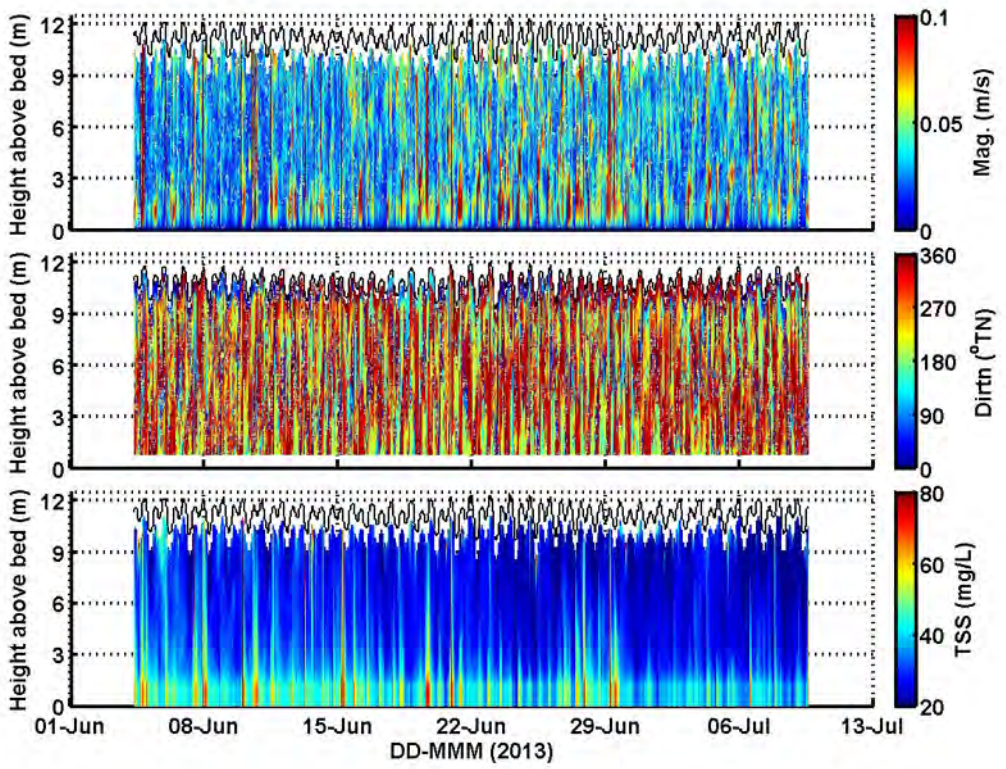


**Figure 9. Current velocity (upper), current direction (middle), and TSS (bottom) as a function of time and height above the sediment bed measured at the mouth of the Lauritzen Channel. Water depth is indicated with solid black lines.**

**Table 2. Statistics for depth-averaged hydrodynamics and sediment parameters measured by instrumentation moored at the mouth and the head of the Lauritzen Channel.**

| | Mean | Minimum | Maximum | Standard deviation |
|---|---|---|---|---|
| ***Mouth*** | | | | |
| Current velocity (m/s) | 0.01 | 0 | 0.24 | 0.01 |
| TSS (mg/L) | 29.7 | 20.1 | 92.8 | 5.0 |
| $D_{10}$ (μm) | 8.1 | 5.3 | 61.6 | 2.84 |
| $D_{50}$(μm) | 41.7 | 9.4 | 196.8 | 20.0 |
| $D_{90}$(μm) | 153.3 | 25.8 | 277.2 | 53.0 |
| ***Head*** | | | | |
| Current velocity (m/s) | 0.006 | 0 | 0.10 | 0.004 |
| TSS (mg/L) | 22.7 | 15.4 | 70.2 | 3.1 |
| $D_{10}$ (μm) | 7.15 | 5.3 | 118.0 | 5.5 |
| $D_{50}$(μm) | 36.0 | 10.3 | 179.8 | 20.2 |
| $D_{90}$(μm) | 141.9 | 26.8 | 282.7 | 50.5 |

Similar to most systems, TSS increased from minimal values at the surface to greater concentrations at the sediment bed. TSS appeared to vary with tidal oscillations and exhibited intermittent, high frequency spikes in concentration that decreased from high values at the bed to lower values near the surface (Figure 9). Time-averaged, depth-averaged TSS was greater at the mouth (29.7 mg/L) than at the head (22.7 mg/L) of the Lauritzen Channel (Table 2). Particle diameters were greater at the mouth as well; time-averaged, depth-averaged $D_{50}$ was 41.7 μm at the mouth and 36.0μm at the head of the channel (Table 2). The LISST measures the size of the in-situ particles in the water column including flocculated and unflocculated particles.

Sediment flux was minimal, as expected given the extremely low current velocities recorded in the Lauritzen Channel. Sediment flux variability, like current velocity, oscillated with the tides such that daily averaged sediment flux was negligible at both the mouth and head of the Channel (Figure 10). The total daily averaged sediment flux over the 34 day mooring deployment period was near zero kg/s at both locations. The near zero sediment flux was observed during a one-month dry period. Overall net accumulation in San Francisco Bay typically occurs during the wet fall and winter periods.

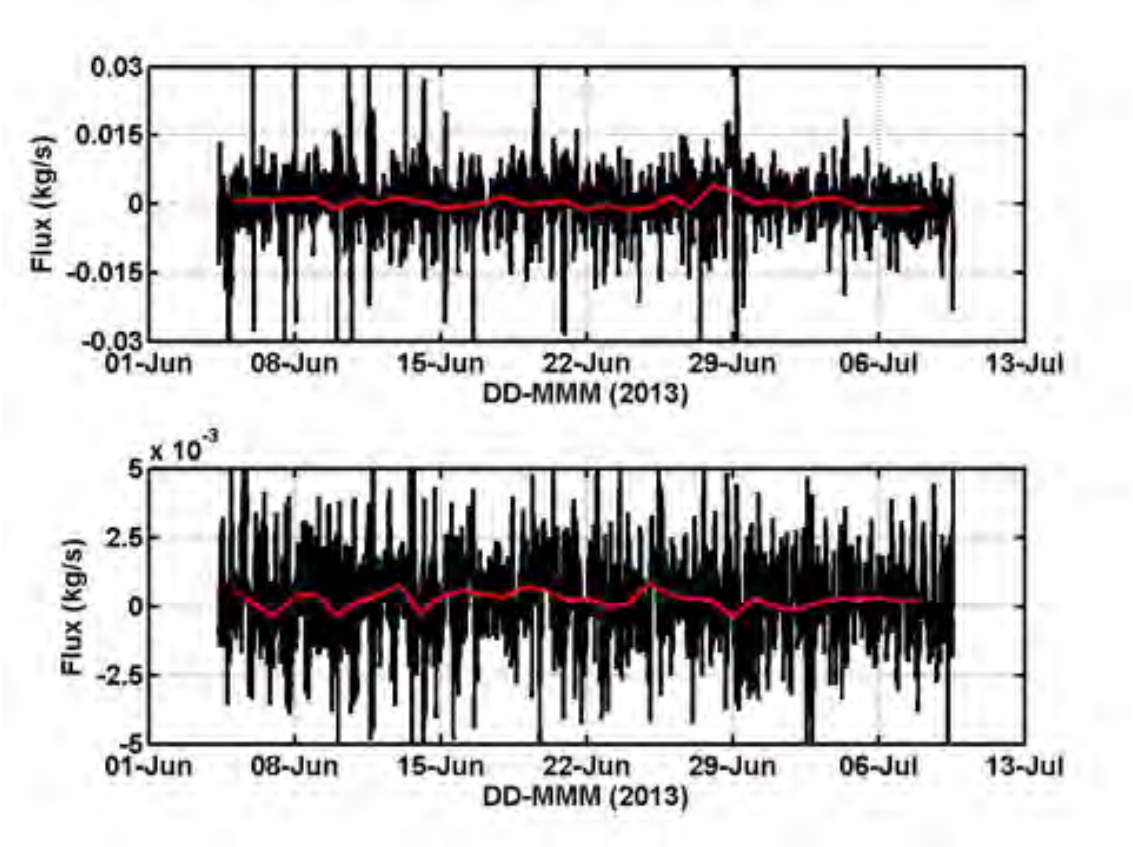


**Figure 10. Time series of sediment flux derived from mid-water column ADCP measurements at the mouth (upper panel) and head (lower panel) of the Lauritzen Channel. The red lines indicate daily averaged sediment flux.**

## 3.2 Tracer Study

Partrac Ltd. was contracted by SEI to provide sediment particle tracking services for the United Heckathorn Superfund Site to assess the fate of bottom sediment impacted by tidal currents and velocities associated with local propeller wash. Partrac developed a dual signature silt tracer of two colors (green and red). Tracer masses of 175 kg for each color were released in the form of low profile, frozen blocks onto the seabed at two locations in the central region of the Lauritzen Channel. Assessment of the mobilization and transport of the silt particles was achieved through the use of powerful, in situ moorings of permanent magnets and collection of sediment grabs. This methodology is otherwise known as Transport Pathway Evaluation (TPE).

TPE is a method in which a sediment transport pathway is visualized using a mass of uniquely labeled fluoro-magnetic (tracer) particles (White T. , 1998) . Tracer particles are released into the environment and subsequent capture of these particles in space and/or time provides information on the localized transport direction and rate (Black, Wilson, & Evans, 2007). TPE experiments require the manufacture of sediment analogues called ‘tracers’, which behave in a

similar way as native sediment. Partrac manufactures tracers with two unique signatures associated with every tracer grain – fluorescent color and magnetic character. These characteristics enable identification and extraction of tracers from environmental samples with the use of powerful (11,000 Gauss) bar-type magnets. Rarely are environmental particles found which are both fluorescent in color and magnetic; this thereby provides a firm foundation for the use of 'dual signature' tracers in tracking the movement of sediment.

A tracer specification for use in the studies was developed from particle size distributions reported in the Tier 1 study. The tracer specifications were:

- Size range: coarse-medium silt tracer (ca. 20 – 70 μm)
- Density: mineral density (~2300 – 2900 kg $m^{-3}$)
- Color; 2 fluorescent colors (red: green)
- Para-magnetic[3] attribute
- Quantity (kg): 175 kg x 2 (red: green)

Partrac manufactured two 175 kg tracer batches of differing color (red and green) according to this specification. The tracers met a series of underlying assumptions (see (Foster, 2000)):

- The tracer's hydraulic and bio-organic properties mimic those of the sediment of interest and therefore the tracer is transported in the same fashion as the native sediment.
- The tracer does not change properties through time (at least over the timescales of interest) and can be monitored.
- The tracer does not manifestly change the transporting system in any way.

Appendix B summarizes the characterization tests performed on the tracer.

### 3.2.1 Study Implementation

The tracer was delivered to SEI's office in 25 kg batches in moist form. During manufacture about 10-15% by mass seawater was added to each batch principally to reduce in advance surface active effects associated with the tracer, which substantially simplifies tracer deployment. It also saves time in the field as it means that the tracer batches, as delivered, can be frozen directly without intervention or addition of additional seawater. All delivered tracer was frozen for 2.5 days at 9°F. During this time small sub-samples of tracer were taken as archive samples.

A background site survey was undertaken as part of the TPE/sediment particle tracking methodology. The purpose of the background survey was to establish several conditions:

[3]Paramagnetism is a form of magnetism whereby the paramagnetic material is only attracted when in the presence of an externally applied magnetic field.

- The nature, and typical mass, of naturally magnetic (but non-fluorescent) particulates in the water column; this information is of generic use in regard to the use of suspended magnets to collect magnetic tracer material.
- The nature, and typical mass, of naturally magnetic (but non-fluorescent) particulates in the bedded sediment; this information is of generic use in regard to the analytical methodology used to determine tracer dry mass in sediment samples.
- The abundance, if any, of naturally occurring magnetic *and* fluorescent particulates at the site.
- The need to collect sediment material for use in preparation of standard curves within the analytical methodology.

The site survey utilized a suspended magnet and bottom sediment grab samples (1 upstream of the tracer drop zone, 1 downstream) prior to deployment of tracers on 13 June 2013.

### 3.2.2 Deployment

On 13 June 2013, each batch of the tracer was deployed. Frozen tracer blocks were rolled onto a tarpaulin sheet and wrapped up by rolling the sheet over the block several times (this minimized contact of the block with seawater on the way to the seabed); two operators then attached ropes to eyelets at the corners of the tarpaulin and gently and slowly lowered the block to the seabed. Once it was on the seabed the tarpaulin was then unrolled slowly leaving the block to slide onto the surface of the seabed. The tarpaulin sheet was then slowly recovered. The locations for each of the patches of the tracer deployed are presented in Figure 11.

Powerful cylindrical rare earth element (REE) magnets, either short (0.3 m; 1 foot) or long (0.6 m; 2 feet) in length, were utilized in this experiment. These were encapsulated in plastic sheaths with end caps and integrated on a mooring line suspended ~1 m and ~2 m above the bed. For 8 of the 12 the magnet moorings, a long magnet (0.6 m) was positioned near the bed (~1 m above the bed), and a short magnet positioned ~1 m above this. The remaining 4 of the 12 utilized two short magnets connected at ~1 m above the bed. In total, 12 magnet moorings were deployed largely around the periphery of the Lauritzen Channel (locations shown in Figure 11). The peripheral locations of the magnet moorings, while not optimal from a sampling standpoint, were necessary so as to not interfere with potential vessel traffic during the study.

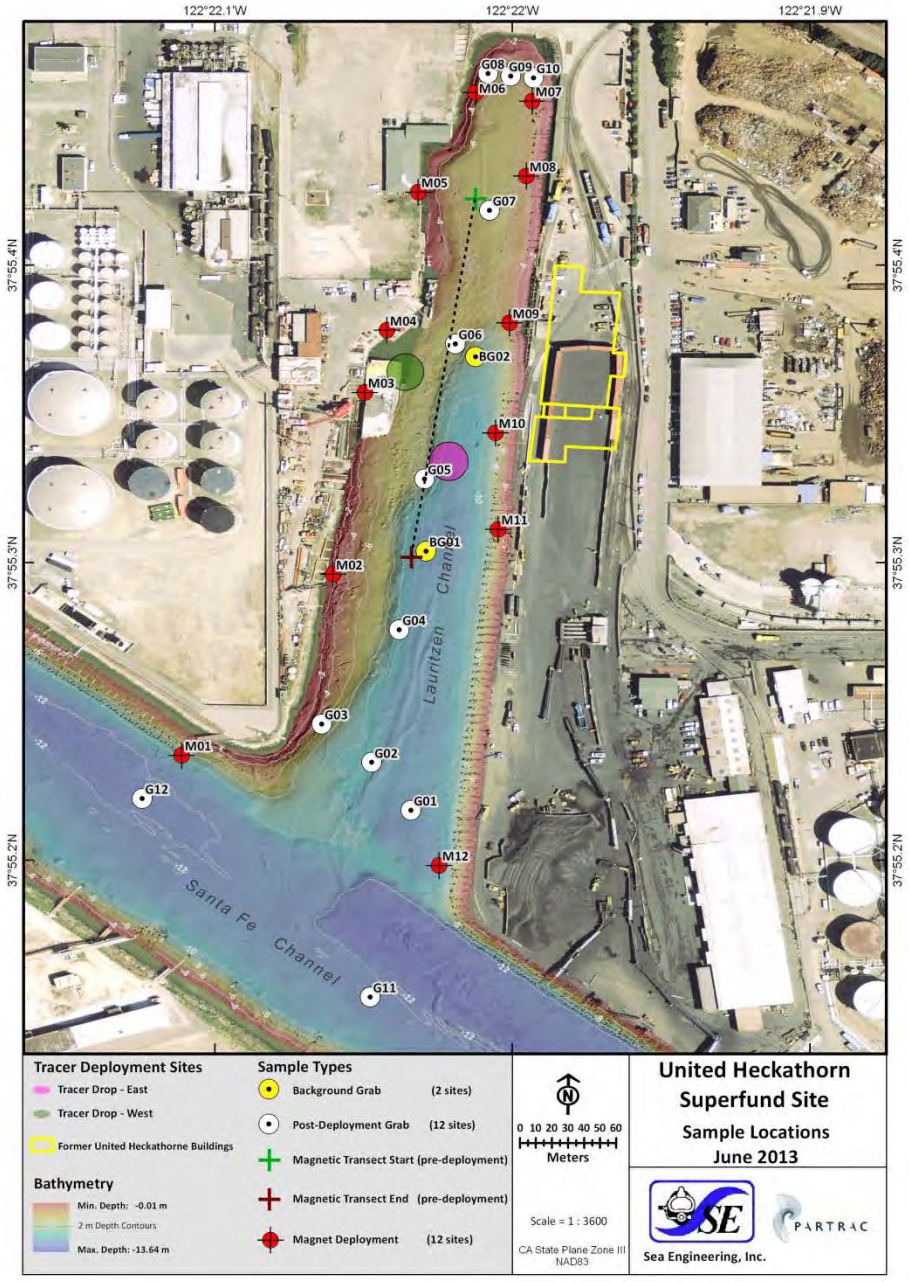


**Figure 11. Magnet moorings and grab sampling locations.**

### 3.2.3 Sampling

Sampling was conducted according to the following schedule:

- Day 0 (*t* = 0; 13 June 2013)
- Day 1 ( *t*= ~24 hours; 14 June 2013)
- Day 2 (*t* = ~48 hours; 15 June 2013)
- Day 4 ( *t*= ~76 hours; 17 June 2013)

- Day 6 (*t* = ~120 hours; 19 June 2013)
- Day 14 (*t* = ~336 hours; 25 June 2013).

All the magnets were serviced and grabs of bed sediment at a series of pre-determined locations (Figure 11) were collected following the scheduled outlined above. Servicing of the magnets involved recovery of the mooring line, careful removal of the sheath of each magnet, and transfer of the sheath to a sample bag, followed by installation of a new clean sheath. The magnet moorings were recovered from the water on Day 14.

Grab samples of bed sediment were collected with a small petit-ponar-style grab. Upon recovery, each sample was inspected to assess that the suitable sample had been retrieved and the surface material of the grab sampler to a depth of 2-3 cm was scooped off with a stainless steel spoon and transferred to a labeled sample bag.

### 3.2.4 Results

Samples were analyzed according to Partrac procedures outlined in Appendix B. Standard (dose response) curves were developed to relate fluorimetric measurements taken on each sample to tracer dye concentration over the range of dry masses (0 – 1 g) as follows: (0.0 g; 0.1 g; 0.2 g; 0.3 g; 0.4 g; 0.5 g; 0.6 g; 0.7 g; 0.8 g; 0.9 g and 1 g)(Figure 12). Results and qualitative visual descriptions (inspection under black light) are given for every sample in Appendix B.

Figure 12 shows the results of the recovered mass from the periodic sampling during the tracer study. Generally, tracer detected on the magnets (samples along the channel sides) showed material that had been resuspended and transported to a particular magnet between each deployment. The magnet sheaths were replaced between each sampling event. The grab samples (samples designated with a G) showed material that had accumulated at the sampled location since tracer deployment on day 1. It is important to note that the grab sample locations can vary by up to 5 m on sampling events possibly resulting in detection of tracer in one event followed by a non-detect in the next.

- Day 2 showed minimal detection of red tracer on the magnets and 5 detects of green tracer on the east side of the channel while over 60% of the grab samples showed both red and green tracer.
- Day 3 showed 8 samples of red in the upper channel and 90% of the magnets with green samples while over 60% of the grab samples showed both red and green.
- Day 4 showed 5 detects of red and 9 detects of green in the upper and west side channel magnets. Over 66% of the grab samples showed red and green.
- Day 6 showed 1 detect of red and 1 detect of green on the west side channel magnets near the deployment site. Approximately 40% of the grab samples showed red and over 50% show green.
- Day 14 showed 5 detects of red and 12 detects of green in the upper and west side channel magnets. Over 75% of the grab samples showed red and 100% showed green.

Overall the particle tracking study provided important insight into the extents of local sediment transport. It was evident that during every sampling period, tracer was redistributed from both sources in the channel. The magnets generally showed that material resuspended in the water column can be transported into the upper and west side of the channel and occasionally (2 events) along the east side. The grab samples generally all showed tracer presence from both sources throughout the sampling period. By the end of the sampling period, 75% of the samples contained tracer from the deeper red deployment site, while 100% of the samples contained tracer from the shallow green deployment site.

Since tidal currents have been demonstrated as an unlikely source of resuspension, vessel traffic (primarily tug and barge movement on the west side of the channel) was the likely source of tracer movement and responsible for tracer distribution in the channel sediment. In particular, day 3 sampling showed 90% of the magnets with green tracer, which is likely indicative of tug movement over the green deployment location that resulted in tracer dispersal throughout the water column. During this same time period, approximately 60% of the grab samples showed green tracer. The magnet outside the channel showed 2 green detections and grabs showed detection of both red and green material at generally low levels, indicating that there was some level of suspended solids transport out of the channel that was further evaluated in the modeling analysis.

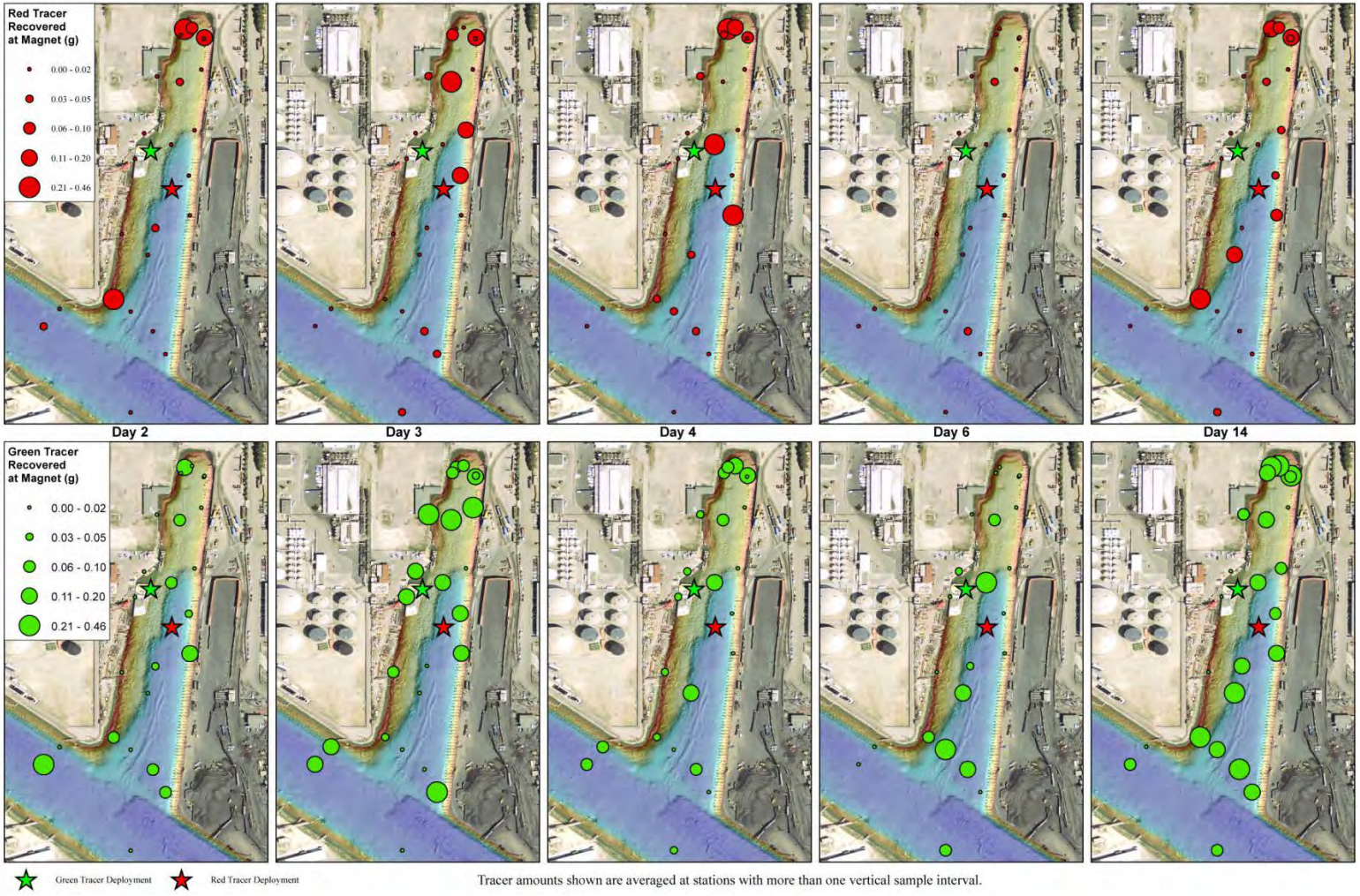


**Figure 12. Mass recovered from magnets and grab samples during the particle tracer study.**

## 3.3 Sedflume Analysis

Morphological bed changes in any aquatic system are dictated by complex and dynamically linked relationships between biological activity, hydrodynamic forcing, and sediment characteristics. When analyzing the sediment transport occurring within a system, numerous variables must be considered; one key aspect is the erosion properties and stability of a site's sediment. SEI conducted a Sediment Erosion at Depth Flume (Sedflume) analysis on 10 sediment cores (named SF01 through SF10) obtained from the Lauritzen Channel. The cores were collected in water depths ranging between 5.8 m to 7.9 m. The primary goal of the work was to characterize the erosion rates and physical properties of the sediment within the study area. The cores were eroded during the Sedflume analysis to determine erosion rates as a function of shear stress and depth. In addition, each core was sub-sampled to determine sediment bulk density and particle size distribution at specific depths within the core. Critical shear stresses were also deduced over five vertical intervals in each core.

### 3.3.1 Core Collection

The ten sediment cores were collected by SEI personnel on 10 and 11 July 2013. At each coring location, a DGPS was used to position a vessel at pre-determined, fixed sampling stations in the Lauritzen Channel. The 10 coring locations are shown in Figure 13; the white squares represent the coring locations. A pole was attached with clamps to a 10 cm by 15 cm rectangular core tube. The core tube was lowered into the water and positioned perpendicular to the sediment bed. Pressure was applied by hand until at least 30 cm and no more than 60 cm of the core tube penetrated into the sediment bed. A valve affixed to the top of the core tube was temporally closed to provide suction when the core was pulled out of the sediment bed. The sediment bed near the mouth of the channel (SF08, SF04, SF05, SF03 and SF09) was stiff and required additional force from a fence-post hammer to achieve core penetration; smaller than 30 cm cores were kept if several core attempts were made at a location and each resulted in recoveries less than 30 cm.

After cores reached the water surface, they were visually inspected for length and quality. Undisturbed cores were capped and secured to minimize sediment disturbance from sloshing water and vessel/vehicle motion. Cores were then transferred from the vessel to land and packed in secure Sedflume core shipping boxes. The cores were then driven by SEI personnel to SEI's EPA certified Sedflume laboratory in Santa Cruz, California. Upon arrival, the cores were again visually inspected to ensure that the sediment structure and surface had been preserved. The cores were then placed in an ambient water bath for preservation until processing.

### 3.3.2 Core Processing

All Sedflume processing and bulk sediment sampling and measuring (bulk density, Loss on Ignition, and particle sizing) was conducted in SEI's Santa Cruz laboratory. For a complete description of Sedflume and the processing techniques used in the analysis, see Appendix C.

Briefly, each core was processed by first inserting the core barrel and the sediment it contained into the bottom of the Sedflume (

Figure 14). The sediment surface was aligned with the bottom of the Sedflume channel. When fully enclosed, water was forced through the flume and over the sediment surface. The shear stress produced by the flow, and imparted on the particles, causes the sediment to erode. As the sediment on the surface of the core eroded, the remaining sediment in the core barrel was slowly moved upward so that the sediment-water interface remained level with the bottom of the flume. The sediment was moved upward by a piston that was inside the core barrel and was in contact with a hydraulic jack. The jack was driven by the release of pressure that was regulated with a switch and valve system controlled by an operator.

At the start of each core analysis an initial reference measurement was made of the starting core length. The flume was then operated at a specific flow rate corresponding to a particular shear stress, and sediment was eroded. As erosion proceeded, the core was raised if needed to keep the core's surface level with the bottom of the flume. This continued until 10 minutes had passed, or the core had been raised roughly 2 cm. The erosion rate for the applied shear stress was then calculated as:

$$E = \Delta z/T \qquad \text{Eq.4}$$

where E is the Erosion rate, Δz is the amount that the sediment was raised during a particular measurement period, and T is the measurement time interval. Critical shear stresses were then computed for each interval by first fitting the erosion rates to a power law following methods outlined by Roberts (1998)

$$E=A\,\tau^{n} \qquad \text{Eq.5}$$

where τ is the bed shear stress, A, n are constants that depend on the sediment characteristics. Once A and n values were calculated, a critical shear stress was determined by setting the erosion rate equal to $10^{-4}$ cm/s (operational definition for critical shear stress). The calculated critical shear stress was then checked against the measured erosion rates and a threshold was applied if necessary. Bulk sediment properties and critical shear stress values for each core interval are presented in Table 3. For both qualitative and quantitative details on each core, including cores pictures, core descriptions, and erosion rate and bulk sediment property data, see Appendix C.

### 3.3.3 Results

The erosion rates of Sedflume cores were highly variable due to inconsistent particle characteristics throughout the cores. The presence of detritus, pebbles, and shells often acted to armor the sediment bed until the applied shear stress was large enough to mobilize these larger particles. When high concentrations of organic material were present in a core, erosion

was often dominated by the mobilization of large chunks of material as organic pieces lifted from the bed surface, while mobilizing the sediment below.

Although erosion rates fluctuated between core intervals, core sediment generally stiffened with depth. This trend is common for sites with cohesive sediment. Calculated critical shear stresses ranged from 0.1 Pa to 1.28 Pa. Cohesive sediment will often self-compact due to the weight of the overlying material. Compaction reduces the potential for sediment mobility. However, Sedflume results must be analyzed in conjunction with other system characteristics, such as hydrodynamic forcing and bed coarsening to assess overall site stability and sediment transport trends.

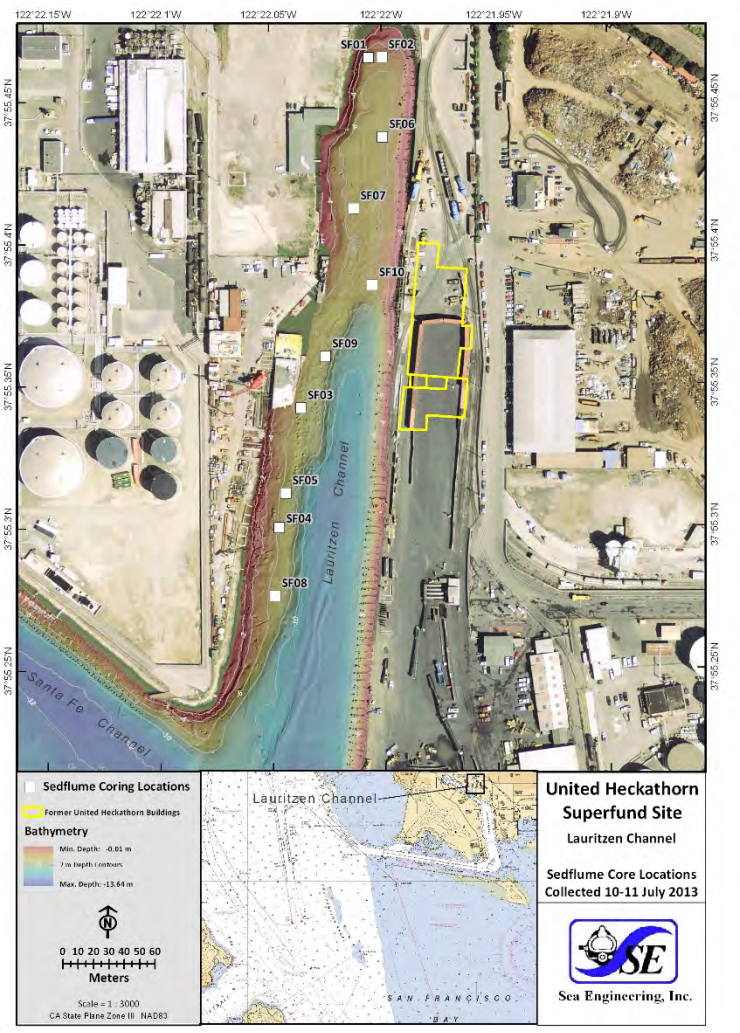


**Figure 13. Map of Sedflume coring locations.**

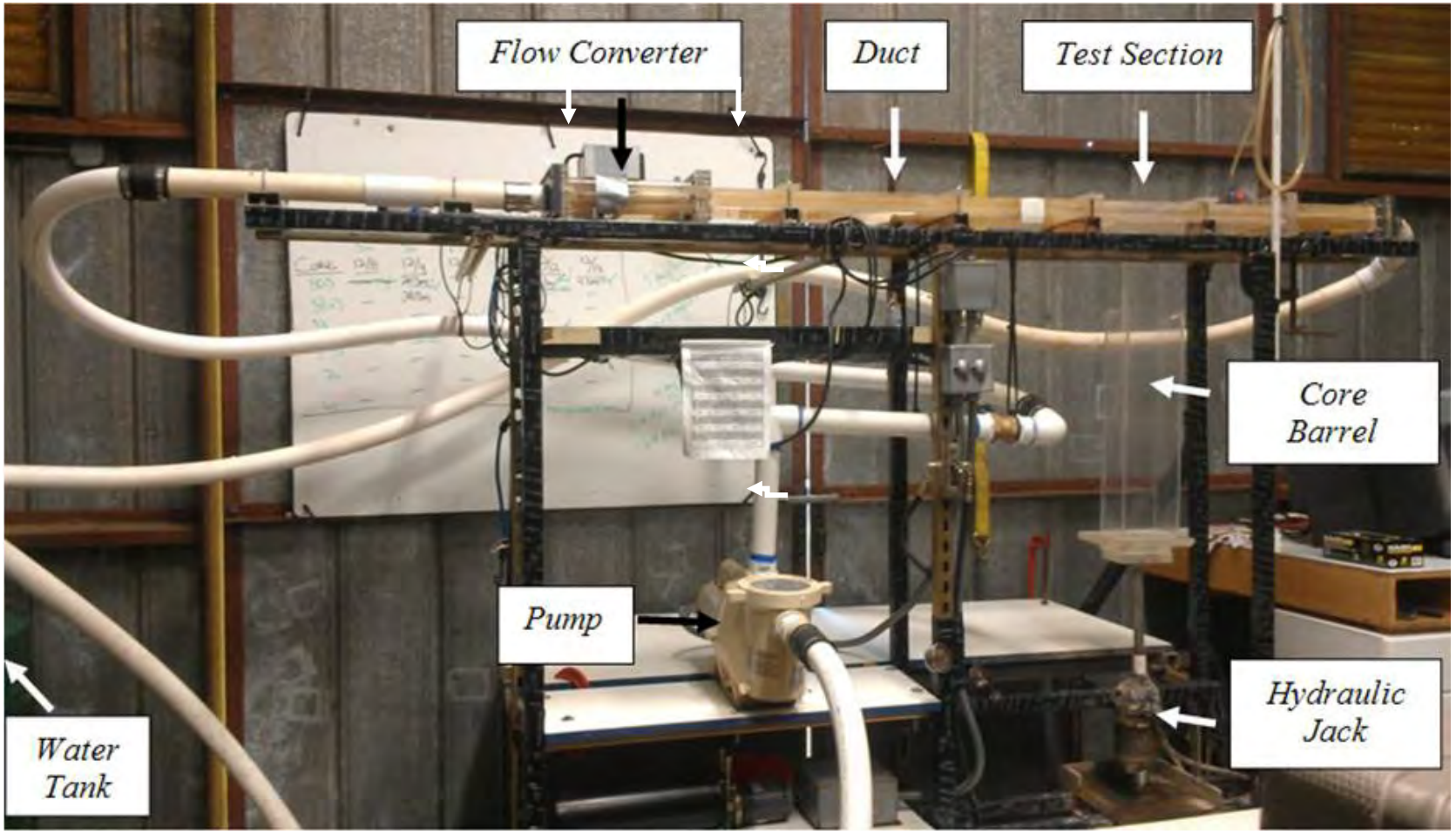


**Figure 14. Sedflume in the Santa Cruz, CA, SEI laboratory.**

**Table 3. Sediment properties and critical shear stress by core interval measured during the Sedflume analysis.**

| | | Core ID | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **SF1** | **SF2** | **SF3** | **SF4** | **SF5** | **SF6** | **SF7** | **SF8** | **SF9** | **SF10** |
| | Lat (N) | 37.9244 | 37.9244 | 37.9224 | 37.9217 | 37.9219 | 37.9240 | 37.9235 | 37.9213 | 37.9227 | 37.9231 |
| | Long (W) | -122.3668 | -122.3667 | -122.3673 | -122.3675 | -122.3674 | -122.3667 | -122.3669 | -122.3675 | -122.3671 | -122.3668 |
| Starting Depth (cm) | Interval 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Interval 2 | 5.60 | 6.90 | 8.90 | 5.30 | 8.60 | 6.80 | 8.20 | 4.00 | 3.10 | 5.30 |
| | Interval 3 | 10.80 | 14.60 | 14.00 | 10.80 | 15.60 | 13.80 | 15.00 | 12.90 | n/a | 13.10 |
| | Interval 4 | 13.30 | 24.40 | 19.00 | 14.30 | 22.30 | 19.00 | 22.90 | n/a | n/a | 21.30 |
| | Interval 5 | 19.50 | 26.40 | 28.50 | 18.00 | 27.20 | 21.20 | N/A | n/a | n/a | 30.60 |
| D10 (um) | Interval 1 | 2.406 | 2.109 | 1.497 | 1.585 | 1.616 | 1.512 | 1.570 | 1.576 | 1.674 | 1.953 |
| | Interval 2 | 1.683 | 2.970 | 1.655 | 1.554 | 1.646 | 1.461 | 1.431 | 1.651 | 1.685 | 1.864 |
| | Interval 3 | 1.580 | 2.130 | 1.610 | 1.629 | 1.870 | 1.742 | 1.753 | 1.555 | n/a | 1.605 |
| | Interval 4 | 2.046 | 2.126 | 1.658 | 1.853 | 1.426 | 1.573 | 1.976 | n/a | n/a | 1.708 |
| | Interval 5 | 2.019 | 2.121 | 1.658 | 1.889 | 1.650 | 1.625 | 1.541 | n/a | n/a | 1.985 |
| D50 (um) | Interval 1 | 14.90 | 18.10 | 5.73 | 6.43 | 6.70 | 5.56 | 6.04 | 6.21 | 7.99 | 9.48 |
| | Interval 2 | 6.77 | 53.89 | 6.97 | 6.23 | 6.88 | 6.52 | 5.40 | 7.63 | 9.16 | 7.98 |
| | Interval 3 | 6.80 | 11.70 | 6.80 | 7.09 | 11.49 | 6.51 | 7.39 | 6.92 | n/a | 7.14 |
| | Interval 4 | 9.80 | 10.07 | 6.58 | 8.78 | 14.42 | 5.79 | 9.31 | n/a | n/a | 6.89 |
| | Interval 5 | 8.79 | 11.26 | 6.74 | 9.13 | 8.40 | 6.31 | 6.01 | n/a | n/a | 10.09 |
| D90 (um) | Interval 1 | 163.40 | 369.30 | 26.97 | 38.48 | 57.84 | 22.94 | 27.02 | 34.20 | 56.91 | 110.90 |
| | Interval 2 | 38.41 | 530.60 | 43.93 | 34.35 | 56.71 | 25.92 | 24.18 | 128.90 | 55.85 | 67.87 |
| | Interval 3 | 41.79 | 239.30 | 44.12 | 59.70 | 124.40 | 36.30 | 72.69 | 86.70 | n/a | 62.41 |
| | Interval 4 | 90.57 | 130.70 | 30.08 | 65.90 | 38.31 | 34.27 | 90.46 | n/a | n/a | 38.34 |
| | Interval 5 | 86.35 | 130.20 | 53.07 | 59.50 | 197.20 | 38.44 | 33.82 | n/a | n/a | 112.70 |
| Dry Bulk Density ($g/cm^3$) | Interval 1 | 0.20 | 0.16 | 0.13 | 0.28 | 0.36 | n/a | 0.17 | 0.35 | 0.40 | 0.32 |
| | Interval 2 | 0.34 | 0.09 | 0.49 | 0.52 | 0.64 | 0.29 | 0.29 | 0.67 | 0.61 | 0.28 |
| | Interval 3 | 0.34 | 0.32 | 0.73 | 0.79 | 1.22 | 0.29 | 0.32 | 0.76 | n/a | 0.38 |
| | Interval 4 | 0.29 | 0.26 | 0.52 | 0.50 | 1.01 | 0.34 | 0.42 | n/a | n/a | 0.38 |
| | Interval 5 | 0.35 | 0.36 | 0.41 | 0.43 | 1.27 | 0.36 | 0.43 | n/a | n/a | 0.51 |
| Critical Shear Stress (Pa) | Interval 1 | 0.10 | 0.10 | 0.20 | 0.10 | 0.20 | 0.22 | 0.10 | 0.43 | 0.10 | 0.20 |
| | Interval 2 | 0.80 | 0.20 | 0.80 | 1.04 | 0.55 | 0.20 | 0.21 | 0.51 | 0.22 | 0.40 |
| | Interval 3 | 0.80 | 0.80 | 0.40 | 0.86 | 0.20 | 0.82 | 0.20 | 0.61 | n/a | 0.53 |
| | Interval 4 | 0.47 | 0.40 | 0.40 | 1.28 | 0.51 | 0.80 | 0.40 | n/a | n/a | 0.40 |
| | Interval 5 | 0.52 | 0.40 | 1.03 | 0.40 | n/a | n/a | n/a | n/a | n/a | 0.80 |
| A | Interval 1 | 0.00358 | 0.02688 | 0.00127 | 0.00301 | 0.00201 | 0.00161 | 0.00321 | 0.00060 | 0.01660 | 0.00054 |
| | Interval 2 | 0.00081 | NA | 0.00026 | 0.00008 | 0.00058 | 0.00649 | 0.00411 | 0.00037 | 0.00652 | 0.00049 |
| | Interval 3 | n/a | 0.00238 | 0.00189 | 0.00021 | 0.00772 | 0.00028 | 0.00235 | 0.00029 | n/a | 0.00054 |
| | Interval 4 | 0.00072 | NA | 0.00096 | 0.00002 | 0.00191 | n/a | 0.00112 | n/a | n/a | 0.00036 |
| | Interval 5 | 0.00075 | 0.03342 | 0.00008 | n/a | n/a | n/a | n/a | n/a | n/a | 0.00028 |
| n | Interval 1 | 1.9 | 2.6 | 1.7 | 2.0 | 2.0 | 1.8 | 1.7 | 2.1 | 2.2 | 1.4 |
| | Interval 2 | 2.5 | NA | 3.0 | 4.9 | 2.9 | 1.7 | 2.3 | 2.0 | 2.8 | 1.0 |
| | Interval 3 | n/a | 4.9 | 2.9 | 5.0 | 2.5 | 5.3 | 1.7 | 2.1 | n/a | 2.7 |
| | Interval 4 | 2.6 | NA | 2.0 | 7.1 | 4.4 | n/a | 2.5 | n/a | n/a | 1.3 |
| | Interval 5 | 3.1 | 3.4 | 6.4 | n/a | n/a | n/a | n/a | n/a | n/a | 3.0 |

# 4.0 Sediment Transport Analysis

The sediment transport analysis performed to determine processes contributing to sediment resuspension and transport in the Laurtizen Channel included the following elements:

- Erosion potential of sediment due to natural and anthropogenic processes.
    - Natural Sediment Transport
    - Anthropogenically Forced Sediment Transport
- Magnitude and frequency of sediment resuspension and the magnitude and direction of net sediment flux.
    - Natural Sediment Transport
- Quantity of sediment transport in areas of high vessel activity.
    - Anthropogenically Forced Sediment Transport
    - Hydrodynamic Model

The hydrodynamic and sediment transport discussions primarily utilize data collected at 1-m above the sediment bed (Table 4) as these are representative of the near-bed processes important to sediment transport. As expected, due to natural settling of particles in the water column, TSS concentrations were greater and particle size was larger near the bed than for depth-averaged values. The low mean current velocities (3 cm/s and lower) are consistent with the theoretical calculations performed in the Tier 1 sediment transport study.

**Table 4. Statistics for hydrodynamic and sediment parameters collected within 1-m above the sediment bed at the mouth and the head of the Lauritzen Channel.**

| | Mean | Minimum | Maximum | Standard deviation |
|---|---|---|---|---|
| ***Mouth*** | | | | |
| Current velocity (m/s) | 0.03 | 0 | 0.17 | 0.02 |
| TSS (mg/L) | 42.5 | 25.2 | 129.0 | 7.9 |
| $D_{10}$ (μm)* | 10.5 | 6.6 | 15.7 | 1.7 |
| $D_{50}$(μm)* | 60.7 | 25.2 | 128.2 | 21.8 |
| $D_{90}$(μm)* | 190.4 | 77.5 | 274.4 | 50.2 |
| ***Head*** | | | | |
| Current velocity (m/s) | 0.02 | 0 | 0.11 | 0.01 |
| TSS (mg/L) | 28.2 | 18.1 | 84.5 | 4.2 |
| $D_{10}$ (μm)* | 7.9 | 5.5 | 12.4 | 1.5 |
| $D_{50}$(μm)* | 41.7 | 18.9 | 106.1 | 15.5 |
| $D_{90}$(μm)* | 150.9 | 48.8 | 254.6 | 48.4 |

*Particle size data within 2-m of the sediment bed were averaged prior to computing statistical parameters.

## 4.1 Natural Sediment Transport

The principal tidal constituents in San Francisco Bay are the M2 semi-diurnal and K1 diurnal tides (Cheng & Gartner, 1984). The tidal periods of the M2 and K1 tide are approximately 12.42 hours and 23.9 hours, respectively. Therefore, in order to investigate tidal oscillations in hydrodynamic and sediment time series, data were band-pass filtered[4] between 8-hr and 30-hr cutoff frequencies. Results indicated that band-pass filtered TSS generally increased during flood tide and decreased during ebb tide (Figure 15). The magnitude of variability of TSS was dependent on tidal phase. Spring tide produced greater TSS variability, with differences of nearly 30 mg/L between low and high tide (Figure 15). The average standard deviation of TSS at 1-m above the sediment bed was 7.88 mg/L (Table 4).

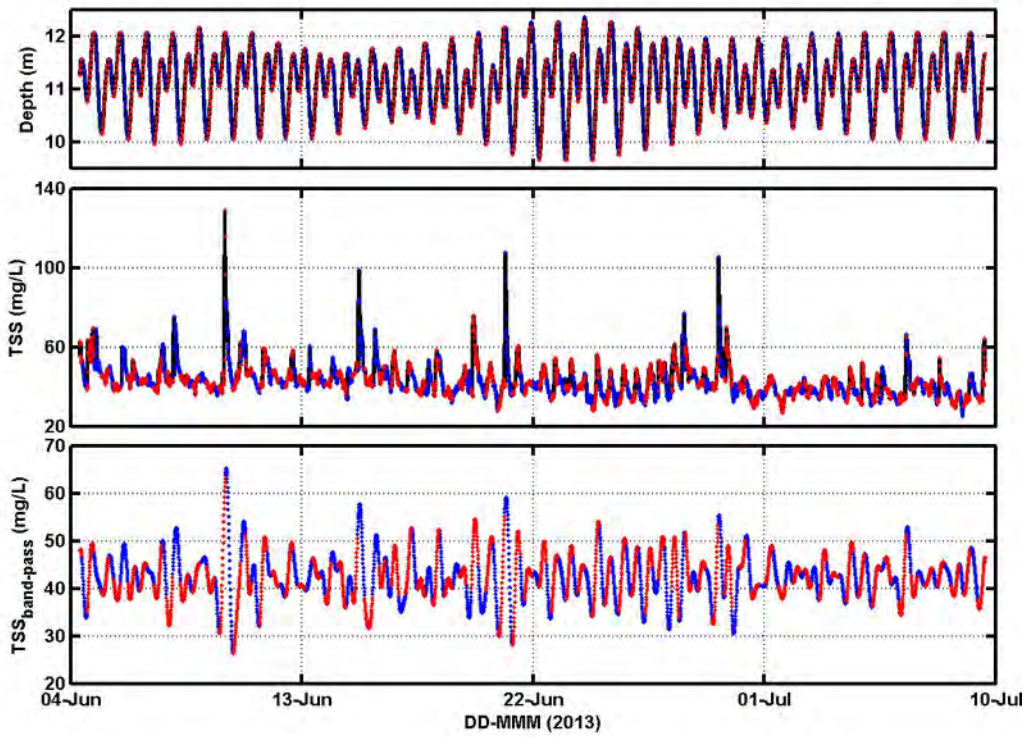


**Figure 15. Time series of water depth (upper), TSS (middle), and band-pass filtered TSS (lower) collected within 1-m above the sediment bed at the mouth of the Lauritzen Channel. Red indicates flood tide periods and ebb tide periods are illustrated in blue.**

[4] A band-pass filter passes frequencies within a certain range (within the cutoff frequencies) and rejects frequencies outside that range.

Quantitative evidence of the relationship between hydrodynamic processes and sediment movement was provided by statistical coherence[5] between TSS and tidal variability (water depth) and between computed sediment flux (the product of ADCP-derived flow rate and sediment concentration, or TSS) and tidal variability. Statistically significant coherence (95% confidence interval) was found at periods of ~12.5 hrs for TSS and at ~12.5 hrs and ~23.5 hrs for sediment flux (Figure 16). These periods coincided with the periods of the principal tidal constituents (M2 and K1) found in San Francisco Bay.

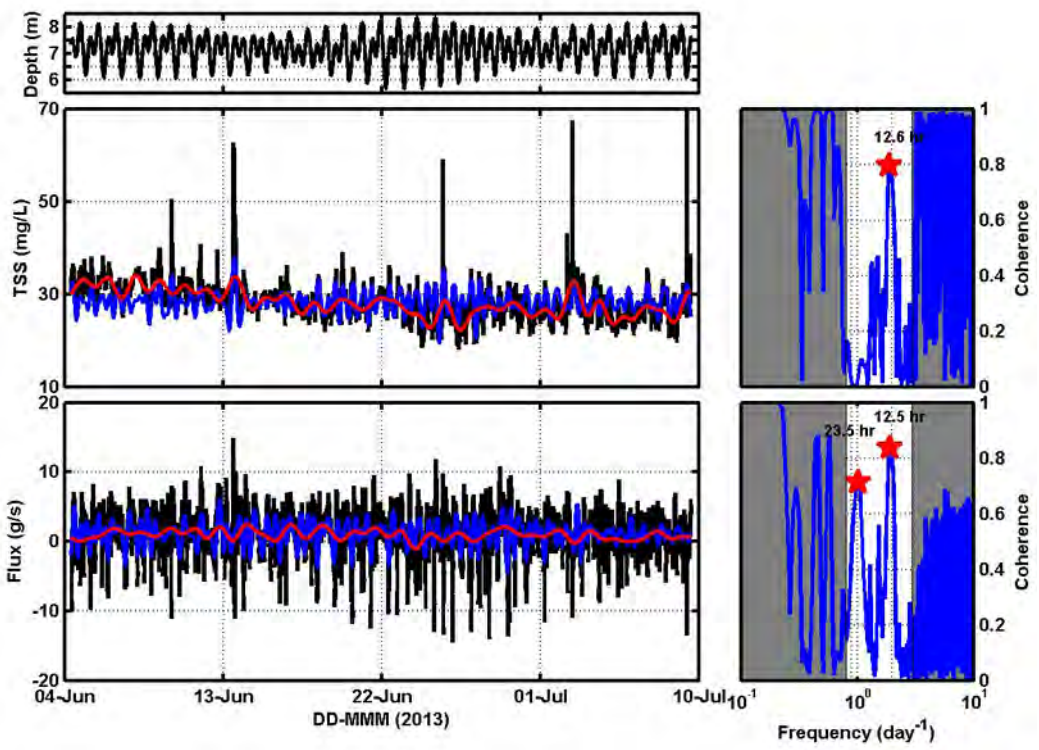


**Figure 16. The left three panels show time series of water depth (upper), TSS (middle), and sediment flux (lower). Band-pass and low-pass filtered (30-hr cut-off frequency) TSS and sediment flux are shown in blue and red, respectively. Positive flux is out of the system (i.e. ebb tide) and negative flux is into the system (i.e. flood tide). The right two panels show coherence between TSS and water depth (upper) and sediment flux and water depth (lower). Statistically significant coherence periods are denoted with red stars and their periods are labeled in units of hours. Data outside of the cut-off frequencies for tidal variability are shaded in gray. TSS and flux data are from within 1-m above the sediment bed.**

The critical shear stress for resuspension of surface sediment ($\tau_c$) was determined using Sedflume. Sedflume results indicated that $\tau_c$ was 0.43 Pa and 0.2 Pa for the mooring platform locations at the mouth and head of the Lauritzen Channel, respectively (see Table 3 and Section 3.3 for more Sedflume details). Band-pass and low-pass (30-hr cutoff frequency) filtered near-bottom shear stress did not exceed the values for critical shear stress at either location

[5] Spectral coherence is a statistic that can be used to examine the relation between two signals or data sets.

(Figure 17). Time-averaged values of band-pass filtered near-bottom shear stress were 0.04 Pa and 0.02 Pa and their maximum values were 0.15 Pa and 0.05 Pa at the mouth and head of the Channel, respectively (Table 5). Therefore, it can be concluded that turbulence was not strong enough to resuspend sediment at frequencies representative of tidal hydrodynamics.

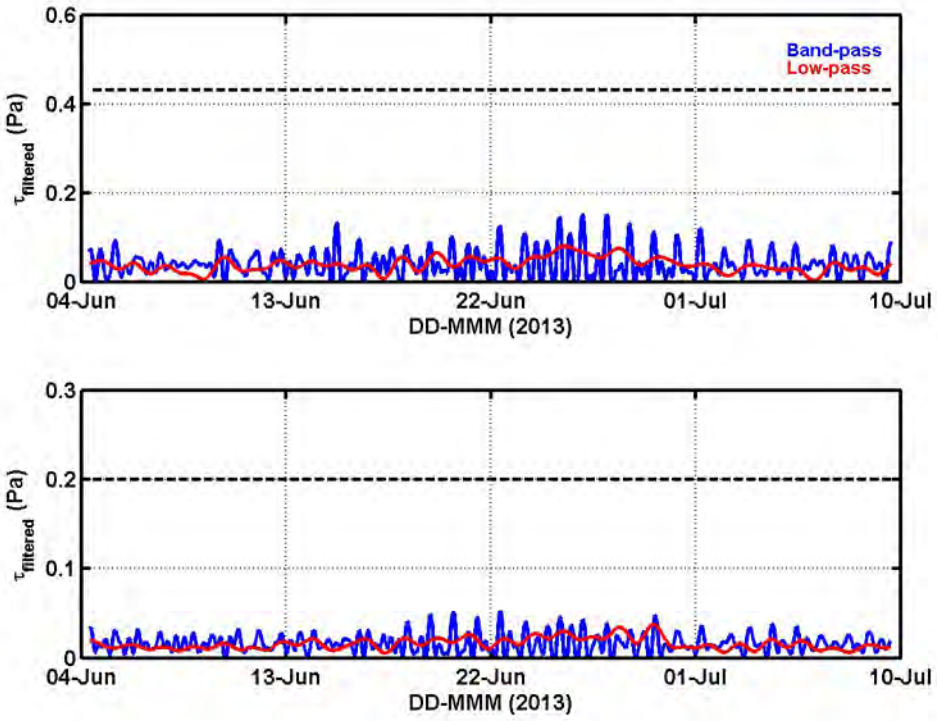


**Figure 17. Time series of band-pass (blue) and low-pass (red) filtered near-bottom shear stress computed from data collected within 1-m of the sediment bed at the mouth (upper panel) and head (lower panel) of the Lauritzen Channel. The black, dashed lines denote the critical shear stress for sediment resuspension determined from Sedflume experiments (0.43 Pa and 0.2 Pa at the mouth and head of the Lauritzen Channel, respectively).**

**Table 5. Statistics for band-pass and low-pass filtered near-bottom shear stress. Data were from within 1-m above the sediment bed.**

| | Mean | Minimum | Maximum | Standard deviation |
|---|---|---|---|---|
| ***Mouth*** | | | | |
| $\tau$ (Pa) band-pass | 0.04 | 0 | 0.15 | 0.03 |
| $\tau$ (Pa) low-pass | 0.04 | 0.002 | 0.08 | 0.02 |
| ***Head*** | | | | |
| $\tau$ (Pa) band-pass | 0.02 | 0 | 0.05 | 0.01 |
| $\tau$ (Pa) low-pass | 0.02 | 0.006 | 0.04 | 0.006 |

While TSS varied with tidal oscillations, particle size distributions in the water column did not vary with the tides at the mouth and were only weakly related to the tides at the head of the

Channel (Figure 18). A general increase in particle concentrations of larger sizes (>100 μm) was observed during flood tide at the head of the Lauritzen Channel. Additionally, a peak in PSD between 6 and 7 μm was observed only during ebb tide conditions at this location. Therefore, no general change in water column suspended solids composition is expected to occur over tidal variations as is common in some estuaries.

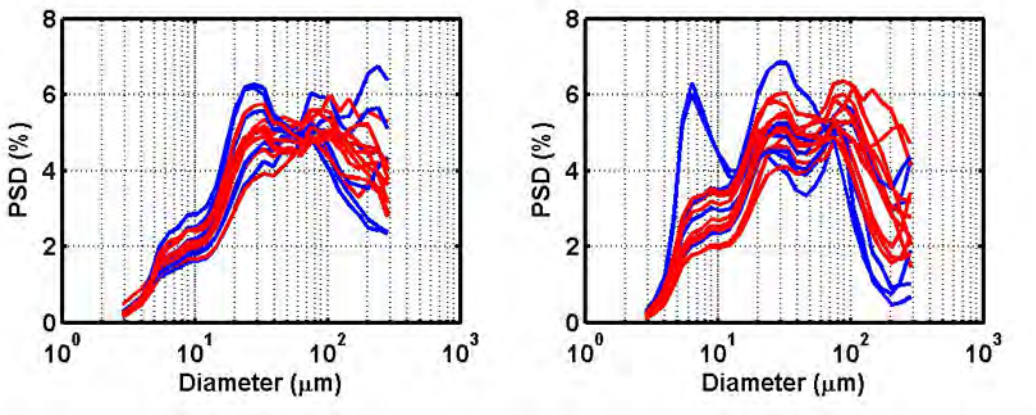


**Figure 18. The average size distribution of particles collected within 2-m of the sediment bed at the mouth (left panel) and head (right panel) of the Lauritzen Channel averaged over ebb tide periods (blue lines) and flood tide periods (red lines).**

## 4.2 Anthropogenically Forced Sediment Transport

The Lauritzen and Santa Fe Channels are active waterways with ship and barge berthing activities that have the potential to affect sediment transport patterns. It was therefore necessary to investigate high temporal frequency hydrodynamic and sediment data in order to identify tug and barge events and to relate anthropogenic forcing to sediment resuspension and transport.

### 4.2.1 Field Data– Tug events

High-pass filtered TSS and time series of near-bottom shear stress were examined in an effort to characterize the effects of anthropogenic activities at the United Heckathorn study site. A high-pass filter allows for the removal of the tidal signal so that other TSS spikes (e.g. non-tidal vessel resuspension) can be clearly identified. The cutoff frequency for high-pass filtered data was 8 hours. Intermittent peaks in TSS were observed six times in high-pass filtered TSS time series (Figure 19 and Figure 20). For the purposes of this evaluation, threshold concentrations were operationally defined as 60 mg/L at the mouth of the Channel and 40 mg/L at the head of the channel. High-pass filtered TSS was found to be elevated above threshold concentrations for 60 to 130 minutes (between 6 and 13 measurements; sampling frequency every 10 minutes).

Near-bottom shear stress exceeded the critical shear stress for erosion of surface sediment for periods of between 20 min and 40 min. The relationship between peaks in TSS and shear stress differed between the two measurement sites. At the mouth of the Lauritzen Channel, peaks in shear stress were more frequent (nine times) than peaks in TSS (six times) over the measurement period. High frequency increases in both TSS and shear stress coincided twice at the mouth of the channel, on 10 June and 15 June 2013 (Figure 19). Peaks in shear stress that were not correlated with peaks in TSS always occurred during flood tide at the mouth, perhaps coincidentally or possibly related to the location of vessel movement relative to the location of the moored bottom instrument platform. TSS increases above 60 mg/L always occurred during slack tide or ebb tide conditions at the mouth of the channel.

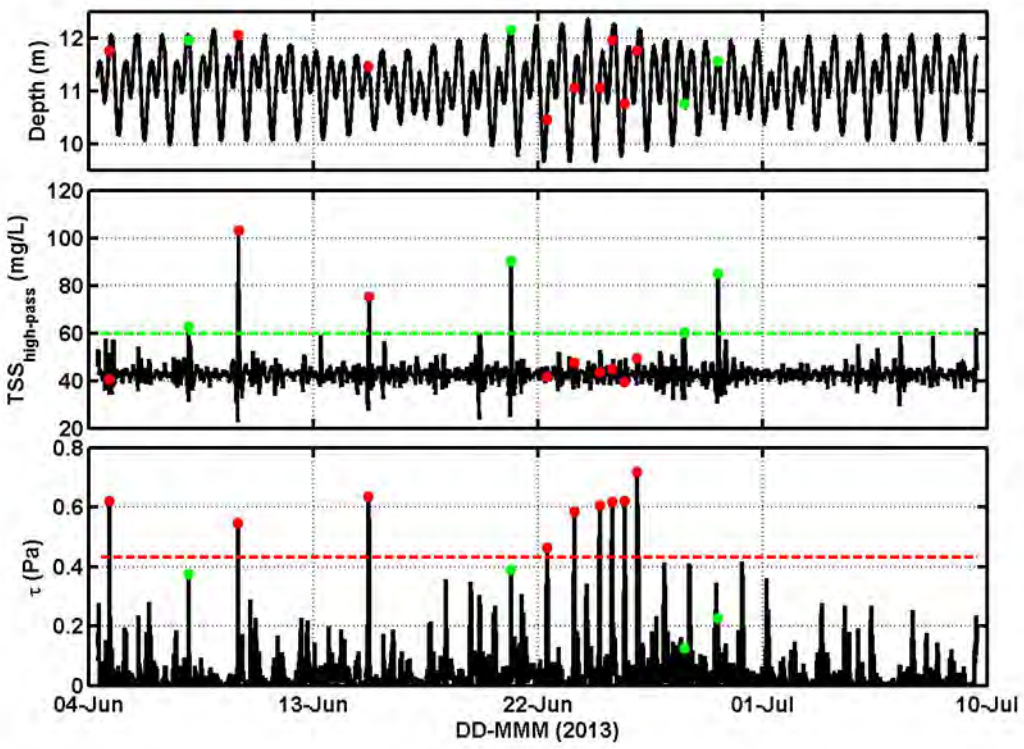


**Figure 19. Time series of water depth (upper), high-pass filtered TSS (middle), and near-bottom shear stress (bottom) measured within 1-m above the sediment bed. Green dots indicate periods when high-pass filtered TSS exceeded an operationally-defined threshold value of 60 mg/L but near bottom-shear stress did not exceed the critical shear stress for erosion of surface sediment as determined from the Sedflume experiments. Red dots indicate periods when near-bottom shear stress exceeded the critical shear stress for erosion. Data were collected at the mouth of the Lauritzen Channel.**

At the head of the Lauritzen Channel, high frequency increases in TSS and shear stress did not coincide and were not tidally dependent (Figure 20). While TSS increases above 40 mg/L occurred six times, peaks in shear stress were observed five times between 4 June and 10 July 2013. Elevation above critical shear stress spanned no more than two measurements, or 20 minutes in duration. The uncorrelated nature of the intermittent, high frequency peaks in

TSS and shear stress was potentially due to the distance between vessel movement and the location of the moored platform. While there is no detailed record of vessel movement during the deployment period, field observations of tug boat movement during sampling days near the west side of the Channel correlates with spikes in the deployment. Additionally, no other observed process in the channel could be responsible for the elevations in shear stress and sediment resuspension. Therefore, elevated TSS observances were likely sediment plumes generated by vessel movement that were advected toward the moored instrumentation.

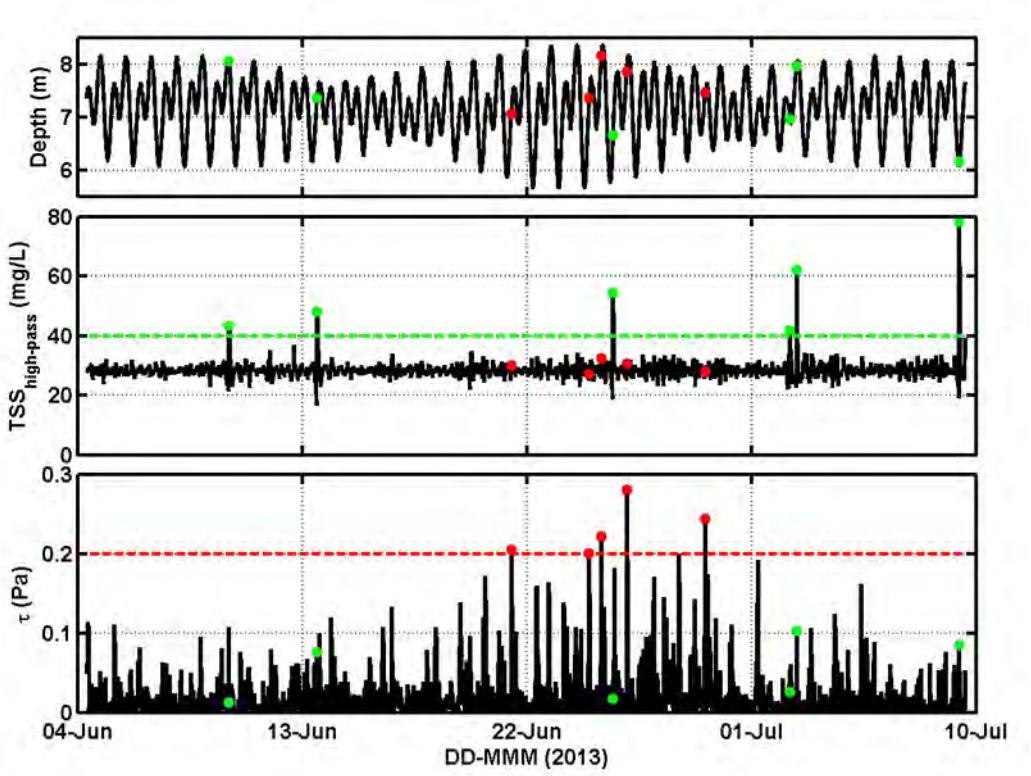


**Figure 20. Time series of water depth (upper), high-pass filtered TSS (middle), and near-bottom shear stress (bottom) measured at the head of the Lauritzen Channel. Data were collected within 1-m of the sediment bed. Red dots indicate periods when near-bottom shear stress exceeded the critical shear stress for erosion of surface sediment as determined from Sedflume experiments. Green dots indicate periods when high-pass filtered TSS exceeded an operationally-defined threshold value of 40 mg/L.**

### 4.2.2 Prop Scour Analysis

Vessel-induced bed scour was evaluated using a propeller wash and ship wake model and site-specific Sedflume and bathymetry data. The propeller wash and ship wake model used was based on an approach developed by the U.S. Army Corps of Engineers and is presented in detail in the Interim Report for the Upper Mississippi River – Illinois Waterway System Navigation (Maynord, 2000). Near bed velocity changes caused by vessel traffic result from two main components:

1) The wake created by the displacement of water from the vessel and
2) The increase in fluid momentum due to the vessel's rotating propeller.

Both components vary spatially and temporally as a vessel undergoes movement. The net bottom velocity, $V_{b,}$ can be calculated as the sum of the two components:

$$V_b = V_{wake} + V_{prop} \quad \text{Eq.6}$$

where $V_{wake}$ is the bottom velocity due to the vessel wake, and $V_{prop}$ is the bottom velocity due to the propeller wash. Wake velocities vary in the longitudinal direction, beginning at the vessel's bow, peaking at the vessel's stern, and then decreasing in the aft direction. Water accelerates at the vessel's propeller and decays in the lateral and longitudinal directions.

Before detailing the equations used in the propeller wash and ship wake analysis, it is important to understand the assumptions and potential shortcomings of the analysis. The propeller wash and ship wake model is based on empirical formulations that were derived from experiments conducted in a navigational flume with little or no field verification. In the current analysis it is assumed the empirical relationships hold in the Lauritzen Channel. The empirical models also greatly simplify the highly turbulent processes that result from propeller rotation. Turbulent fluctuations that may affect velocities and fluid-solid interactions at the bed are not fully represented in the model. Observations during field activities noted tug movement on a daily basis near the Manson facility; however, little information was available on the exact types of vessels frequently operating in Lauritzen Channel or their traffic patterns. Field observations noted during the ADCP deployments and tracer study were used to guide the assumptions related to vessel size and operations. Although the bed scour analysis is based on several assumptions that need to be considered when assessing the model results and accuracy, the analysis gives order-of-magnitude predictions of scour depths and suspended sediment load resulting from tug boat activity in the Lauritzen Channel. Model results were compared to TSS concentrations measured during identified tug boat vessel activities during the ADCP deployments, and calculated scour depths were checked against trends in the bathymetry data to ensure the model results were reasonable.

Bottom velocity components were calculated in a coordinate system fixed to a moving vessel with the x direction aligned with the direction of vessel movement (positive in aft direction) and the y direction aligned perpendicular with the vessel's centerline (Figure 21). The origin [x,y = (0,0)] was centered on the vessel's propeller.

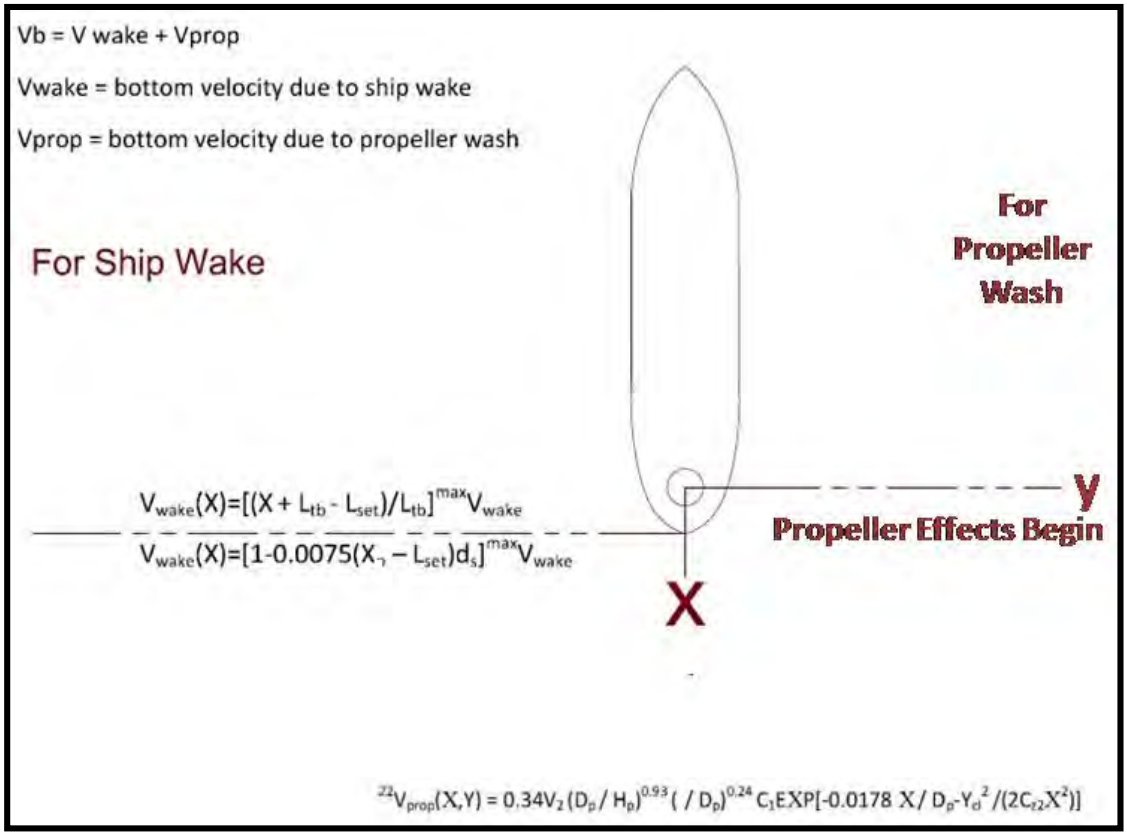


**Figure 21. Schematic of propeller wash and ship wake model coordinate system.**

With the coordinate system illustrated in Figure 21, the wake bottom velocity component ($V_{wake}$) can be computed from the following piecewise function:

For any point forward of the vessels stern ($x < L_{set}$),

$$V_{wake}(x) = [(x + L_{tb} - L_{set})/ L_{tb}]\ ^{max}V_{wake}. \quad \text{Eq. 7}$$

For any point behind the vessel stern ($x > L_{set}$),

$$V_{wake}(x) = [1 - 0.0075(x - L_{set})/d_s]\ ^{max}V_{wake} \quad \text{Eq.8}$$

Where $L_{tb}$ is the length of the vessel, $L_{set}$ is the distance from the vessel's stern to the propeller, $d_s$ is the vessel draft, and $^{max}V_{wake}$ is the maximum wake velocity given by:

$$^{max}V_{wake} = -0.78\ (d_s / h)^{1.81}\ (V_a - V_g) \quad \text{Eq. 9}$$

where $V_a$ is the ambient average channel velocity, h is the water depth, and $V_g$ is the vessel speed relative to the sediment bed. With the same coordinate system, the bottom velocity due to the vessel propeller is defined by the following piecewise function:

For any point forward of the vessels prop ($x < 0$),

$$V_{prop}(x,y) = 0. \quad \text{Eq.10}$$

for any point behind the vessel stern ($x>L_{set}$),

$$V_{prop}(x,y) = 0.34\ V_2\ (D_p/H_p)^{0.93}\ (x/D_p)^{0.24}\ C_1\ EXP[-0.0178\ x/D_p - y^2/(2\ C_{z2}x^2)] \quad \text{Eq.11}$$

Where $D_p$ is the propeller diameter, $H_p$ is the distance from the propeller axis to the sediment bed, $C_1$ is a propeller coefficient (0.85 for Kort propeller), $C_{z2}$ is a distance coefficient ($C_{z2} = 0.84\ (x/D_p)^{-0.62}$), and $V_2$ is the velocity increase caused by a second propeller and is given by:

$$V_2 = (1.13 / D_p)\ (31.82\ P_{hp}^{0.974} - 5.4\ (V_a - V_g)^2\ P_{hp}^{0.5})/\ \rho)^{1/2} \quad \text{Eq. 12}$$

where $P_{hp}$ is the ship's horsepower. Once bottom velocities were known, the quadratic stress law was used to calculate bed shear stresses:

$$\tau = \rho C_f V_b^2 \quad \text{Eq.13}$$

where $C_f$ is the bottom friction coefficient, estimated using (Parker, 2004):

$$C_f = k^2 Ln^{-2}(11\ h/k_s) \quad \text{Eq. 14}$$

where k is von Karman's constant (0.4), and $k_s$ is the effective bed height roughness (taken as two times the average $D_{90}$ of the sediment in the Sedflume cores, or 0.00017 m).

Results from the propeller wash and ship wake analysis were coupled with the Sedflume data to calculate erosion rates as a function of bed shear stress. A site-wide average for the A and n coefficients were logarithmically (for A) and arithmetically (for n) averaged over five 6-cm intervals (Table 6). A specific core's interval contributed to the site-wide average interval if the end depth fell within the cumulative averaged interval thickness; a 6-cm depth interval was chosen because it was close to the average interval size in the Sedflume analysis. The site-averaged A and n values were then utilized to determine a critical shear stress ($\tau_{crit}$) for each interval. Interval-averaged dry bulk density values were also computed to allow for suspended sediment mass to be computed. By integrating the erosion rates over time, bed scour and sediment loadings due to vessel activity in the Lauritzen Channel were calculated.

**Table 6. Site-wide average values of sediment core properties from Sedflume analysis.**

| Interval | Depth Range (cm) | A | n | $\tau_{crit}$ | Dry Bulk Density ($g/cm^3$) |
|---|---|---|---|---|---|
| 1 | 0-6 | 0.00230 | 1.9 | 0.20 | 0.28 |
| 2 | 6-12 | 0.0019 | 2.5 | 0.31 | 0.33 |
| 3 | 12-18 | 0.00085 | 2.6 | 0.43 | 0.43 |
| 4 | 18-24 | 0.00059 | 3.4 | 0.60 | 0.48 |
| 5 | 24+ | 0.00087 | 3.4 | 0.53 | 0.58 |

Due to the infrequent use of the Levin Richmond Terminal Corporation (LRTC) berth in the channel in comparison with the near daily use of the Manson Construction facilities, two main vessel operational patterns were identified in the Lauritzen Channel that had potential to

significantly affect sediment transport. Tug boats berthing at Manson Construction were observed motoring in and out of the channel on several occasions (vessel names were Peter M. and Fat Cat). Manson Construction tug boats were also observed maneuvering a barge into the channel by pushing up against the barge's side. While this was occurring, the tugboat was nearly stationary, but the vessel was in gear and the propeller was spinning (force from the propeller was balanced by the weight of the barge). No logs of Manson tug activity are available. A barge was observed tied to LRTC's dock, but Levin had no shipping activity in the Lauritzen. The barge was moved on June 3rd during the instrument deployment, but the specifics of the operations are not available.

In order to best estimate ship scour and associated sediment transport processes, the two vessel operation types were investigated separately. The approaches for analyzing each are presented in the paragraphs that follow, where the separate cases are referred to as the Transiting Case and the Stationary Case. For both cases, two sets of ship parameters were investigated to give a range of effects (Table 7). Because data were not available for the two tug boats observed in the Lauritzen Channel (Peter M. and Fat Cat), parameters for comparable tugboats berthed in San Francisco Bay were used. Based on observations, Silia, which is operated by Greger Pacific Marine, is thought to be similar in size to Peter M and was used for parameter specification (Vessel 1 in Table 7) (Greger Pacific Marine, 2013). The Foss Maritime harbor tug, Edith Foss, was used as a representative vessel for the Fat Cat (supplied values for Vessel 2 in Table 7) (Foss Maritime Company, 2013). Although the Silia and Edith Foss may not identically match the vessels operating within Lauritzen Channel, it is believed these tug boats are realistic representations of the types of vessels that operate within the channel. As mentioned above, the parameters used in the analysis are ship length ($L_{tb}$), ship draft ($d_s$), distance from stern to propeller ($L_{set}$), propeller diameter ($D_p$), maximum power in terms of brake horsepower ($P_{hp}$), and the propeller type. $L_{set}$ and depth of propeller (deltap) were not defined for the Silia or Edith Foss, so they were estimated based on ratios derived from similar sized vessels. $L_{set}$ was computed as 1/10 the length of the vessel, and deltap was defined as ¾ the ship draft.

**Table 7. Ship parameters used in the propeller wash and ship wake model.**

| | $L_{tb}$ (m) | $D_s$ (m) | $L_{set}$ (m) | $D_p$ (m) | deltap (m) | Proptype |
|---|---|---|---|---|---|---|
| Vessel 1 | 16.76 | 2.13 | 1.67* | 1.25 | 1.58* | Kort Nozzle |
| Vessel 2 | 23.46 | 3.47 | 2.35* | 2.13* | 2.13* | Kort Nozzle |

* Indicates values that were estimated

Bottom velocities increased as vessels moved in and out of the Lauritzen Channel due to the vessel's wake and propeller wash. To estimate the potential for erosion given a transiting vessel, bottom velocities, shear stresses, and erosion rates were calculated at five different transects within Lauritzen Channel. The transects are shown in Figure 22. Cross-sectional depths along each transect were extracted from the digital elevation map. The following steps

were then applied to each transect line to calculate bottom shear stresses and erosion rates given the formulations for $V_{prop}$ and $V_{wake}$ as a function of vessel transit time. It was assumed that the vessel's bow crossed the transect at t = 0 and was moving at a constant rate $V_g$ for time T in a straight line perpendicular to the transect.

1) Because bottom velocities along the transect are dependent on the location of the propeller relative to the transect, the distance between the propeller and the transect was calculated every second from t = 0 to t = T.
2) Knowing the distance from the propeller to the transect, which is the x coordinate in the bottom velocity equations for the given setup, bottom velocities along the transect were calculated.
3) Bottom shear stresses and erosion rates were then computed using the site-wide averaged A, n, and critical shear stress values.
4) The bed profile along the transect was adjusted by calculating the bed height change, which was the product of the erosion rate and the time step between iterations (1 second). The bed was only eroded if the shear stress at the bed was greater than the critical shear stress.
5) The process was repeated from t = 0 to t = T. After running this process for both vessel types on all five transects, it was found that after 2 minutes of vessel transit time the effects of the vessel on bottom velocities along the transect were minimal. T was accordingly chosen as 2 minutes.

The six steps were applied to each transect for both vessels given four different percentages of their maximum power (25%, 50%, 75% and 100%). Various maximum powers were investigated to give a range of the effects that could occur depending on how fast vessels move in and out of the Lauritzen Channel; however, it is likely that vessel movement occurs in the channel using 25% or lower of the maximum power. The six steps were designed to be an iterative process that accounts for bed erosion as the vessel passes.

As a ship moved past a point, the influence of each velocity component ($V_{prop}$ and $V_{wake}$) varied in magnitude. When the vessel's bow first passed a particular transect, the bed velocities increased due to the bow wake. A typical contour plot of $V_{wake}$ as a function of time is shown inFigure 23. This particular plot was created at Transect 5 for vessel 2 operating at 100% of its maximum power; however, the spatial velocity trends were similar for both vessel types and all power percentages. The magnitude of the velocities changed, but spatial distribution varied only slightly. The vertical gray line in Figure 23 denotes the centerline position of vessel 2 as it transited past the transect. The two horizontal black lines mark the time when the propeller (top line) and stern (bottom line) crossed the transect. The bed profile of Transect 5 is given in the top panel. $V_{wake}$ increased as the vessel began motoring over the transect and peaked as the stern passed. After this time, $V_{wake}$ decreased as the boat traveled further away from the transect and was nearly zero after roughly a minute and a half. $V_{wake}$ was also dependent on the water depth. On the edges of the transect, where waters are shallower, $V_{wake}$ was relatively

large. This suggests that near shoreline areas may be the most influenced by vessel wakes. However, the equations used in the propeller wash and ship wake model become less reliable in steep slope regions because they were derived from flat bottom experiments and analysis. To avoid steep side slope regions where the model is not applicable, the transects were cut at a depth of roughly 6 m (20 m contour line).

A typical contour plot of $V_{prop}$ is shown in Figure 24, with the boat centerline and propeller and stern passing times. Again, this particular plot was created at Transect 5 for vessel 2 operating at 100% of its maximum power but the trends were consistent for all boat and transect combinations. Before the propeller passed the transect, $V_{prop}$ was zero along the profile but sharply increased immediately after it passed. For this particular boat-transect combination, $V_{prop}$ reached a maximum of 0.93 m/s roughly 25 seconds after transiting began. As the vessel motored further from the transect, the magnitude of $V_{prop}$ dissipated. Total bottom velocities, $V_b$, are shown in Figure 25. Being a combination of $V_{wake}$ and $V_{prop}$, $V_b$ was highest in shallow regions and directly behind the vessel once it passed the transect.

A contour plot of bed shear stress derived from $V_b$ as a function of time is presented in Figure 26. Times and locations along the transect that experienced large shear stress corresponded to larger erosion depths. Maximum bed velocities, shear stresses, erosion depths, and predicted TSS concentration for all boat, transect and power combinations are presented in Table 8. The maximum bed erosion of all cases, 0.50 cm, occurred for vessel 2 transiting over profile 5 at full power. The analyses presented did not take into account bed armoring or deposition, so the erosion depth values are likely an upper limit to what actually occurs. The TSS concentrations presented in Table 8 were calculated assuming that all sediment that mobilized remained in the water column and dispersed uniformly in the vicinity of the transect. This assumption is not completely accurate; however, given the turbulent mixing that occurred due to propeller rotation, it is likely valid.

To estimate the total mass of sediment that would enter the water column in the Lauritzen Channel if the vessels transited from Manson (Transect 1) to the mouth of the Lauritzen Channel (Transect 5), the average TSS concentrations from each individual transiting event were examined in conjunction with water volumes in the channel. Water volumes for the segments between transects were computed from the distance between neighboring transects and bathymetry profiles as follows:

1) *Water volume between Transect 1 and Transect 2* – the water volume between Transect 1 and Transect 2 was calculated by multiplying the distance between Transect 1 and Transect 2 by the cross sectional area of the water column at Transect 1 (assuming a 0 m tide relative to MLLW). The cross sectional area of Transect 1 was chosen for the volume calculation because it best represents the channel from Transect 1 to Transect 2.
2) *Water volume between Transect 2 and Transect 3* – the water volume between Transect 2 and Transect 3 was calculated by multiplying the distance between Transect 2 and Transect 3 by the cross sectional area of the water column at Transect 2

(assuming a 0 m tide relative to MLLW). The cross sectional area of Transect 2 was chosen for the volume calculation because it best represents the channel from Transect 2 to Transect 3.

3) *Water volume between Transect 3 and Transect 5* – the water volume between Transect 3 and Transect 5 was calculated by multiplying the distance between Transect 3 and Transect 5 by the average cross sectional area of the water column of Transect 3, Transect 4, and Transect 5 (assuming a 0 m tide relative to MLLW). The average cross sectional area was used because the berth is uniformly expanding between *Transect 3 and Transect 5.*

Once the water volumes were known, the sediment mass in each segment was calculated by multiplying the calculated volume by the TSS concentration for the segment. The total mass into the system was then computed as the sum of the mass in each segment. Total mass input predictions for both vessel types under all power percentages investigated are presented in Table 9. Because Vessel 1 did not cause erosion for any profile-power fraction considered, it never mobilized sediment. Under full power, Vessel 2 caused 699 kg of sediment to be suspended into the water column. When considering these mass predictions, it is important to remember that any coarse grain sediments that are mobilized will quickly settle from the water column, reducing the chance of large-scale transport. Under 20% power, Vessel 2 mobilized 20 kg of sediment when moving from Manson to the mouth of the Lauritzen Channel.

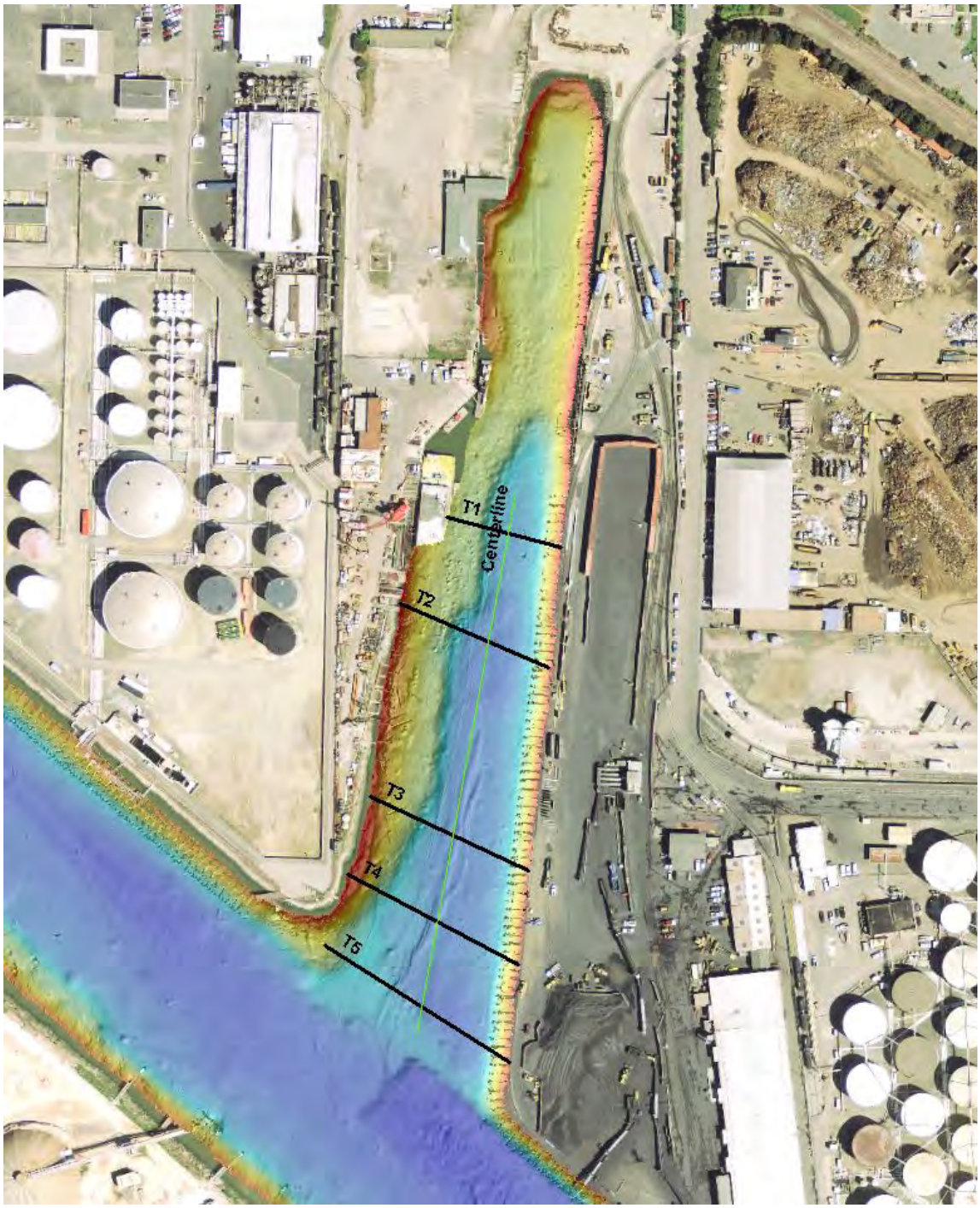


**Figure 22. Profile lines used to create the beds for the Transiting Case of the propeller wash and ship wake model.**

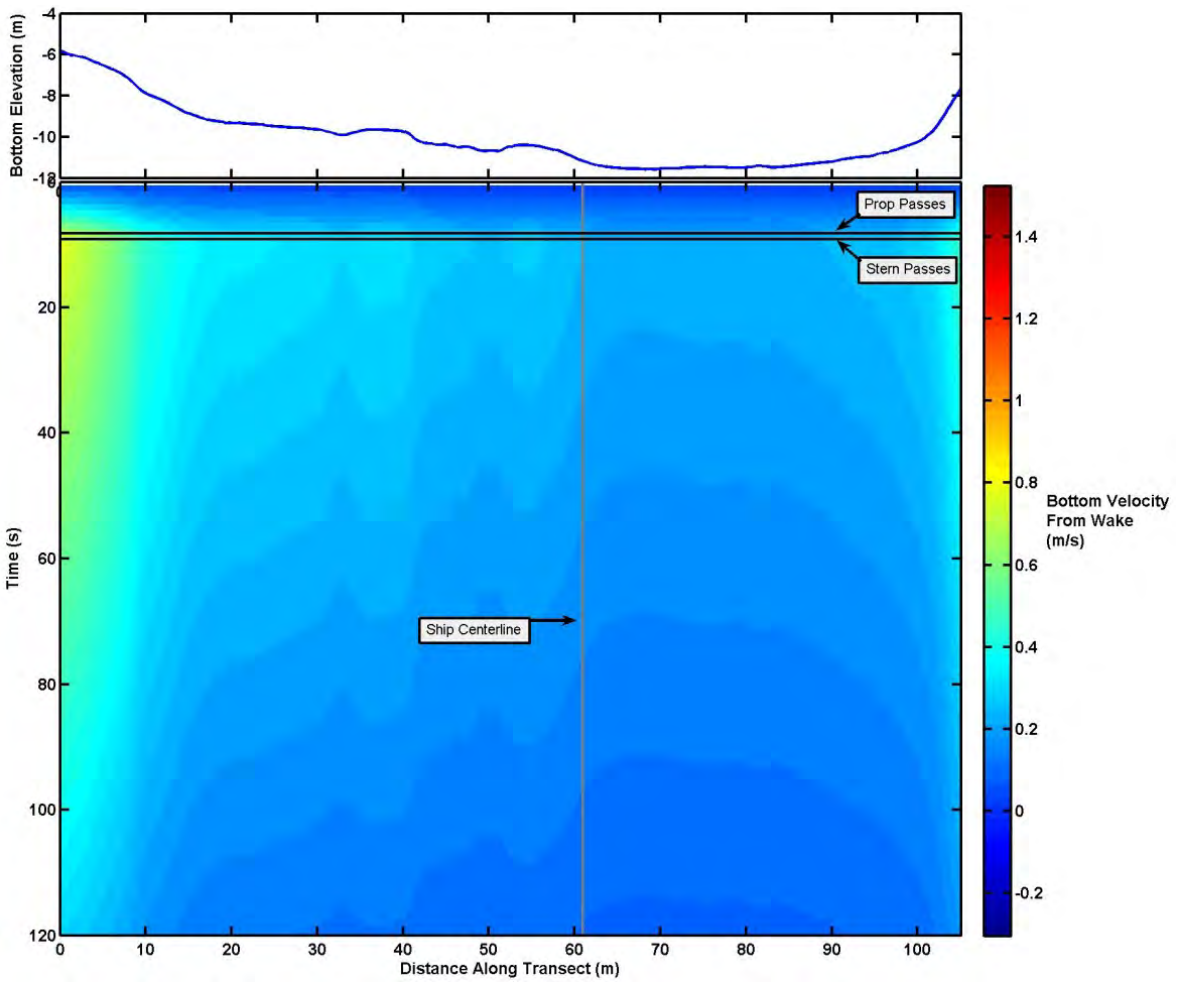


**Figure 23. Contour plot of the ship wake component of the bottom velocity (m/s) along Transect 5 as a function of time for Vessel 2 running at 100% of its maximum power. The tiop panel is a plot of the starting bathymetry along the transect.**

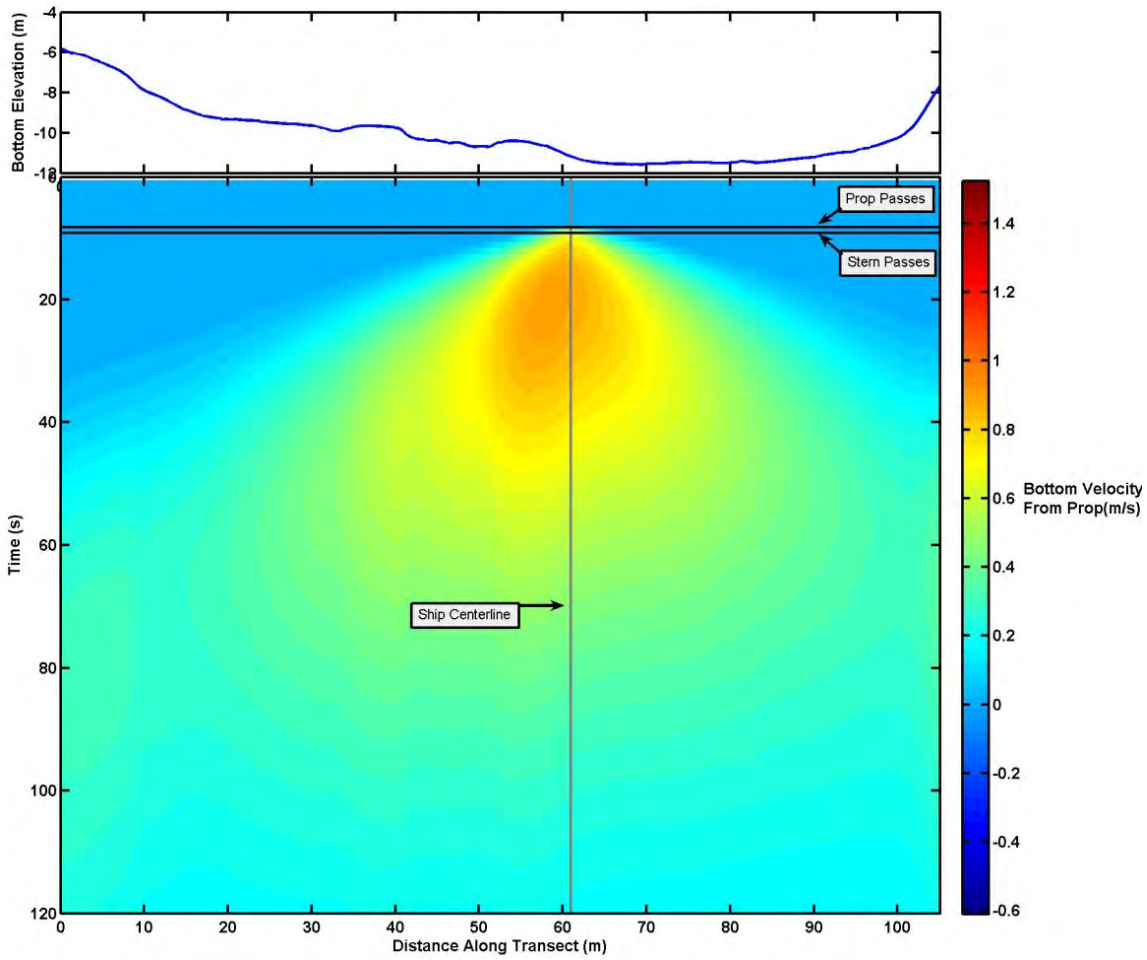


**Figure 24. Contour plot of the propeller component of the bottom velocity (m/s) along Transect 5 as a function of time for Vessel 2 running at 100% of its maximum power. The top panel is a plot of the starting bathymetry along the transect.**

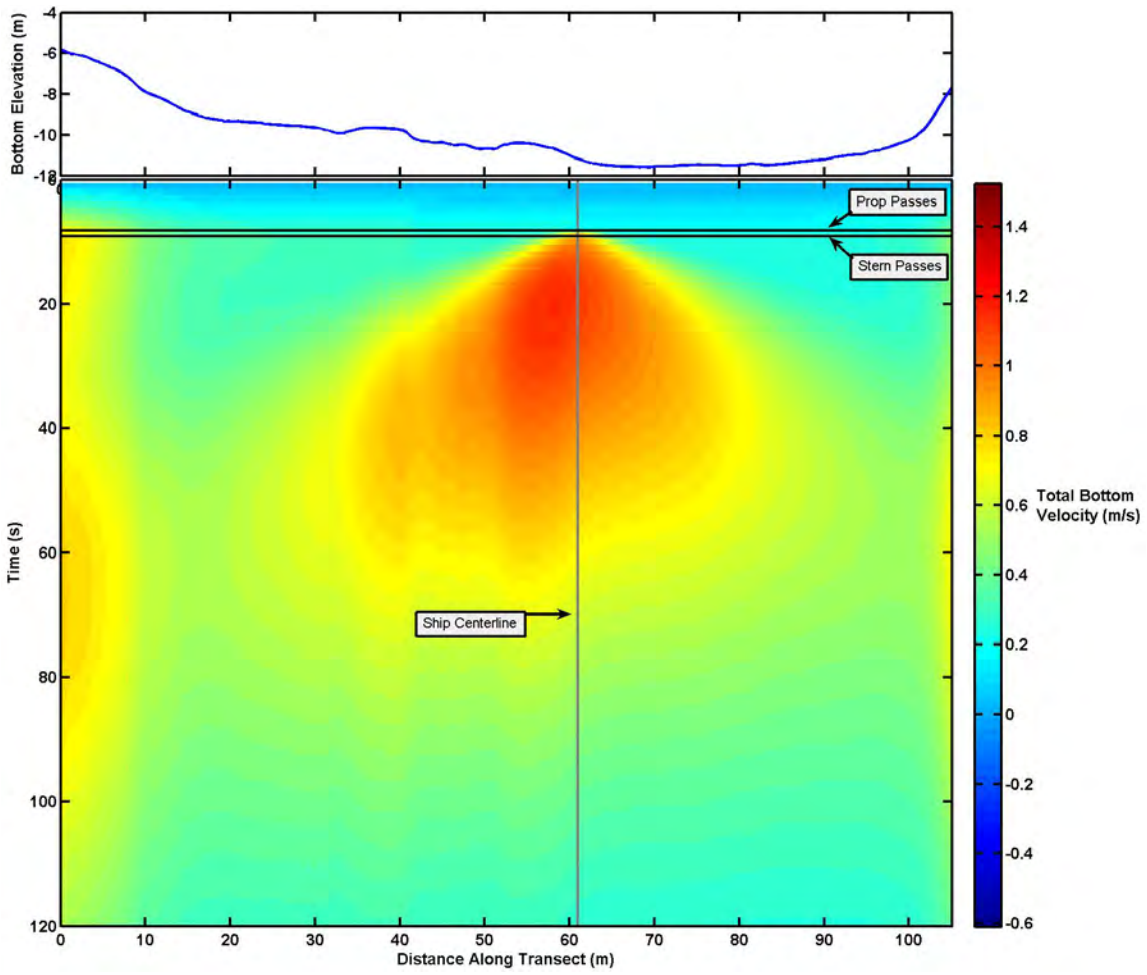


**Figure 25. Contour plot of the total bottom velocity (m/s) along Transect 5 as a function of time for Vessel 2 running at a 100% of its maximum power. The top panel is a plot of the starting bathymetry along the transect.**

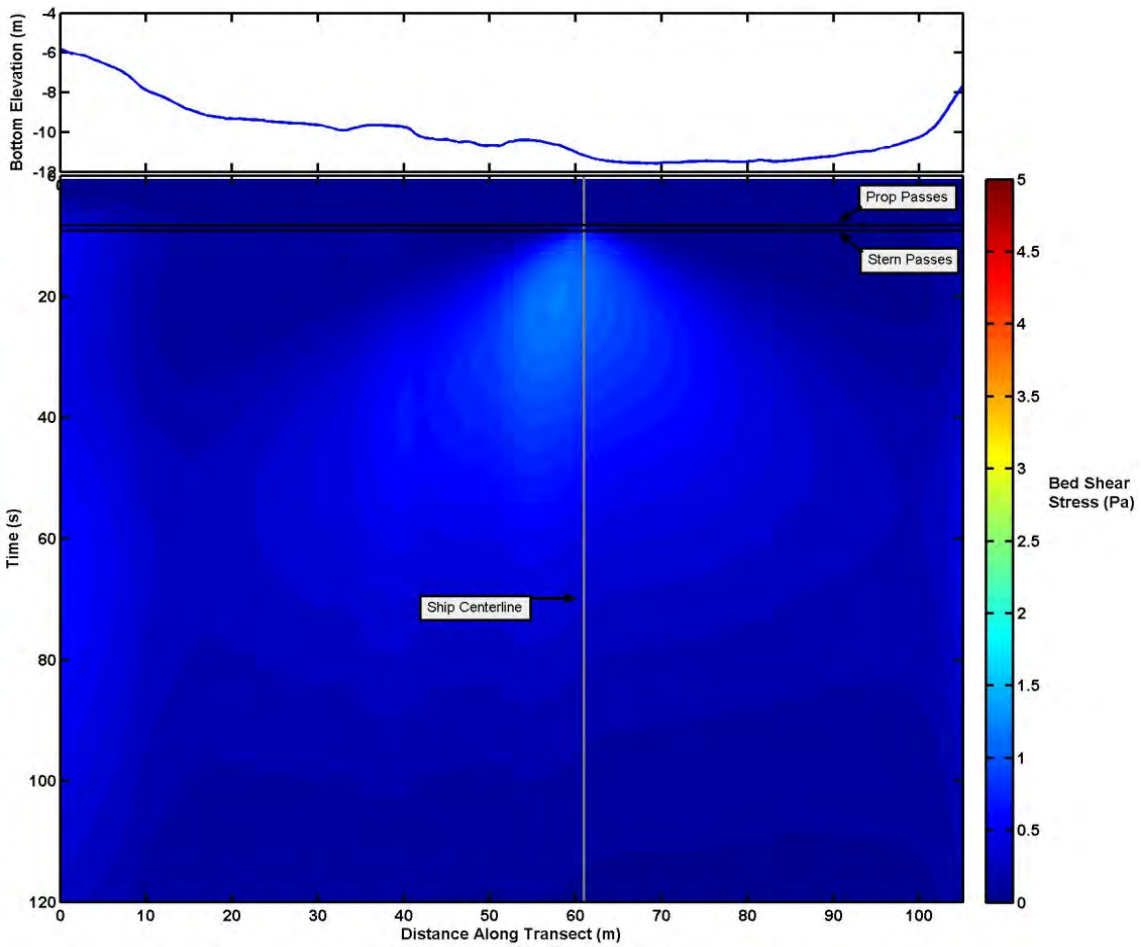


**Figure 26. Contour plot of the bed shear stress (Pa) along Transect 5 as a function of time for Vessel 2 running at a 100% of its maximum power. The Top panel is a plot for the starting bathymetry along the transect.**

**Table 8. Maximum bottom velocity (m/s), maximum bed shear (Pa), maximum bed erosion (cm) and the average TSS concentration in Lauritzen Channel given different vessel and profile combinations for transiting case.**

| | | | Max Bottom Velocity (m/s) | Max Bed Shear (Pa) | Max Bed Erosion (cm) | Average TSS Concentration of Domain (mg/L) |
|---|---|---|---|---|---|---|
| 100 % Throttle | Profile 1 | Vessel 1 | 0.69 | 0.43 | 0.00 | 0.0 |
| | | Vessel 2 | 1.55 | 2.13 | 0.03 | 4.5 |
| | Profile 2 | Vessel 1 | 0.63 | 0.35 | 0.00 | 0.0 |
| | | Vessel 2 | 1.40 | 1.94 | 0.06 | 2.8 |
| | Profile 3 | Vessel 1 | 0.64 | 0.36 | 0.00 | 0.0 |
| | | Vessel 2 | 1.69 | 2.89 | 0.49 | 10.5 |
| | Profile 4 | Vessel 1 | 0.65 | 0.38 | 0.00 | 0.0 |
| | | Vessel 2 | 1.66 | 2.76 | 0.39 | 2.3 |
| | Profile 5 | Vessel 1 | 0.63 | 0.36 | 0.00 | 0.0 |
| | | Vessel 2 | 1.16 | 1.19 | 0.00 | 0.1 |
| 75 % Throttle | Profile 1 | Vessel 1 | 0.61 | 0.33 | 0.00 | 0.0 |
| | | Vessel 2 | 1.25 | 1.46 | 0.01 | 1.1 |
| | Profile 2 | Vessel 1 | 0.55 | 0.27 | 0.00 | 0.0 |
| | | Vessel 2 | 1.30 | 1.67 | 0.03 | 1.1 |
| | Profile 3 | Vessel 1 | 0.56 | 0.28 | 0.00 | 0.0 |
| | | Vessel 2 | 1.58 | 2.52 | 0.26 | 5.1 |
| | Profile 4 | Vessel 1 | 0.57 | 0.29 | 0.00 | 0.0 |
| | | Vessel 2 | 1.55 | 2.40 | 0.20 | 1.1 |
| | Profile 5 | Vessel 1 | 0.56 | 0.27 | 0.00 | 0.0 |
| | | Vessel 2 | 1.03 | 0.94 | 0.00 | 0.0 |
| 50 % Throttle | Profile 1 | Vessel 1 | 0.50 | 0.23 | 0.00 | 0.0 |
| | | Vessel 2 | 1.09 | 1.14 | 0.00 | 0.1 |
| | Profile 2 | Vessel 1 | 0.46 | 0.18 | 0.00 | 0.0 |
| | | Vessel 2 | 1.18 | 1.38 | 0.01 | 0.3 |
| | Profile 3 | Vessel 1 | 0.49 | 0.25 | 0.00 | 0.0 |
| | | Vessel 2 | 1.45 | 2.11 | 0.11 | 2.1 |
| | Profile 4 | Vessel 1 | 0.48 | 0.23 | 0.00 | 0.0 |
| | | Vessel 2 | 1.42 | 2.01 | 0.09 | 0.5 |
| | Profile 5 | Vessel 1 | 0.46 | 0.19 | 0.00 | 0.0 |
| | | Vessel 2 | 0.88 | 0.68 | 0.00 | 0.0 |
| 25 % Throttle | Profile 1 | Vessel 1 | 0.37 | 0.12 | 0.00 | 0.0 |
| | | Vessel 2 | 0.93 | 0.85 | 0.00 | 0.0 |
| | Profile 2 | Vessel 1 | 0.38 | 0.14 | 0.00 | 0.0 |
| | | Vessel 2 | 1.03 | 1.04 | 0.00 | 0.0 |
| | Profile 3 | Vessel 1 | 0.49 | 0.25 | 0.00 | 0.0 |
| | | Vessel 2 | 1.28 | 1.64 | 0.04 | 0.6 |
| | Profile 4 | Vessel 1 | 0.48 | 0.23 | 0.00 | 0.0 |
| | | Vessel 2 | 1.25 | 1.56 | 0.03 | 0.1 |
| | Profile 5 | Vessel 1 | 0.33 | 0.10 | 0.00 | 0.0 |
| | | Vessel 2 | 0.78 | 0.60 | 0.00 | 0.0 |

**Table 9. Total sediment mass resuspended into system from Vessel 1 and Vessel 2 operating at different fractions of their maximum power when transiting from Manson to the mouth of the Lauritzen Channel.**

| | | Total Mass Resuspended Into Lauritzen Canal With Ship Moving from Profile 1 to Profile 5 (kg) |
|---|---|---|
| 100% Throttle | Vessel 1 | 0 |
| | Vessel 2 | 699 |
| 75% Throttle | Vessel 1 | 0 |
| | Vessel 2 | 290 |
| 50% Throttle | Vessel 1 | 0 |
| | Vessel 2 | 96 |
| 25% Throttle | Vessel 1 | 0 |
| | Vessel 2 | 20 |

The procedures for determining suspended sediment loads caused by transiting vessels were modified to analyze the bed effects of a stationary vessel with a spinning propeller. For the stationary analysis, vessels were assumed fixed in position, but operating at a constant power for 10 minutes. This situation mimics a tug boat pushing against the side of a barge. Sediment beds were constructed for the stationary analysis by taking the five bed profiles examined in the Transiting Case, and extending the profiles roughly 30 m in both the north and south direction (i.e. assumed constant channel geometry in near proximity to the profile locations). Vessels were placed in the created domain 15.25 m from the western shoreline oriented with the propeller facing toward the center of the channel. Bottom velocities, bed shear stresses, and bed erosion were calculated in a similar fashion as the Transiting case with two main exceptions: 1) the bed velocity had no wake component because the vessels were stationary, and 2) the bed was analyzed over a domain instead of a transect. The stationary analysis was carried out for both Vessel 1 and Vessel 2 at the same four power percentages as the Transiting Case (25%, 50%, 75% and 100%). Again, the computations were iterative; near-bottom velocities, bed shear stresses, and erosion rates were calculated every second from t = 0 to t = 10 minutes, and the bed elevation was adjusted accordingly between time steps. The site-wide averaged sediment properties given in Table 6 were used in the analysis.

A contour plot of bottom velocities over the entire domain created using Transect 2 are presented in Figure 22. Profile lines used to create the beds for the Transiting Case of the propeller wash and ship wake model. The results are for Vessel 2 operating at 100% power at the end of the 10 minute period; however, the spatial velocity distributions were similar for all other combinations and times. The conical velocity distribution was consistent over all constructed domains but varied in magnitude with bathymetry changes between domains. The location of Vessel 2 in Figure 27 is marked by a white circle. Note that Figure 27 differs from the bottom velocity plot for the Transiting Case (Figure 24) in that it gives bottom velocities as a function of positioning (x and y) not distance along transect and time.

Similarly, bed shear stresses are presented in Figure 28. A maximum shear stress of 2.38 Pa occurred directly behind the propeller roughly five propeller diameters away. Erosion occurred when shear stress in a cell was greater than the critical shear stress of erosion of sediment. A spatial map of total erosion after a 10 minute time period is shown in Figure 29. Peak values for all three variables (bottom velocity, bed shear stress, and erosion) occurred approximately 10 m behind the propeller. High velocities occur at the far end of the model domain which is a shallow steep sloped region of bathymetry at the head of the Lauritzen Channel.

Maximum bottom velocities, maximum bed shear stresses, maximum bed erosion, and average TSS concentration over the domain are presented in Table 10 for all vessels, power and bed configurations analyzed. Average concentrations were calculated by assuming that all mobilized sediment remained suspended in the water column and uniformly mixed throughout the domain. The presented concentration values do not account for particle settling. The greatest erosion (approximately 10 cm) occurred for Vessel 2 operating at full power at Transect 3. Erosion depths created by Vessel 1 were less than 1 cm for all combinations except for Profile 2 with 100% power which had a maximum scour depth of approximately 10 cm. Maximum bed shear stresses ranged from 0.11 Pa to 2.52 Pa.

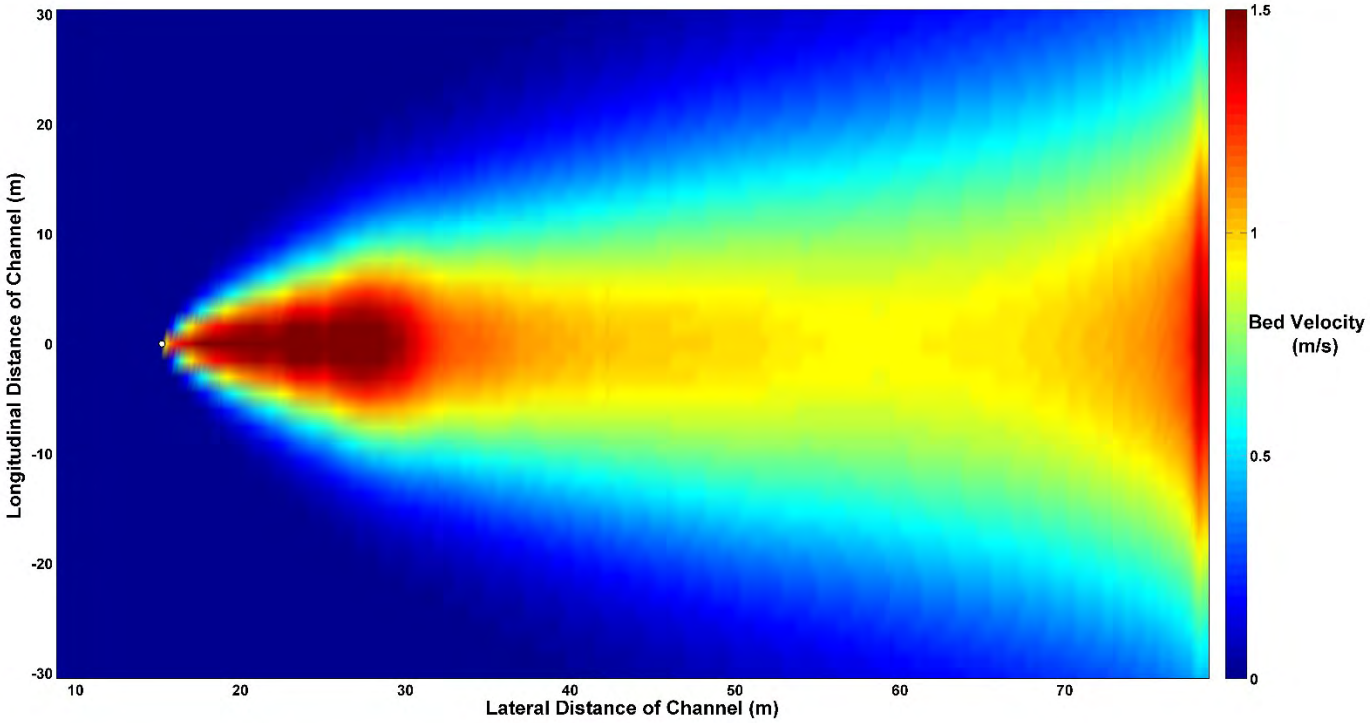


**Figure 27. Bed Velocity due around Transect 2 due to 100% power from Vessel 2.**

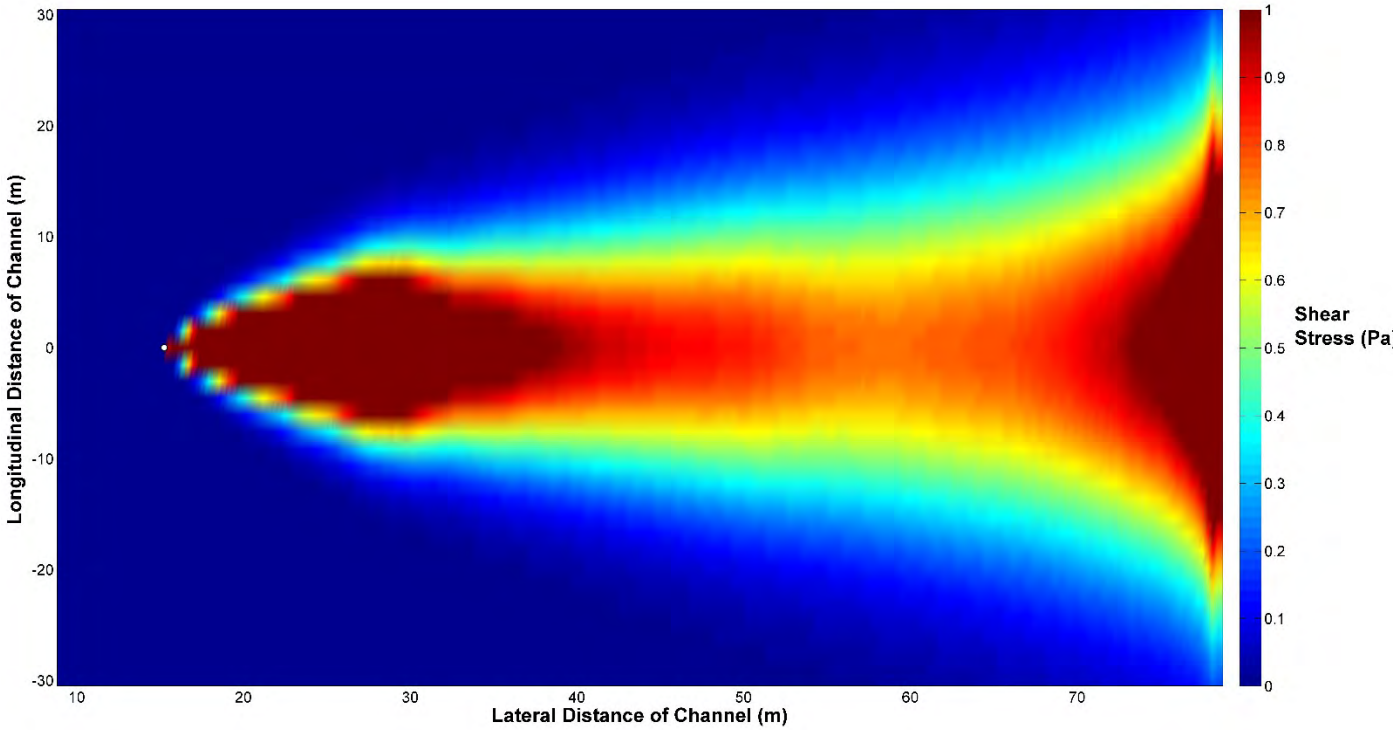


**Figure 28. Bed Shear Stress around Transect 2 due to 100% power from Vessel 2.**

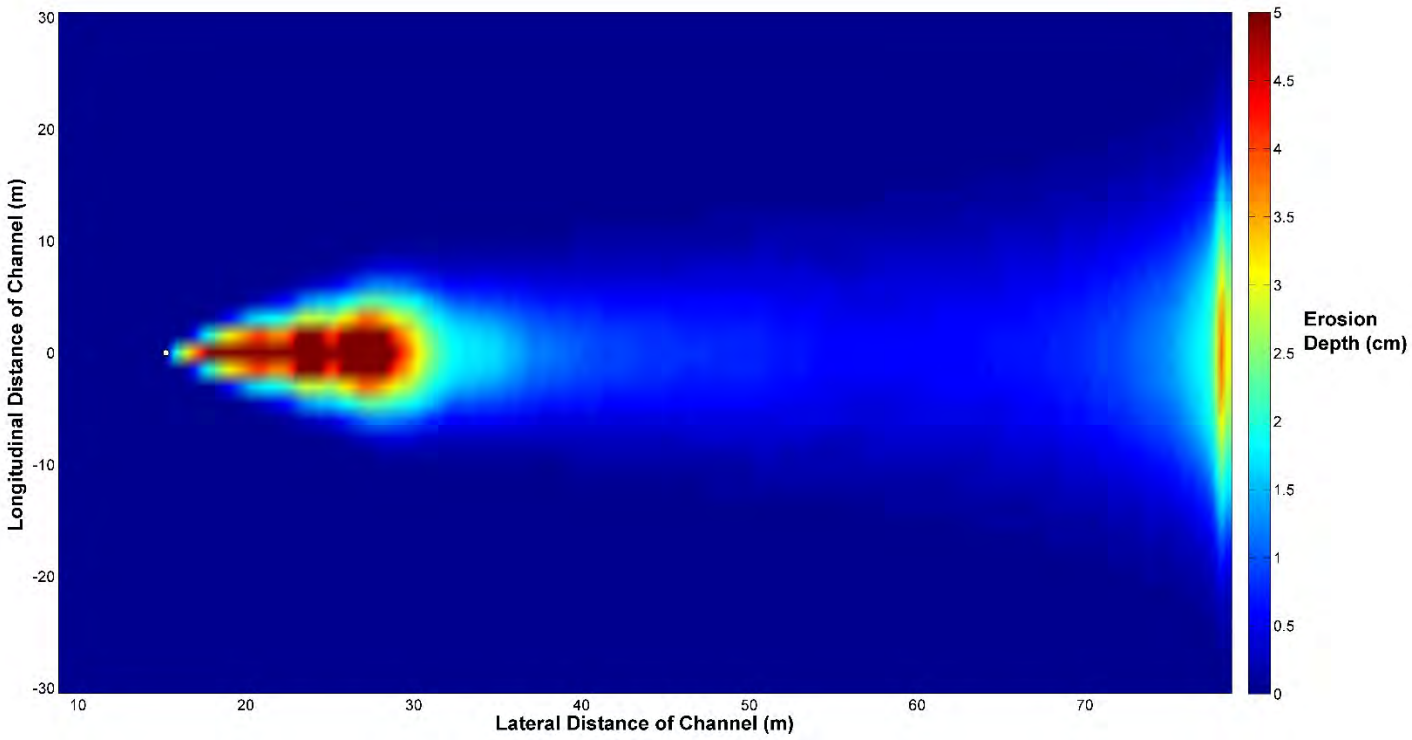


**Figure 29. Bed erosion around Transect 2 due to 100% power from Vessel 2.**

**Table 10. Stationary vessel scour analysis results.**

| | | | Max Bottom Velocity (m/s) | Max Bed Shear (Pa) | Max Bed Erosion (cm) | Average TSS Concentration of Domain (mg/L) | Total Sediment Mass (kg) |
|---|---|---|---|---|---|---|---|
| 100 % Throttle | Profile 1 | Vessel 1 | 0.83 | 0.65 | 0.38 | 4.3 | 19.9 |
| | | Vessel 2 | 1.49 | 2.08 | 4.70 | 75.3 | 349.5 |
| | Profile 2 | Vessel 1 | 1.03 | 1.02 | 1.10 | 10.8 | 51.1 |
| | | Vessel 2 | 1.58 | 2.38 | 8.22 | 169.7 | 918.9 |
| | Profile 3 | Vessel 1 | 1.07 | 1.11 | 1.50 | 8.0 | 40.9 |
| | | Vessel 2 | 1.62 | 2.52 | 10.68 | 146.9 | 894.2 |
| | Profile 4 | Vessel 1 | 0.76 | 0.55 | 0.25 | 2.0 | 14.6 |
| | | Vessel 2 | 1.31 | 1.61 | 2.62 | 88.9 | 681.2 |
| | Profile 5 | Vessel 1 | 0.71 | 0.46 | 0.16 | 1.5 | 14.3 |
| | | Vessel 2 | 1.20 | 1.34 | 1.97 | 63.4 | 636.0 |
| 75 % Throttle | Profile 1 | Vessel 1 | 0.73 | 0.49 | 0.19 | 0.8 | 3.2 |
| | | Vessel 2 | 1.31 | 1.59 | 2.56 | 38.5 | 177.5 |
| | Profile 2 | Vessel 1 | 0.90 | 0.08 | 0.59 | 4.8 | 22.3 |
| | | Vessel 2 | 1.39 | 1.84 | 3.36 | 83.0 | 450.2 |
| | Profile 3 | Vessel 1 | 0.94 | 0.84 | 0.74 | 3.5 | 17.4 |
| | | Vessel 2 | 1.43 | 1.97 | 3.99 | 69.8 | 429.2 |
| | Profile 4 | Vessel 1 | 0.66 | 0.41 | 0.12 | 0.5 | 3.4 |
| | | Vessel 2 | 1.14 | 1.22 | 1.73 | 43.6 | 332.5 |
| | Profile 5 | Vessel 1 | 0.62 | 0.34 | 0.08 | 0.3 | 3.2 |
| | | Vessel 2 | 1.04 | 1.02 | 1.19 | 30.3 | 302.8 |
| 50 % Throttle | Profile 1 | Vessel 1 | 0.60 | 0.33 | 0.07 | 0.0 | 0.1 |
| | | Vessel 2 | 1.07 | 1.07 | 1.36 | 13.9 | 63.9 |
| | Profile 2 | Vessel 1 | 0.73 | 0.52 | 0.22 | 1.5 | 6.8 |
| | | Vessel 2 | 1.15 | 1.24 | 1.70 | 32.4 | 171.1 |
| | Profile 3 | Vessel 1 | 0.77 | 0.56 | 0.27 | 1.0 | 4.9 |
| | | Vessel 2 | 1.18 | 1.34 | 1.90 | 26.4 | 157.3 |
| | Profile 4 | Vessel 1 | 0.55 | 0.27 | 0.00 | 0.0 | 0.0 |
| | | Vessel 2 | 0.97 | 0.82 | 0.70 | 16.3 | 107.9 |
| | Profile 5 | Vessel 1 | 0.51 | 0.23 | 0.00 | 0.0 | 0.0 |
| | | Vessel 2 | 0.86 | 0.69 | 0.44 | 8.5 | 83.1 |
| 25 % Throttle | Profile 1 | Vessel 1 | 0.42 | 0.17 | 0.00 | 0.0 | 0.0 |
| | | Vessel 2 | 0.76 | 0.54 | 0.25 | 0.9 | 3.8 |
| | Profile 2 | Vessel 1 | 0.53 | 0.26 | 0.00 | 0.0 | 0.0 |
| | | Vessel 2 | 0.82 | 0.64 | 0.37 | 3.9 | 18.3 |
| | Profile 3 | Vessel 1 | 0.55 | 0.29 | 0.00 | 0.0 | 0.0 |
| | | Vessel 2 | 0.85 | 0.69 | 0.44 | 2.7 | 13.3 |
| | Profile 4 | Vessel 1 | 0.39 | 0.14 | 0.00 | 0.0 | 0.0 |
| | | Vessel 2 | 0.67 | 0.42 | 0.10 | 0.3 | 1.9 |
| | Profile 5 | Vessel 1 | 0.36 | 0.11 | 0.00 | 0.0 | 0.0 |
| | | Vessel 2 | 0.61 | 0.35 | 0.08 | 0.1 | 0.5 |

## 4.3 Hydrodynamic Model

To better understand flow patterns and sediment transport at the United Heckathorn Superfund Site, a hydrodynamic and sediment transport model was developed using the Environmental Fluid Dynamics Code (EFDC). EFDC is a public domain modeling system that is currently maintained by Tetra Tech, Inc. and supported by the United States Environmental Protection Agency (USEPA). The modeling framework has been widely used to model hydrodynamic patterns and water quality in rivers, lakes, and coastal areas, with peer reviewed applications at over 50 sites (Hayter, 2006). EFDC solves depth-averaged Navier-Stokes equations and can be run in 2D or 3D (in 3D, vertical velocity components are solved using sigma layering and mass conservation) on both rectangular and curvilinear grids. Since tidal resuspension is not a concern in the system, the primary use of the model is to evaluate the dispersion of material resuspended during vessel activities. Model setup, model calibration and validation, and model results are presented below.

### 4.3.1 Model Domain and Grid Creation

A domain was chosen for the hydrodynamic model such that the circulation patterns in the Lauritzen Channel were accurately simulated. The domain extended from the turning basin in the northwest edge of the Santa Fe Channel to Richmond Inner Harbor. It included Richmond Yacht Harbor, Lauritzen Channel, and Parr Canal. In order to increase modeling resolution in the Lauritzen Channel, a curvilinear grid was created with varying resolution. In total, the domain contained 1,453 cells with 7 vertical sigma layers. The Santa Fe Channel was gridded with 637 relatively coarse cells (average area of 716 $m^2$) that increased in resolution near the mouth of the Lauritzen Channel (Figure 30). The Lauritzen Channel was meshed with high resolution using 816 cells with an average area of 49 $m^2$. Bathymetry data from the multibeam survey conducted by SEI during Tier 1 investigation was interpolated onto the grid by averaging all depth values within a cell. Cells that did not contain any bathymetry data were interpolated using a nearest neighbor approximation.

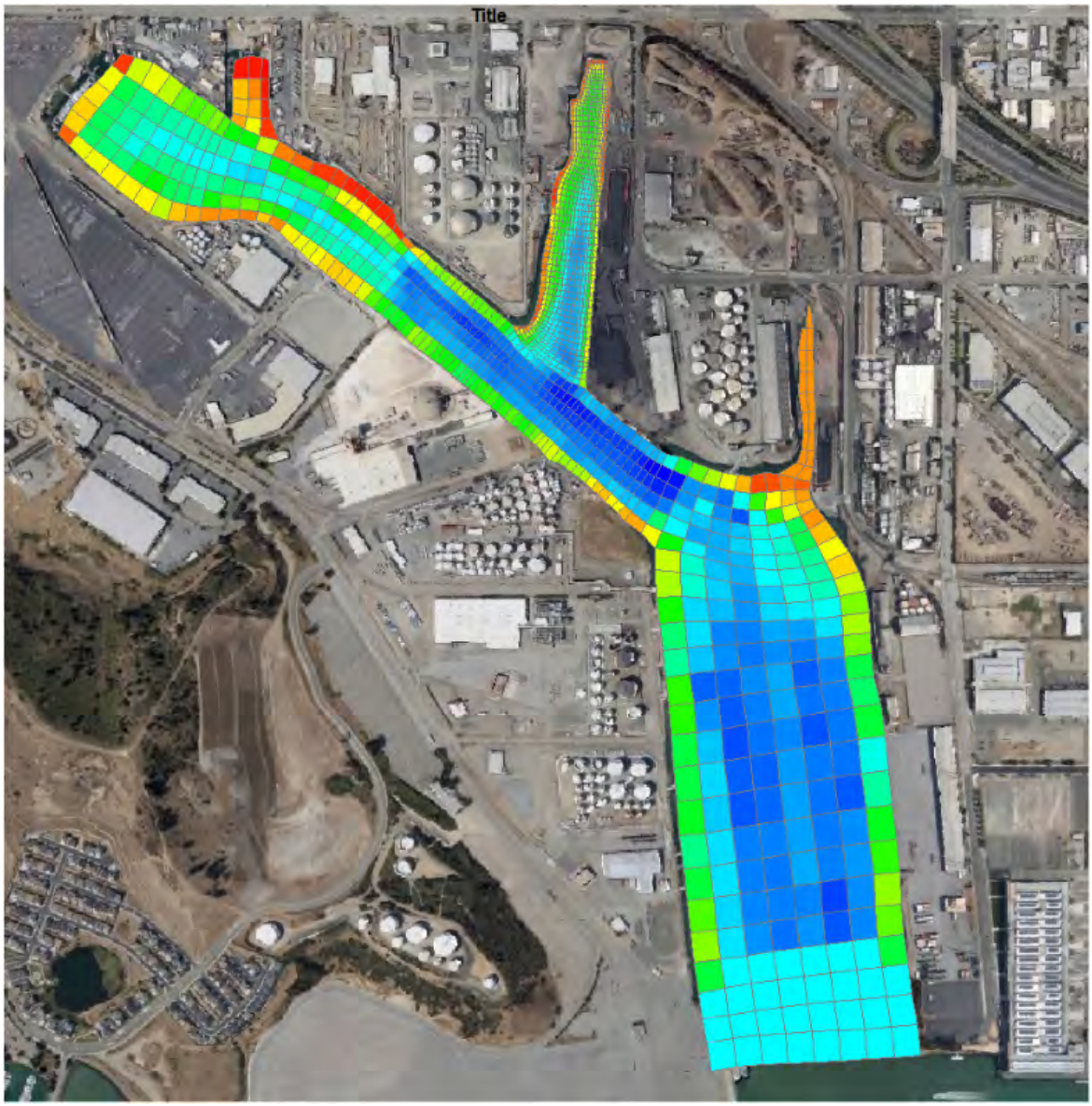


**Figure 30. United Heckathorn hydrodynamic and sediment transport model domain and grid.**

### 4.3.2 Boundary Conditions

The hydrodynamic model was forced by two conditions: 1) a water level was specified at the southern end of the Santa Fe Channel (southernmost boundary), and 2) a wind shear was applied uniformly over the domain. The specified water levels are displayed in Figure 31, which were obtained from the tidal predictor at the Richmond Inner Harbor station shown in Figure 32. Wind data came from the National Oceanic and Atmospheric Administration (NOAA) station at Richmond, CA. The Richmond station was chosen because data at the Point Potrero Station, nearest the study site, was incomplete for the study period.

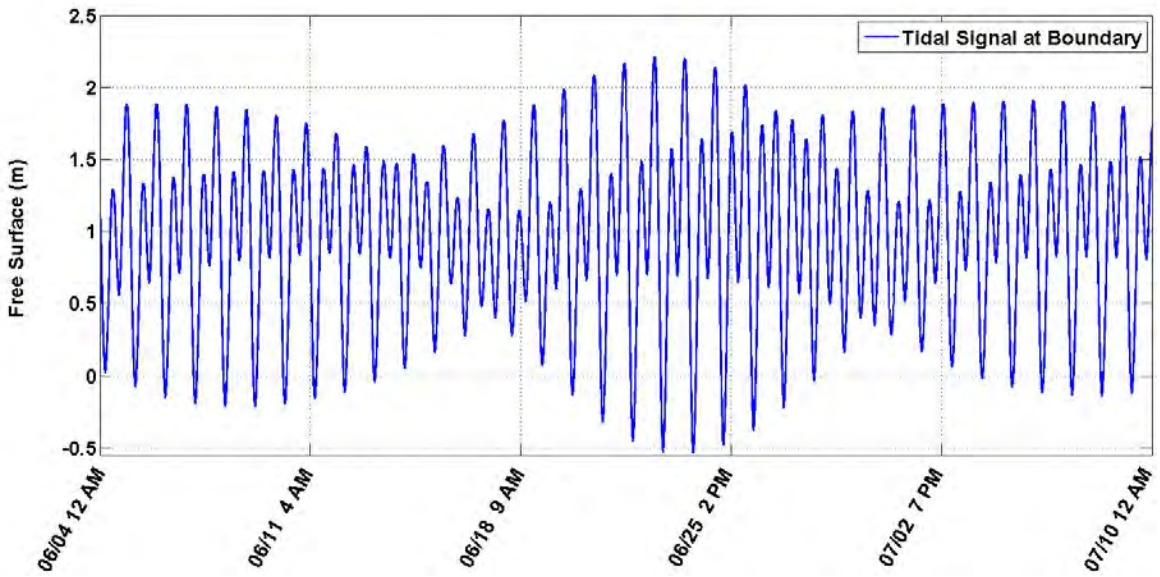


**Figure 31. Tidal boundary conditions at the southern forced boundary of the model.**

**Figure 32. Locations of boundary condition data.**

### 4.3.3 Model Validation

Modeled water level fluctuations were consistent with ADCP recorded water levels at both locations in the Lauritzen Channel. Figure 33 shows the entire study period for the station at the mouth of the Channel. The bottom panel highlights the consistency between modeled and measured water surface elevations in finer detail. The comparison of modeled to measured water level is very good with no drift over the 34 day measurement period. Some stair-stepping in the model data can be seen due to model output intervals (15 min.)

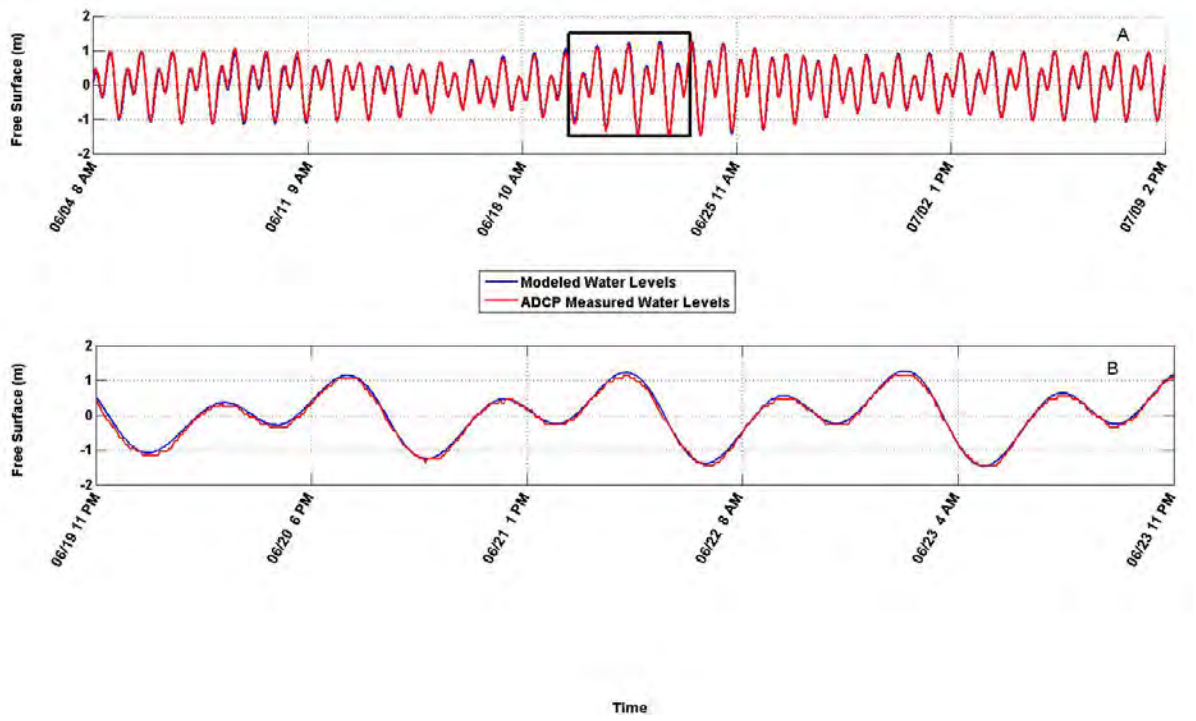


**Figure 33. Water level comparison at mouth of Lauritzen Channel. Upper: Full study period. Lower: Zoomed in plot of boxed area in shown in the upper panel.**

Velocities within the water column obtained at Station 1 from the ADCP were compared and used as a measure for the model velocities. Velocities were compared throughout the water column due to the multidirectional, low velocities (< 5 cm/s) recorded by the ADCP. Velocities from the ADCP were averaged based on the sigma layer thickness at each timestep from the model. Velocities were filtered to isolate variability due to tides. The modeled tidal velocities were within 2 to 3 cm/s (~ 30%) of the peak measured velocities but the low signal-to-noise velocities in the system did not facilitate direct model comparison. Analytical solutions of tidal velocities based on the tidal prism of the channel produced velocities consistent with the model (average velocities of 1 cm/s). The water levels described above were used as the primary calibration and validation metrics. Overall, the model was insensitive to adjustments in background eddy viscosities and bottom roughness, typical of similar systems, giving confidence in the model for the applications below.

### 4.3.4 Model Results

A study of the distribution of suspended sediment due to propeller wash from a stationary vessel was conducted to evaluate the patterns of sedimentation in Lauritzen Channel. Transects 1 and 4, corresponding to the location of the Manson Construction Company and LRTC sites were chosen to assess distribution characteristics. A total of 16 simulations assessing each vessel type at each location over peak flood, peak ebb, slack high water, and slack low water conditions were performed. TSS values in Table 11 were input at the propeller locations coincident with the stationary scour analysis.

**Table 11. TSS values for sediment distribution analysis.**

| Transect | Vessel | TSS (mg/L) |
|---|---|---|
| 1 | 1 | 32.5 |
| | 2 | 109.7 |
| 4 | 1 | 25.9 |
| | 2 | 242.9 |

TSS values were calculated as the ratio of mass flux and flowrate.

$$TSS = \frac{Mass\ Flux}{Flow} \quad \text{Eq. 16}$$

where Mass Flux was defined as the total mass suspended in the stationary propeller scour analysis over the duration of the suspension event. Flow was based on the maximum velocity experienced at the bed applied to the propeller area. Two sediment size classes were applied to the model representing two distinct grain sizes. Class 1 had a particle diameter of 10 µm and was based on the average $D_{50}$ over all sediment cores collected for Sedflume analysis as representative of resuspended sediment. Class 2 was defined as the average $D_{50}$ obtained during the LISST deployment as representative of what is in the water column and had a diameter of 51 µm. Settling velocities were calculated from (Cheng N. , 1997).

Sediment distributions in Figure 34 through Figure 41 are displayed as concentration suspended in the water column in mg/L or as deposited sediment mass in kg one day after release at a location along Transect 1. These figures represent conditions during the flood and slack low water events corresponding to maximum and minimum velocities present in the system. Transect 1 was chosen due to the significant tugboat traffic at the Manson Construction Company's facility and estimates of TSS input by both vessels was applied using the most conservative values related to the 100% horsepower approximations.

Sediments deposited to the bed during a flood tide event based on vessel 1 parameters are shown in Figure 34. Suspended sediments that have not yet settled after one day are shown in Figure 35. Both figures show confinement to the Lauritzen Channel. Larger initial TSS concentrations for Vessel 2 resulted in a greater distribution of sediment and an overall larger mass deposited to the bed (Figure 36) and still suspended within the water column one day after release (Figure 37). In this case, the deposited sediment was still confined to the channel, but the suspended sediment extended into the Santa Fe Channel. This suggests that the coarser sediments were settling out but the finer material remained in suspension and was transported throughout the system. Distribution of sediment during and after a slack tide event predominantly resulted in the confinement of both deposited and suspended sediment to the Lauritzen Channel as seen in Figure 38 through Figure 41. Most sediment quickly deposited near the mobilization point along the western edge of the Lauritzen channel, and did not reach the eastern bank. Similarly, sediments that remained suspended in the water column predominantly remained along

the western bank.  Sediment suspended by Vessel 2 during slack tide, was transported to the main section the channel but was confined to the immediate vicinity of the channel mouth. In all cases where sediment was found outside of the Lauritzen Channel, higher masses were found near the shallower banks rather than in the deeper, larger flow regions near the center. These results are consistent with the particle tracking study's findings that solids released in Lauritzen Channel are being transported throughout the Lauritzen Channel over time.

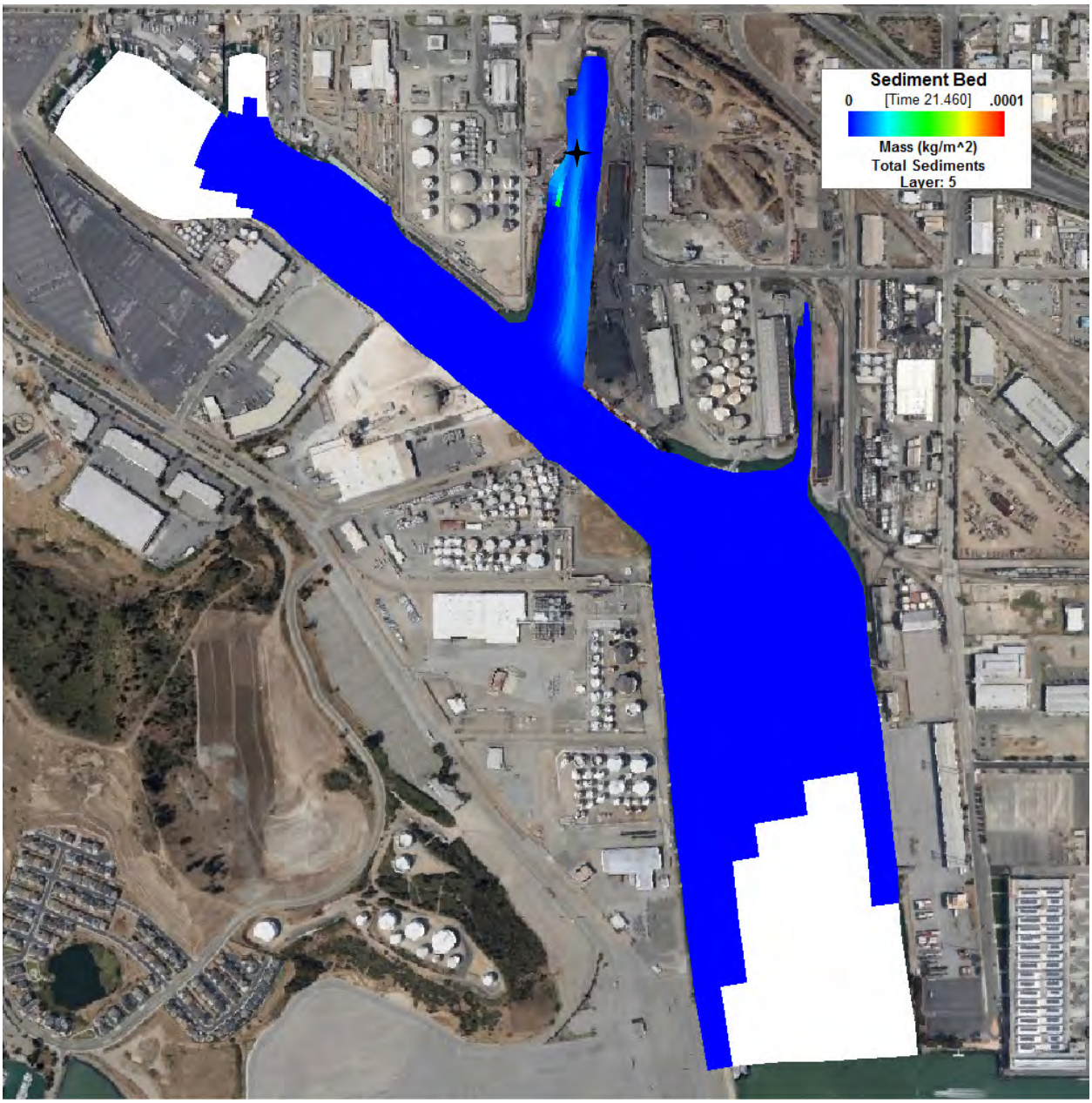


**Figure 34. Distribution of mass at the sediment bed due to Vessel 1 parameters 1 day after release during maximum flood tide. Black Star denotes release point.**

**Figure 35. Distribution of suspended sediment due to Vessel 1 parameters 1 day after release during maximum flood tide. Black Star denotes release point.**

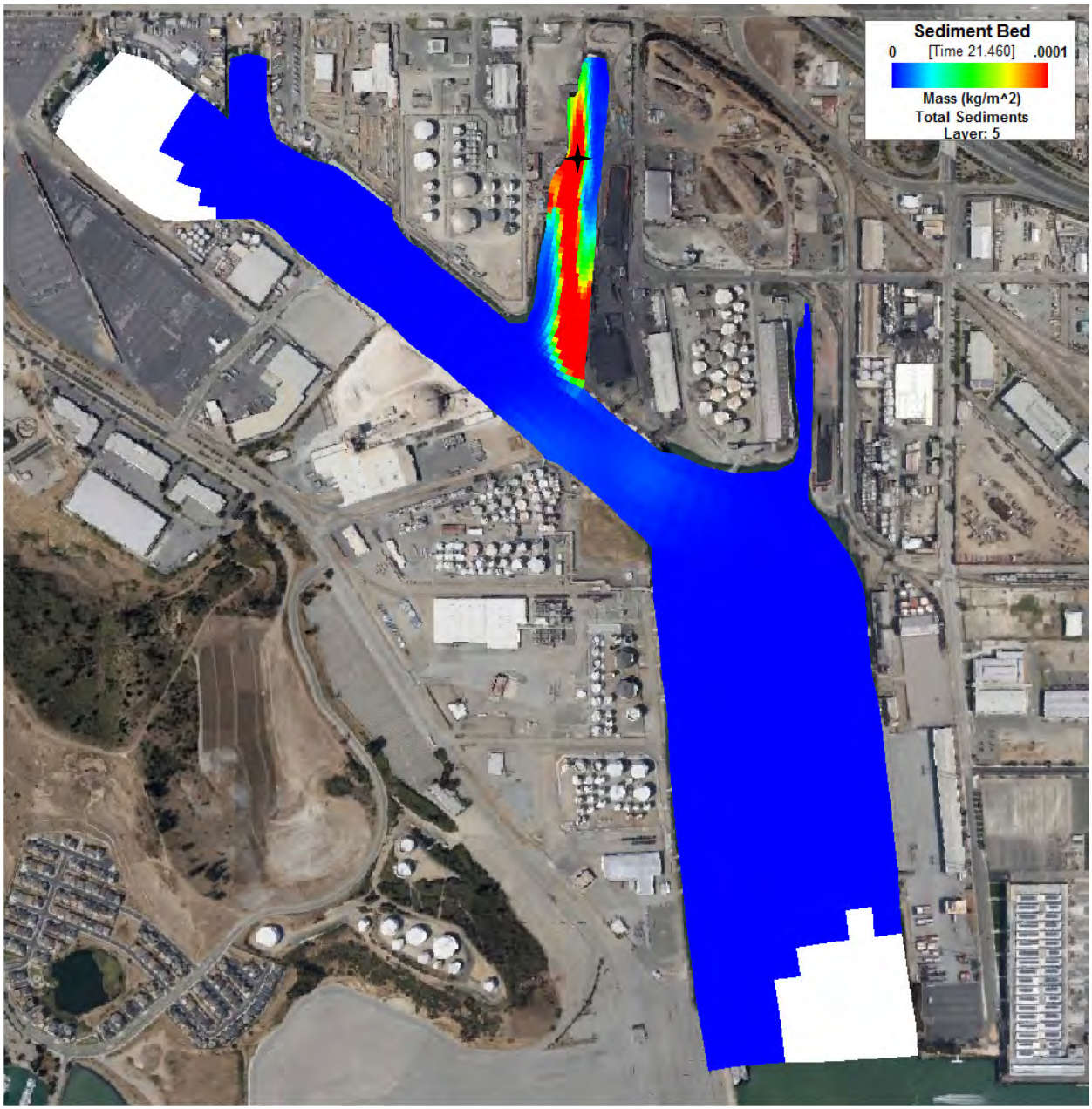


**Figure 36. Distribution of mass at the sediment bed due to Vessel 2 parameters 1 day after release during maximum flood tide. Black Star denotes release point.**

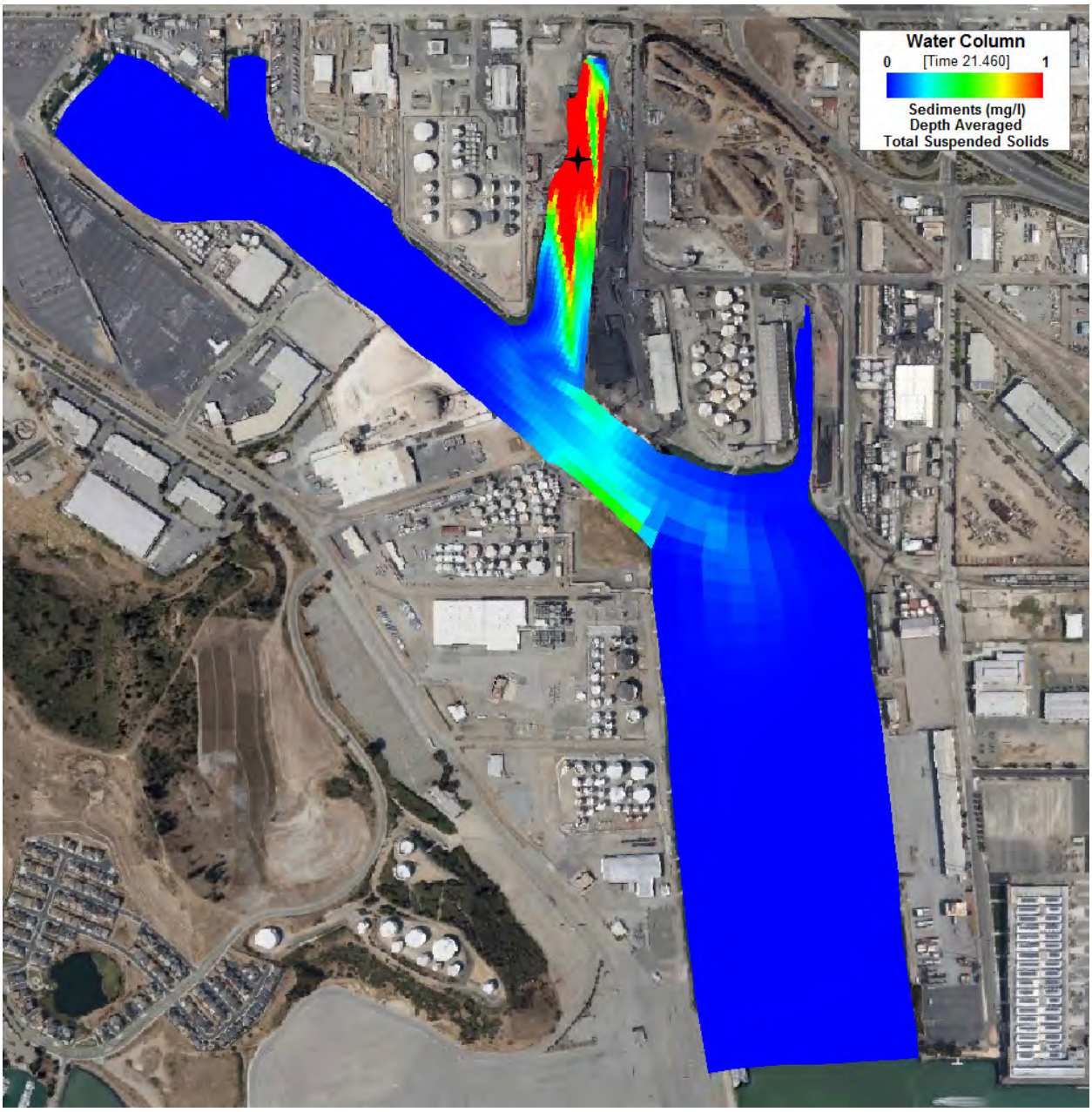


**Figure 37. Distribution of suspended sediment due to Vessel 2 parameters 1 day after release during maximum flood tide. Black Star denotes release point.**

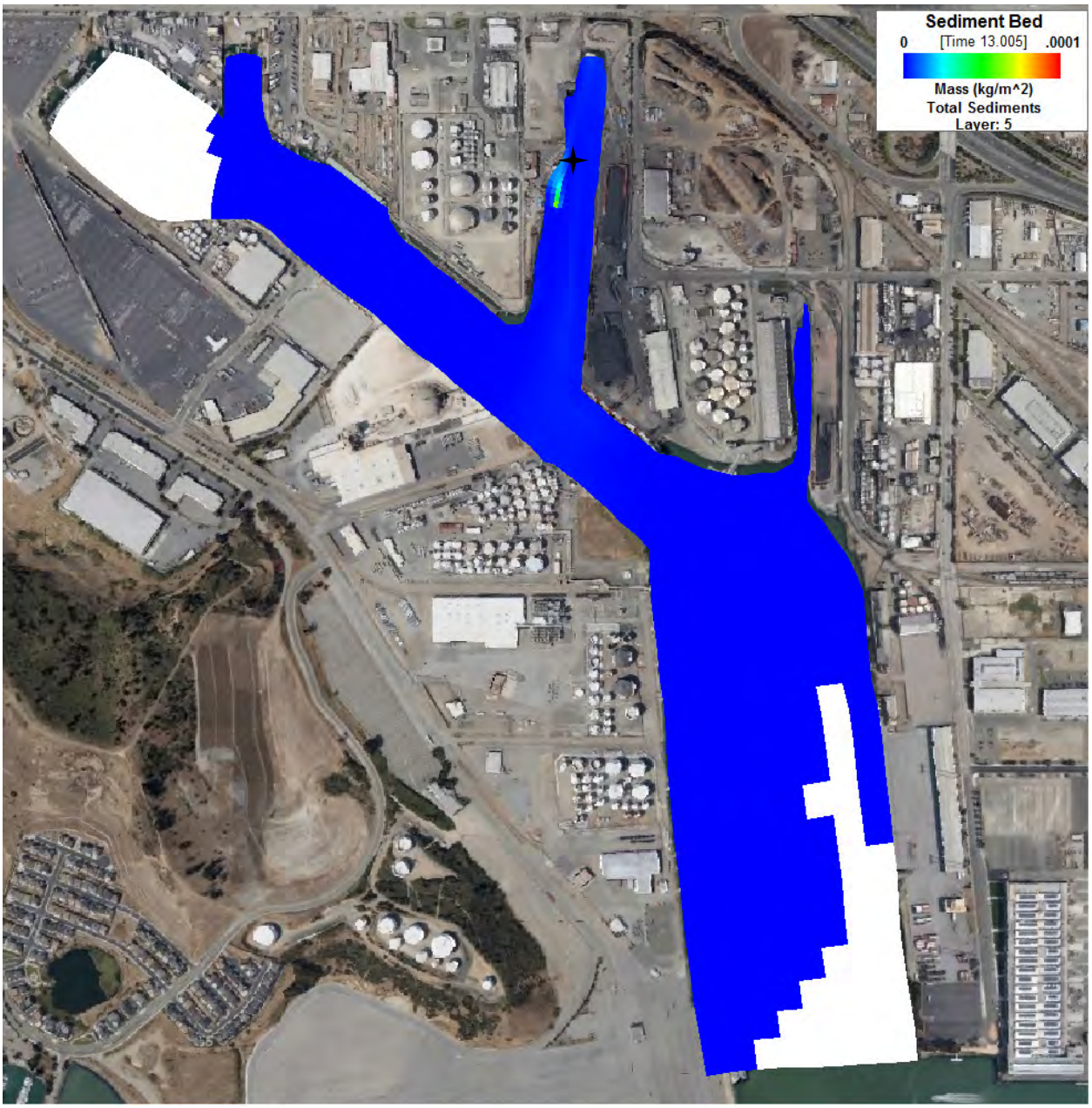


**Figure 38. Distribution of mass at the sediment bed due to Vessel 1 parameters one day after release during a slack low tide event. Black Star denotes release point.**

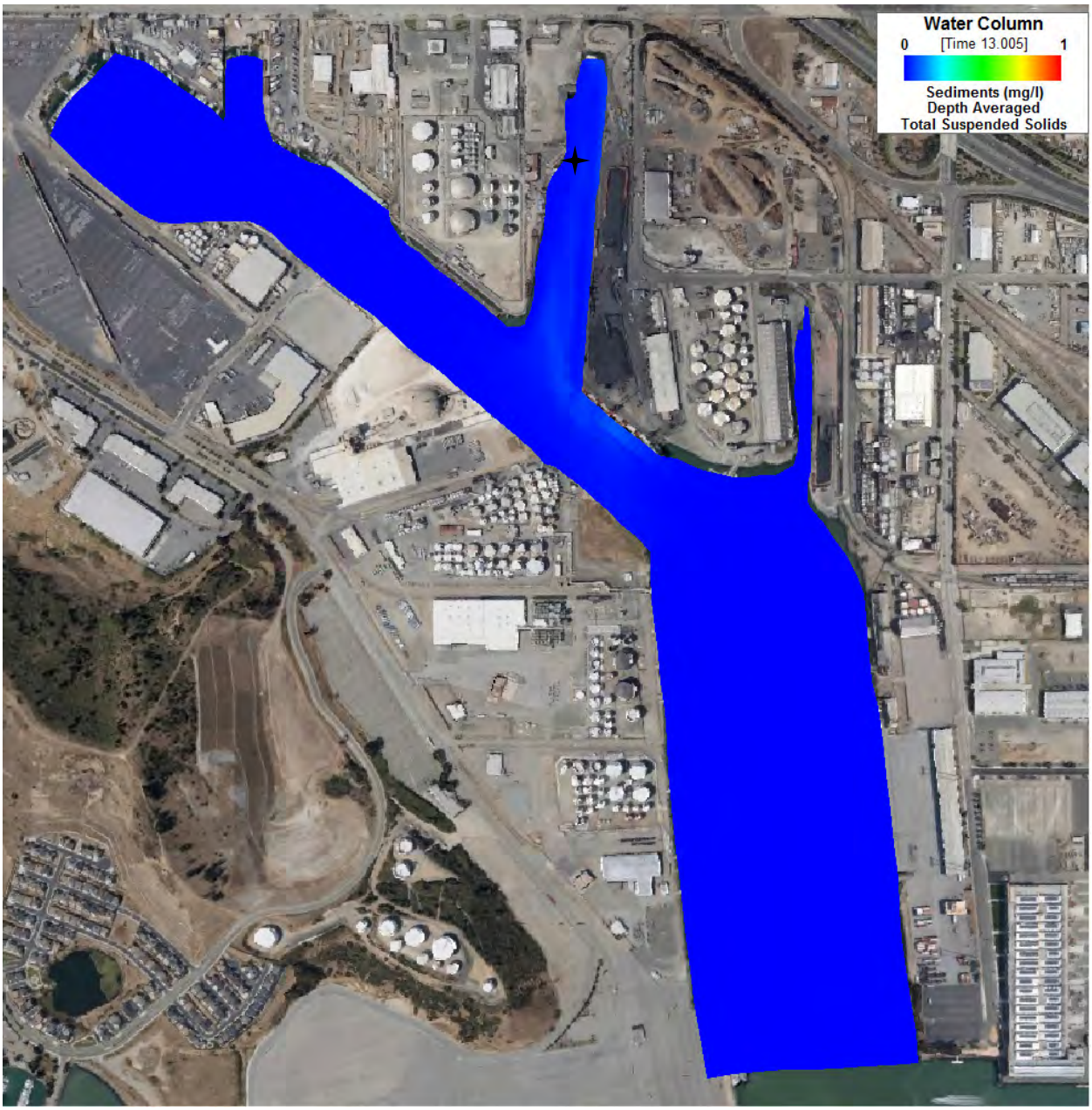


**Figure 39. Distribution of suspended sediment due to Vessel 1 parameters one day after release during a slack low tide event. Black Star denotes release point.**

**Figure 40. Distribution of mass at the sediment bed due to Vessel 2 parameters one day after release during a slack low tide event. Black Star denotes release point.**

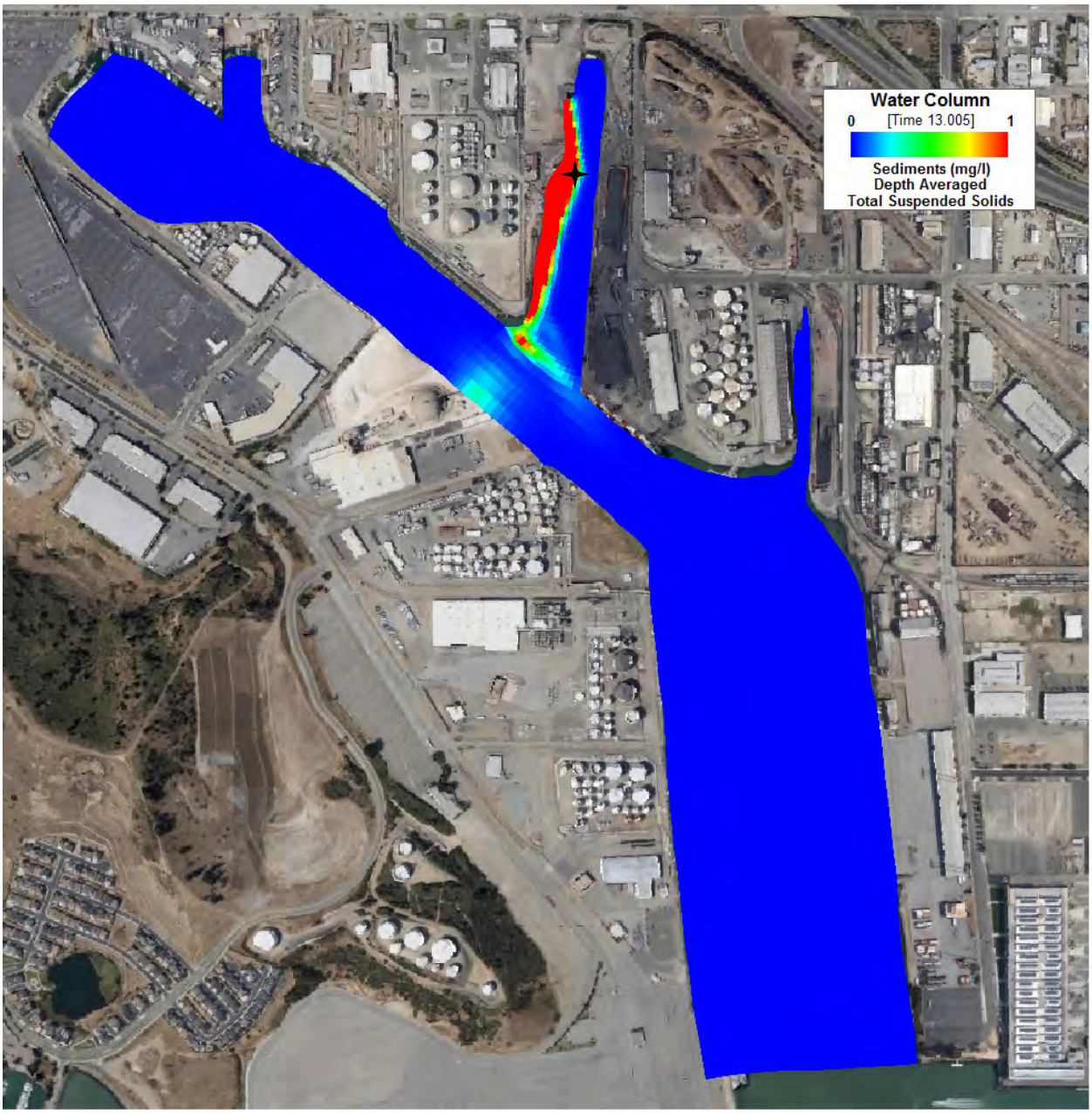


**Figure 41. Distribution of suspended sediment due to Vessel 2 parameters one day after release during a slack low tide event. Black Star denotes release point.**

# 5.0 Refined Sediment Transport CSM and Sediment Budget

At the Lauritzen Channel, where sediment-bound contaminants are the key risk factor, a sediment transport CSM is critical to addressing sediment management questions. The sediment transport CSM synthesizes all available data, describes a mass balance (i.e., a simple representation of all inputs and outputs to a system), and describes inferred sediment transport patterns (areas of deposition and erosion) based on grain size distribution, contaminant distribution, and hydrodynamic data. Potential

sediment transport trends were originally identified and described for the Lauritzen Channel in the Tier 1 CSM. The description was based the available data during Tier 1 investigations. In the paragraphs that follow, the Tier 1 CSM is refined to incorporate the data and results from Tier 2.

## 5.1 Sediment Transport Process Summary

In the absence of anthropogenic activity, the Lauritzen Channel is a low energy, constructed channel that is dominated by tidal circulation. Time-averaged, depth-averaged current velocity measured by both the ADCPs near the mouth and head of the Lauritzen Channel was near 0.01 m/s. Velocities calculated from the hydrodynamic model were similar in magnitude to the measured ADCP values, further validating the low energy of system. The small tidal velocities in the channel limit any potential for sediment resuspension due to tidal currents. Critical shear stresses measured during the Sedflume analysis ranged from 0.1 Pa to 1.28 Pa, while time-averaged tidally induced near-bottom shear stresses derived from the ADCP data were 0.04 Pa and 0.02 Pa for the mouth and head of the Lauritzen Channel, respectively (Table 5). Even the maximum tidally induced near-bottom shear stresses measured by the ADCPs (0.15 Pa) was only slightly above the measured critical shear stresses from the Sedflume analysis. It is concluded that turbulence fluctuations originating from tidal currents do not play a significant role in mobilizing sediment in the Lauritzen Channel. Generally, with the continuation of the San Francisco Bay as a primary sediment source, the channel on the whole is a sediment sink as seen in the continuous accumulation of YBM. In the absence of anthropogenic activity (e.g. dredging, vessel operations), the channel would continue to fill until a dynamic equilibrium between the tides and sediment sources is achieved (Bearman, Friedrichs, Jaffe, & Foxgrover, 2010).

The geophysical surveys show that vessel scour and spud anchoring activities have a widespread effect on mixing sediment up to 0.5 m in depth over wide swaths. The propeller wash and ship wake model used to assess the effects of vessel activity showed that the larger sized vessels operating in the Lauritzen Channel have the potential to mobilize sediment. Resuspension caused by a stationary vessel pushing against a barge or dock area was shown to be greater than resuspension from a transiting vessel, though both vessel operation types can lead to sediment suspension by increasing near-bottom velocity and the corresponding bed shear stress. The stationary vessel scour averages 1.4 cm of sediment resuspension with a maximum depth of approximately 10 cm. The wake caused by a transiting vessel, however, has a chance of mobilizing sediment near or under piers and in shoreline areas throughout the channel as a whole. However, the mass of sediment suspended during this type of operation would be low in comparison to the sediment suspended behind an operating stationary vessel. Overall, the vessel scour analysis shows that the deeper 0.5 m scour marks may be due to vessel keels dragging in the sediment instead of propeller scour. A keel drag would constitute a sediment mixing with very little net resuspension compared to the propeller scour even though the mixing at the bed is greater.

The particle tracking study also provided important insight into the importance of vessel activity on sediment transport. It was evident that during every sampling period, tracer was redistributed from both source areas in the channel. The magnets generally showed that material resuspended in the water column can be transported to the upper and west side of the channel and occasionally (2 events) along

the east side. The grab samples generally showed tracer presence from both sources throughout the sampling period. Since tidal currents have been demonstrated to be a negligible source of resuspension, vessel traffic (primarily tug and barge movement on the west side of the channel) was the likely source of tracer movement and responsible for tracer distribution in the channel sediment. The magnet outside the channel indicated that there was detectable transport out of the channel; however, the mass of material was at the detection limit of the method (i.e. very low mass). The modeling analysis also showed this to be a very low magnitude pathway.

The modeling simulations indicated that sediment deposition was minor to nonexistent outside of the Lauritzen Channel 1 day after releasing a hypothetical sediment plume comparable in size to the largest event that is expected from vessel activity. The results presented in Table 12 indicate over 93% of the sediment was deposited within Lauritzen Channel. In the model, some of the finer grained sediment remained suspended in the water column and advected into the Santa Fe Channel, but TSS concentrations were below 0.5 mg/L for even the most conservative case with the largest vessel (Vessel 2) operating at 100% power. Elevated TSS concentrations measured by the ADCPs likely resulted from sediment plumes generated by vessel activity, but it is difficult to correlate increased bottom velocity to the TSS spikes because of the potential for advective transport; an ADCP platform can be unaffected by a propeller jet but close enough to measure the advected sediment plume. All evidence suggests the net effect of vessel activities is a vertical mixing of the sediment, high local dispersion, and low far-field dispersion of sediment resuspended during vessel activities. The contaminant distribution pattern seen in the RI, which was characterized by over an order of magnitude decline in sediment DDT concentration with increasing distance from the Lauritzen Channel, further confirms low net transport out of the channel (White, Kohn, Gardiner, & Word, 1994). The low tidal circulation indicates that most of the sediment suspended during vessel operations would disperse locally and settle within the channel. Transport out of the Lauritzen Channel to the Santa Fe Channel does occur, but the sediment transport measurement and analysis conducted suggests that it is limited (approximately 7% of the resuspended material).

**Table 12. Percentage of deposited sediment by location.**

| | Vessel 1 | | Vessel 2 | |
|---|---|---|---|---|
| | Flood | Ebb | Flood | ebb |
| Percent Deposited - Lauritzen Channel | 98.45 | 97.48 | 93.28 | 96.61 |
| Percent Deposited - Santa Fe Channel | 1.55 | 2.52 | 6.72 | 3.39 |

The net effect of the vessel activity in the low energy depositional channel can also be examined by looking at trends in YBM mass (Figure 5) and bathymetric change (Figure 4). Both show general accumulation behavior of sediment in the Lauritzen Channel. The largest amount of sediment accumulation is in the berth on the east side of the channel. The accumulation is occurring in the region where currents are likely the lowest, causing the dredged berth to behave locally as a sediment trap. Conversely, the west side of the channel, which experiences high vessel activity in shallow regions, exhibits low to no sediment accumulation of YBM and potential erosion in the bathymetric change (Figure 4). Finally, the head of the channel with low energy shallow water and moderate barge activity

shows a moderate YBM accumulation and a mix of potential erosion and deposition. Although each line of evidence has uncertainty associated with it, they are completely independent of each other and all express similar trends, thereby increasing the confidence in the overall pattern.

Since the remedial dredging and sand placement in 1996 and 1997, no dredging activities have been conducted in the Lauritzen Channel. Follow-on sampling in the channel revealed that the sand layer was not present in the majority of cores, including those where the YBM and Older Bay Mud (OBM) interface was present. The sampling additionally revealed that the sand distribution was heterogeneous throughout the channel. The fact that the sand, where present, is often buried to a depth of 0.5 m or more shows that there has been either deposition or downward mixing of the sand at locations throughout the channel (or both).The patchy distribution of the sand could be due to some combination of inconsistent sand placement and sediment disturbance.

Contaminants, particularly DDT, can also act as an indicator of sediment movement. Contaminant patterns in the Lauritzen Channel show heterogeneity similar to the sand distribution. The highest DDT concentrations are in regions of sediment accumulation in the head of the channel and the deep area on the east side of the channel. Lower concentrations are present along the west side of the channel, consistent with the thin YBM layer and potential sediment erosion in this region. It is important to note that bioturbation can mix sediment over an interval of a few mm to about 10 cm depending upon the resident species. However, given the large-scale mixing and heterogeneity in both the vertical and lateral distribution of sediment and DDT in the channel, it can generally be considered a secondary process with respect to sediment transport.

In summary, the Lauritzen Channel is a low-energy protected region with tidal velocities that are not likely to result in resuspension. The low energy coupled with sediment input from San Francisco Bay result in a net sediment accumulation in the channel. Ongoing vessel operations in the channel are responsible for localized mixing of the sediment bed, resuspension, and redistribution of sediment within the channel. A portion of the resuspended material may also be tidally dispersed into the Santa Fe Channel. The net effect of sediment transport processes in Lauritzen Channel is likely a heterogeneous distribution of contaminants with generally higher concentrations in areas of low sediment accumulation.

## 5.2 Conceptual Sediment Budget

A sediment budget is developed to account for the external inputs, outputs, and storage of sediment in a region due to the net effects of all of the sediment transport processes. The budget provides a useful tool for accounting for sediment and evaluating the effects of any changes to the system. Essentially the sediment budget is described by:

$$Sediment\ Input - Sediment\ Output = \Delta Sediment\ Storage$$

At a contaminated site in particular, the sediment budget provides the basis for accounting for contaminated sediment movement into and out of the system and storage within the system. The goal of the conceptual sediment budget is to identify the external inputs and outputs of sediment to the

system and identify potential methods for quantifying these processes. It is important to note that processes such as propeller scour can significantly alter deposition and erosion patterns within the system while the external exchange of sediment between the channel and the estuary remains unchanged if the mobilized sediment settles before transporting out of the channel. The propeller wash and ship wake model showed that up to 900 kg of sediment can be mobilized if the larger sized vessel operating in the Lauritzen Channel is stationary and running at 100% of its power for 10 minutes. This scenario is unlikely, but it gives a conservative upper limit to the amount of sediment that can be mobilized from vessel activity. The sediment transport modeling showed that the largest fraction of the suspended sediment settled within a 100 m of the vessel activity and did not contribute to the overall sediment budget of the Lauritzen Channel.

The key external sediment inputs to the Lauritzen Channel are the tidal delivery of sediment from San Francisco Bay and upland runoff during wet weather. The bay provides a constant delivery of silt and clay to the margins, including harbors. Tidal delivery of sediment was investigated by examining sediment fluxes calculated from the ADCP data. Sediment flux oscillated with tidal variability; daily averaged flux values were negligible. When summed over the entire 34 day deployment period, the net sediment transport due to tidal delivery was nearly zero. However, the ADCPs were deployed during summer months when sediment delivery from the bay is generally low (Schoellhamer, 1996). Had the ADCPs been deployed during winter months, increased flux from the bay may have been more apparent. In order to quantify the overall mass exchange of the Lauritzen Channel with the Santa Fe Channel over a long time period, additional ADCP data are required, particularly during winter months.

The delivery of sediment from upland sources is primarily due to the municipal stormwater outfall at the head of the channel. Data are not readily available on the yearly flow and associated sediment load associated with the outfall. Because little rainfall occurred during the ADCP deployment period, no effects of the outfall were seen in the water column with the exception of anecdotal observations of a TSS plume near the outfall that was not detected at either of the platforms. The “Simple” method of load estimation from the U.S. Department of Agriculture (1986) can be used for the total load from local upland sources. Assuming the drainage area of the catchment draining into the channel is approximately 100 acres (anecdotal evidence from drainage areas) and the local industrial land use TSS associated with outfall discharges is 120 mg/L (United States Department of Agriculture (USDA); Natural Resources Conservation Service (NRCS), 1986), the local average annual rainfall of 23 in (58 cm) can be used to determine an average yearly sediment load of ~ 20,000 kg.

A balance of sediment sources verifies that the tidal delivery of sediment is the largest order of magnitude external sediment source to the region. The net result of the YBM thickness analysis is that from 2001 to 2013 the sediment accumulation rate is 2.5 million kg/yr. Comparison of the sediment accumulation rate to the loading from the adjacent upland area shows that the upland loading could be responsible for a maximum of 1% of the accumulation in the channel. These calculations, even with associated uncertainty, show that the tidal delivery of sediment from the Bay is the largest contributor of sediment to the channel. Note that while the measured flux of sediment was negligible, the

measurements are only representative of a dry month and not wet periods when the primary delivery of sediment from all sources occurs.

The head of the Lauritzen Channel and the LRTC berth appear to be the regions of most consistent sediment deposition. While the San Francisco Bay does represent the largest external source of sediment, the persistence of high contamination in the channel is most likely due to an incomplete removal during remedial activities as discussed in the Source Identification Study Report (CH2MHILL, 2013b). The propeller wash and ship wake model indicated that the larger vessels operating in the Lauritzen Channel can mobilize sediment and redistribute them within the channel. Given enough time, deposition of sediment from the Bay will bury the contaminants, but the process will be slow because of the remixing from vessel activity.

The sediment outputs are the net result of suspended sediment in the channel that can be transported out by the tide. The key resuspension processes that have been identified are the vessel operations. As discussed, the props, keels, and anchor spuds of vessels may cause localized resuspension. Another source of suspended sediment in the system is suspended solids from outfalls during storm events. Although much of this material is likely to accumulate locally in the Lauritzen Channel, DDT contamination in the Santa Fe Channel suggests that low-level tidal dispersion and transport of sediment resuspended in the channel occurs.

# 6.0 Summary and Sediment Management Questions

The magnitude and frequency of sediment resuspension and transport due to anthropogenic processes were quantified to accurately determine the potential for sediment accumulation, contaminant redistribution, and potential for recontamination; and to support the development of effective remedial alternatives in the FFS.

The following field activities were performed to provide the necessary data for the transport quantification:

- Acoustic and optical sensors were deployed to measure profiles of velocity and proxies for TSS at two locations.
- Sediment flux throughout the channel was determined from measurements of channel velocity and TSS.
- Erosion rate measurements were made using Sedflume to develop a spatial picture of sediment erosion properties in order to better understand the potential for future sediment mixing, erosion, and transport.
- Sediment tracers were deployed and monitored in an area of high vessel activity to assist in quantifying sediment transport due to vessel activity.

In addition to the field activities, further analytic activities were performed as part of the Tier 2 analysis to support the quantification of the sediment and contaminant transport processes. The following analytic activities were performed:

- A sediment flux analysis was conducted to determine offsite transport and potential recontamination within the Lauritzen Channel based on the field data. The flux analysis provided quantitative information on the movement of sediment in the Channel.
- Erosion potential was determined using models of propeller scour to quantify sediment mixing depths and volumes during typical vessel operations using the bathymetric, sediment erosion, and suspended solids data.
- Modeling of the area using EFDC was performed to determine spatial and temporal patterns of suspended sediment transport in the Lauritzen and Santa Fe Channels. The primary goal of the modeling was to determine transport and deposition patterns of material resuspended during various anthropogenic events.
- The quantitative model was coupled with the field data analysis to refine the CSM. The refined CSM can be used to help answer sediment management questions and help assess the remedial alternatives development.

## 6.1 Site Management Questions

This document developed a Tier 2 sediment transport CSM for the United Heckathorn Superfund Site. The Tier 2 CSM has been used address the following sediment management questions:

- What is the source(s) of the sediment accumulating in the Lauritzen Channel?

The low energy Lauritzen Channel provides an ideal environment for deposition of sediment. The supply comes primarily from the San Francisco Bay with minimal input (~ 1%) from the outfalls into the Lauritzen Channel. Although the low nature of the flux during the dry period of measurement does not allow for direct quantification, the tidal delivery of sediment on a daily basis, even during the dry summer months, generally indicates that the bay is the primary source of accumulating sediment.

- How does sediment transport lead to the redistribution of contamination within the Lauritzen Channel, or movement of contamination out of the channel?

The velocities measured during the Tier 2 field study verify that the tidal velocities are very low, allowing for sediment deposition. The observations during the Tier 2 study verified the Tier 1 conclusion that vessel activity is the primary source of resuspension and redistribution in the Lauritzen Channel. The tracer study provided evidence of vessel resuspension and redistribution of sediment at the tracer locations throughout the channel. Vessel scour analysis showed that while the vessels can scour up to approximately 10 cm of sediment, the modeling studies showed that the greatest portion of this sediment settles locally leading to local redistribution of contamination within the channel. A portion of the material resuspended, particularly near the mouth during an ebb tide, could be transported out to the Santa Fe Channel; however, the tracer and modeling study showed the mass to be negligible. Evidence indicates that the primary region of resuspension is along the Manson facility and not at the mouth of the channel.

- If part of the Lauritzen Channel is actively remediated, could sediment transport lead to the recontamination of the remediated area?

The natural transport processes alone would not lead to recontamination of the remediated areas. If high contaminant concentrations remain in locations that could be disturbed by anthropogenic activities, they could be redistributed to actively remediated areas.

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# Appendix A. Hydrodynamic Field Study

## Introduction

Sea Engineering, Inc. (SEI) conducted hydrodynamic field studies in the Lauritzen Channel as part of the CH2MHill Tier 2 Sediment Transport Study, United Heckathorn Superfund Site. SEI deployed two bottom-mounted mooring platforms, each equipped with a Teledyne RDI 1200 kHz Workhorse Sentinel Acoustic Doppler Current Profiler (ADCP) and a Yellow Springs, Inc. (YSI) water quality sonde with temperature, pressure, and optical turbidity probes. The two instrumented platforms were deployed at the mouth and near the head of the channel in ~11 m and ~7 m mean water depth between 4 June and 9 July 2013.

SEI also conducted vessel-mounted ADCP surveys during the initial deployment and the final recovery. Water samples for laboratory analysis of total suspended solids concentration (TSS) and vertical profiles of particle size distribution (PSD) using a Sequoia Scientific, Inc. LISST-100X were collected at the moored platform locations during ADCP survey activities.

The primary objective of the hydrodynamic data collection was to determine the magnitude and frequency of sediment resuspension and the magnitude and direction of sediment flux. This document describes hydrodynamic data collection procedures and presents the hydrodynamic data collected during the Tier 2 Sediment Transport Study, Task 2 Hydrodynamic Data Collection. The study area and field sampling assets are shown in Figure 1.

**Figure 1. Site map. The locations of the two bottom-mounted platforms are represented by red circles and ADCP survey lines are indicated in green.**

## Methods

*Bottom-Mount Platforms*

The ADCPs were mounted "uplooking" on bottom-mount platforms (Figure 2) and programmed to collect data every 10 minutes at a vertical cell spacing of 0.25 m. Factory recommended calibrations and maintenance were performed prior to the initial deployment of the ADCPs. The internal compass checks were performed, the functionality of the electronic circuitry and memory was verified, the battery was tested, and beam continuity was checked to verify transducer functionality.

The water quality sondes were fixed to the bottom-mount platforms as shown in Figure 2. Water quality data were collected every 15 minutes at a height of 0.5 m above the seabed. Optical turbidity measurements were calibrated to USEPA standards using a two-point calibration and calibration standards, 0 NTU and 126 NTU.

**Figure 2. Bottom-mount platform with ADCP and water quality sonde (YSI) indicated.**

*Vessel Surveys*

A "downlooking" ADCP was mounted on the port side of the SEI vessel and measured the spatial distribution of the vertical current profile in the system concurrently with a differential GPS for sub-meter scale location accuracy. The vessel-mounted ADCP was calibrated as described in the *Bottom-Mount Platform* section and programmed to collect data at 0.25 m vertical bins. Surveys were conducted on 4 and 5 June and 8 and 9 July 2013 following the three transect lines indicated in Figure 1. The ADCP transects were conducted in both directions (i.e. back and forth) across each transect line to decrease any directional bias in the data. Vessel speed was regulated to a maximum of 1 m/s to reduce velocity prediction errors.

Water samples for analysis of TSS were collected for the purpose of relating moored backscatter time series data to analytical TSS data over a range of tidal conditions. Eighteen samples were collected as nearest as possible to each of the two bottom-mounted platforms at approximately 0.5 m above the bed. Half of the samples were collected during the June surveys and the other half were collected during the July vessel surveying activities.

Water column profiles of PSD from surface to about 0.5 m above the bed were also collected near the two bottom-mounted platforms using a LISST-100X, type C. PSDs were measured between approximately 3 μm and 280 μm. The median particle diameter ($d_{50}$), $10^{th}$ percentile ($d_{10}$), $90^{th}$ percentile ($d_{90}$), and cumulative volume particle size distributions were computed from LISST data.

## Results

*Bottom-Mount Platforms*

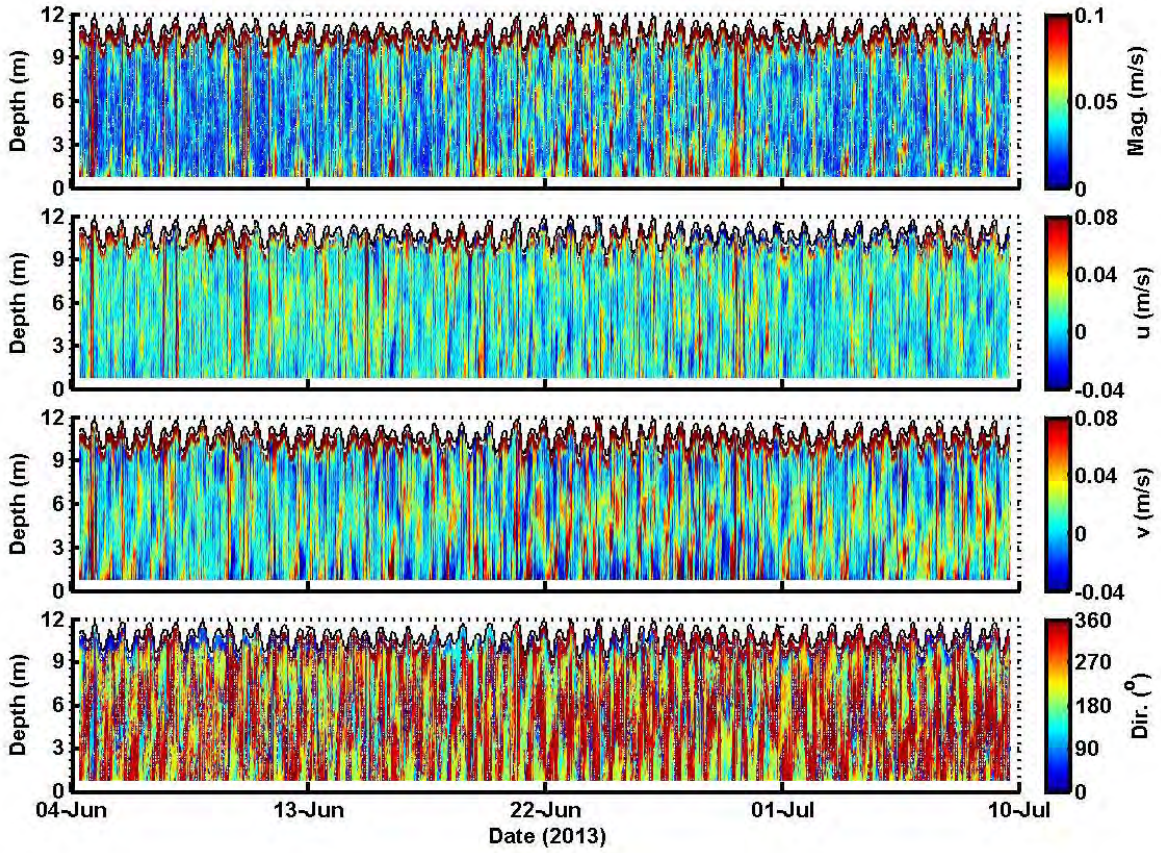


**Figure 3. Time and depth resolved current velocity magnitude (top), u and v current components (second and third panels), and current direction recorded at ADCP Platform #1 (mouth of Lauritzen Channel) from 4 June to 9 July 2013.**

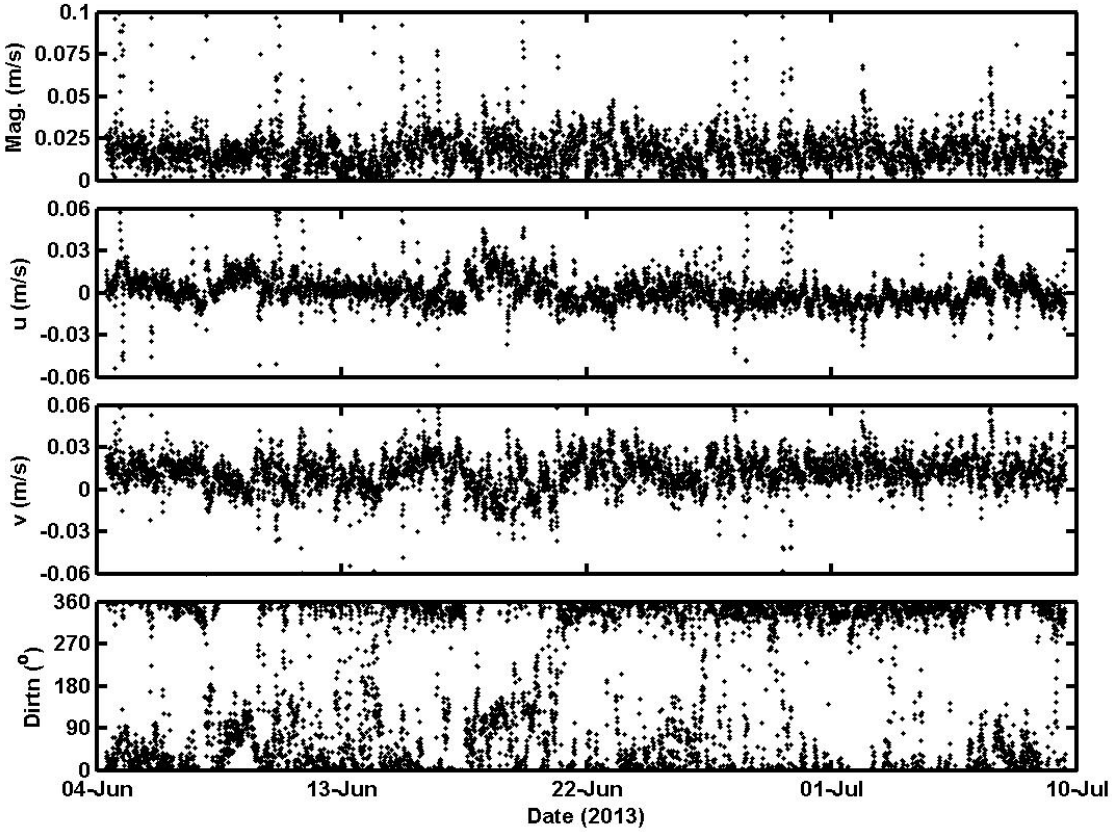


**Figure 4. Depth averaged time series of current magnitude (top), u and v current components (second and third panels), and current direction recorded at ADCP Platform #1 (mouth of Lauritzen Channel) from 4 June to 9 July 2013.**

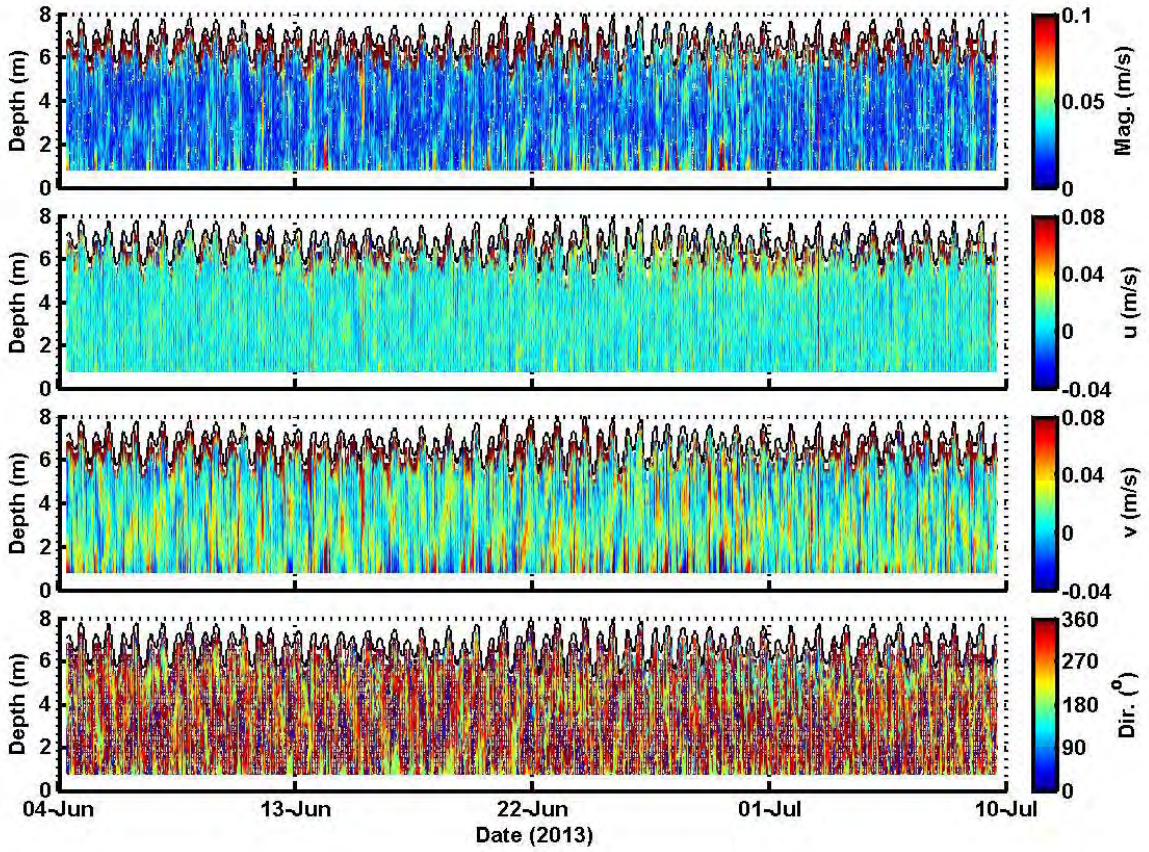


**Figure 5. Time and depth resolved current velocity magnitude (top), u and v current components (second and third panels), and current direction recorded by ADCP Platform #2 (near head of Lauritzen Channel) from 4 June to 9 July 2013.**

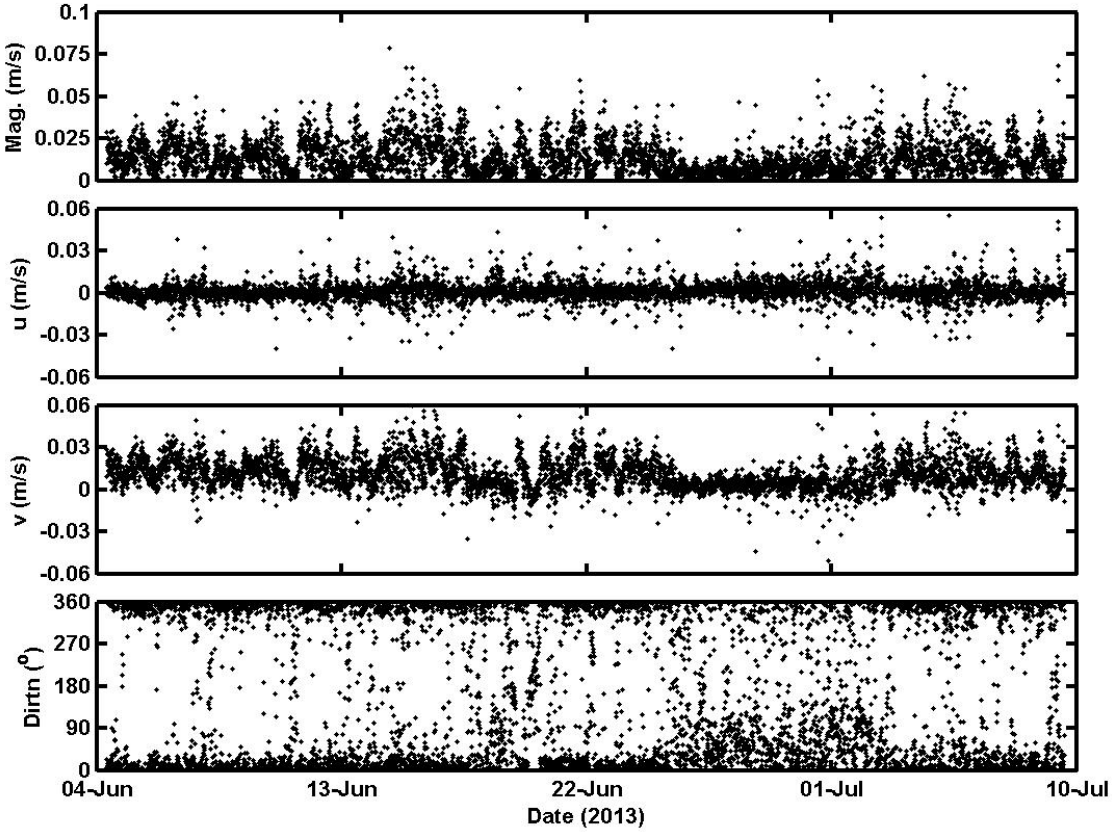


**Figure 6. Depth averaged time series of current magnitude (top), u and v current components (second and third panels), and current direction recorded at ADCP Platform #2 (near head of Lauritzen Channel) from 4 June to 9 July 2013.**

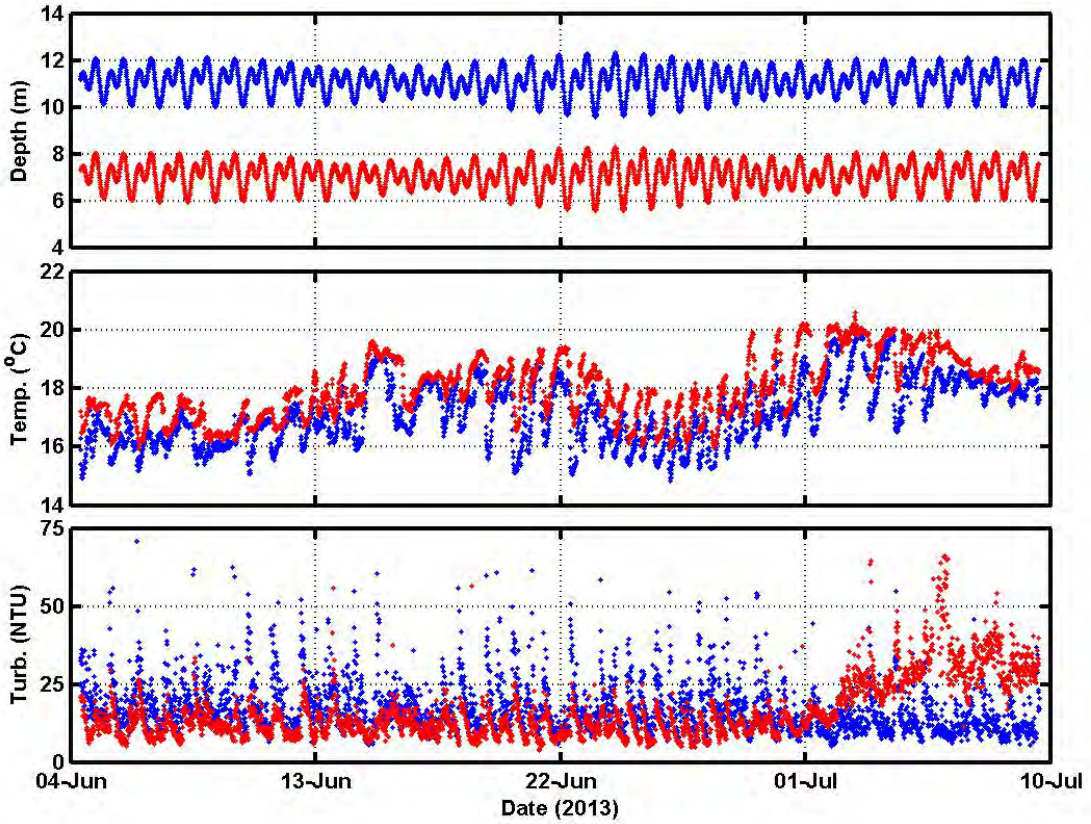


**Figure 7. Time series of water depth, temperature, and optical turbidity data collected by the water quality sonde at ADCP Platform #1 (blue) and ADCP Platform #2 (red). ADCP Platform #2 optical turbidity data appear to be affected by biofouling near the end of the deployment period.**

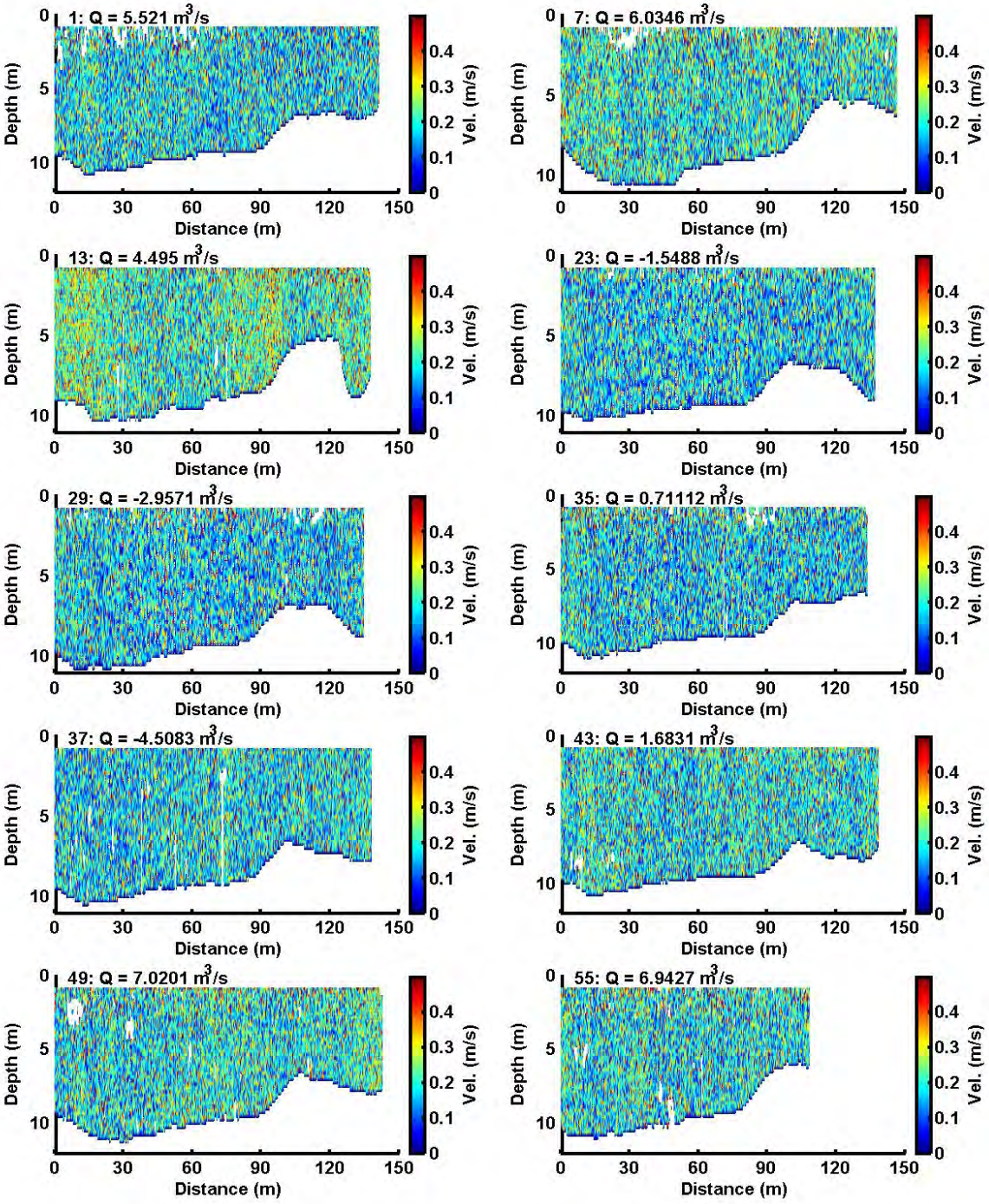


**Figure 8. Cross sectional velocity magnitude (m/s) profiles recorded along survey line #1 (see Figure 1) on 4 and 5 June 2013. The flow rate, Q, calculated from each transect is given at the top of each panel alongside each transect number.**

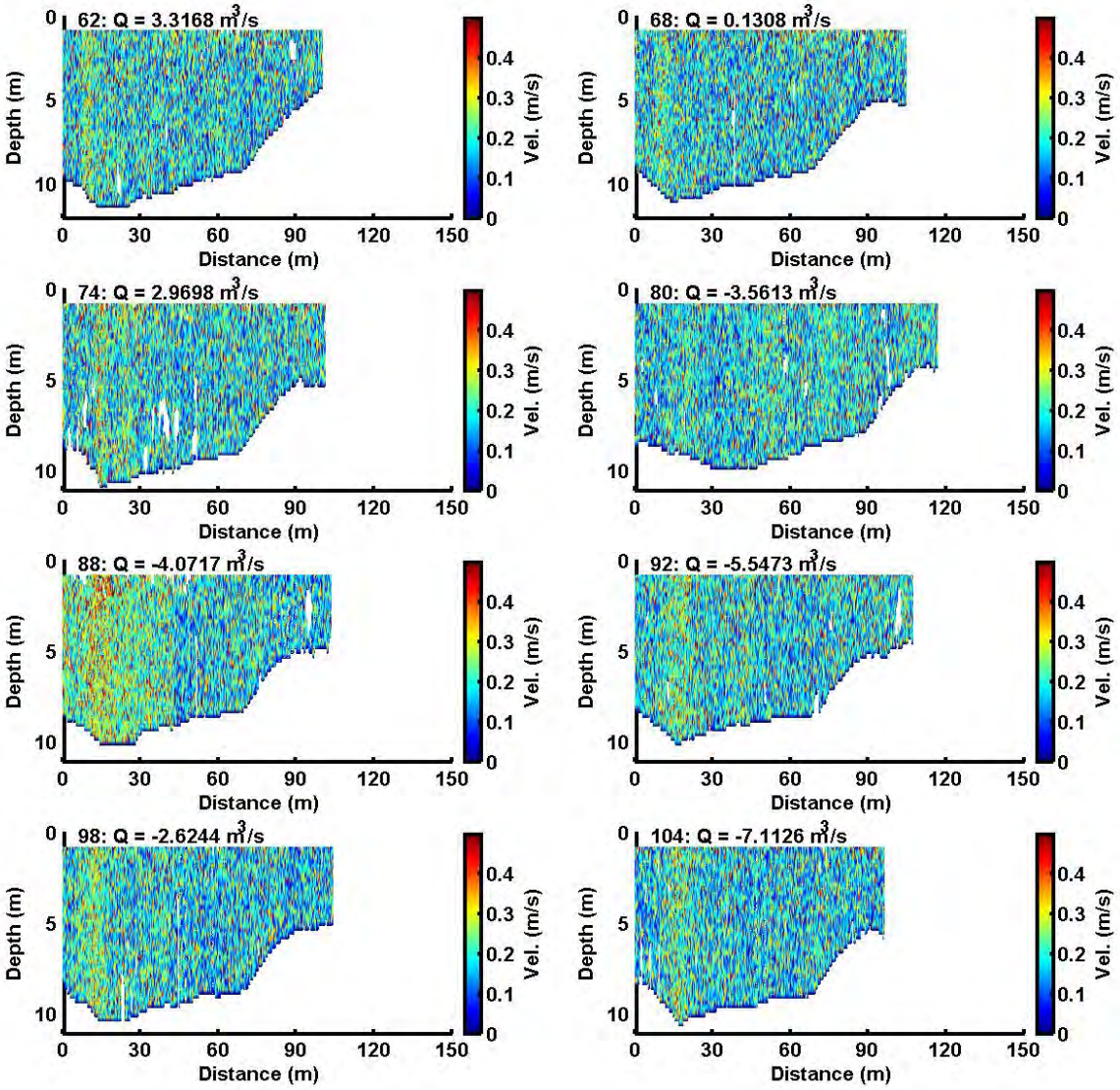


**Figure 9. Cross sectional velocity magnitude (m/s) profiles recorded along survey line #1 (see Figure 1) on 8 and 9 July 2013. The flow rate, Q, calculated from each transect is given at the top of each panel alongside each transect number.**

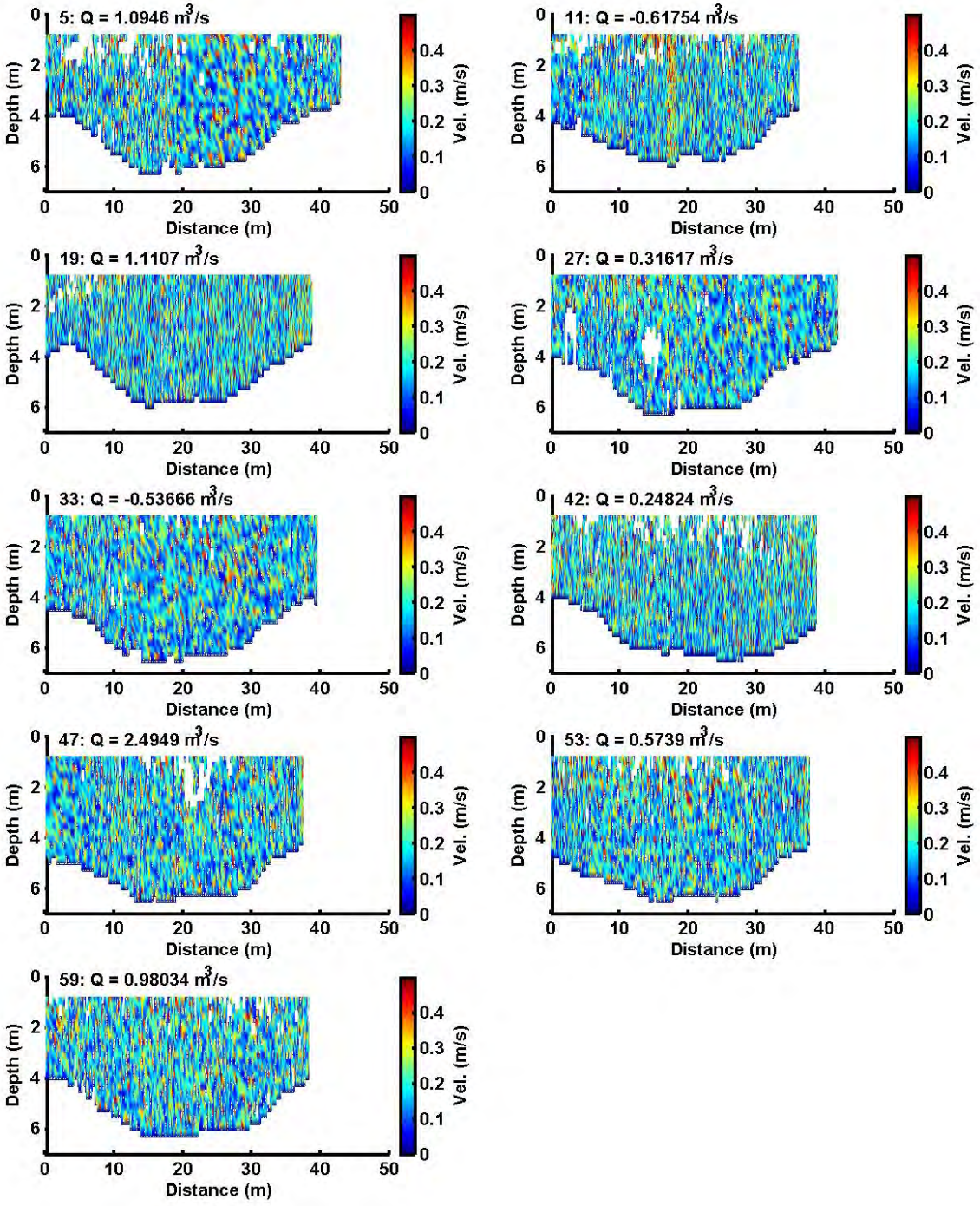


**Figure 10. Cross sectional velocity magnitude (m/s) profiles recorded along survey line #2 (see Figure 1) on 4 and 5 June 2013. The flow rate, Q, calculated from each transect is given at the top of each panel alongside each transect number.**

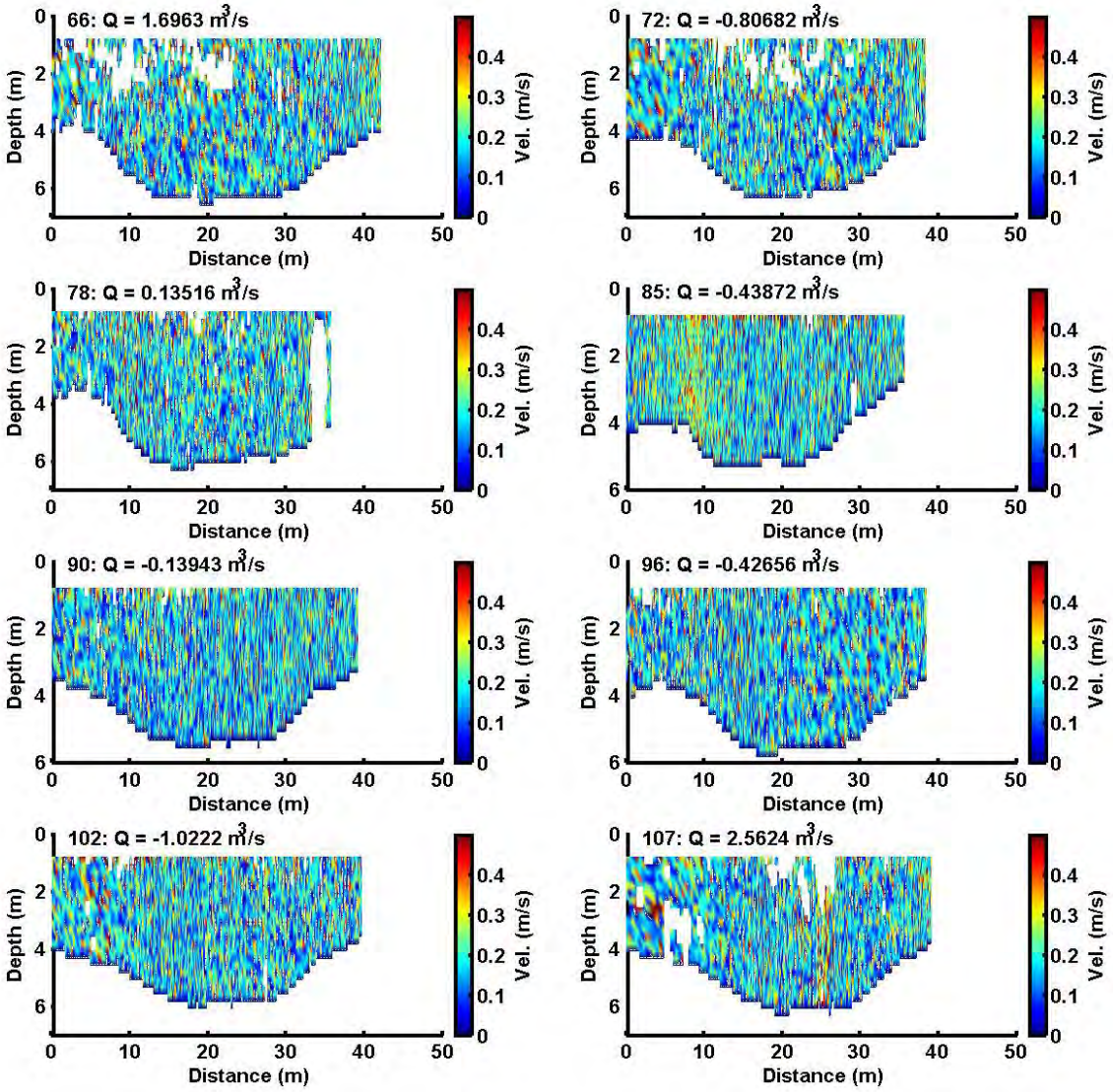


**Figure 11. Cross sectional velocity magnitude (m/s) profiles recorded along survey line #2 (see Figure 1) on 8 and 9 July 2013. The flow rate, Q, calculated from each transect is given at the top of each panel alongside each transect number.**

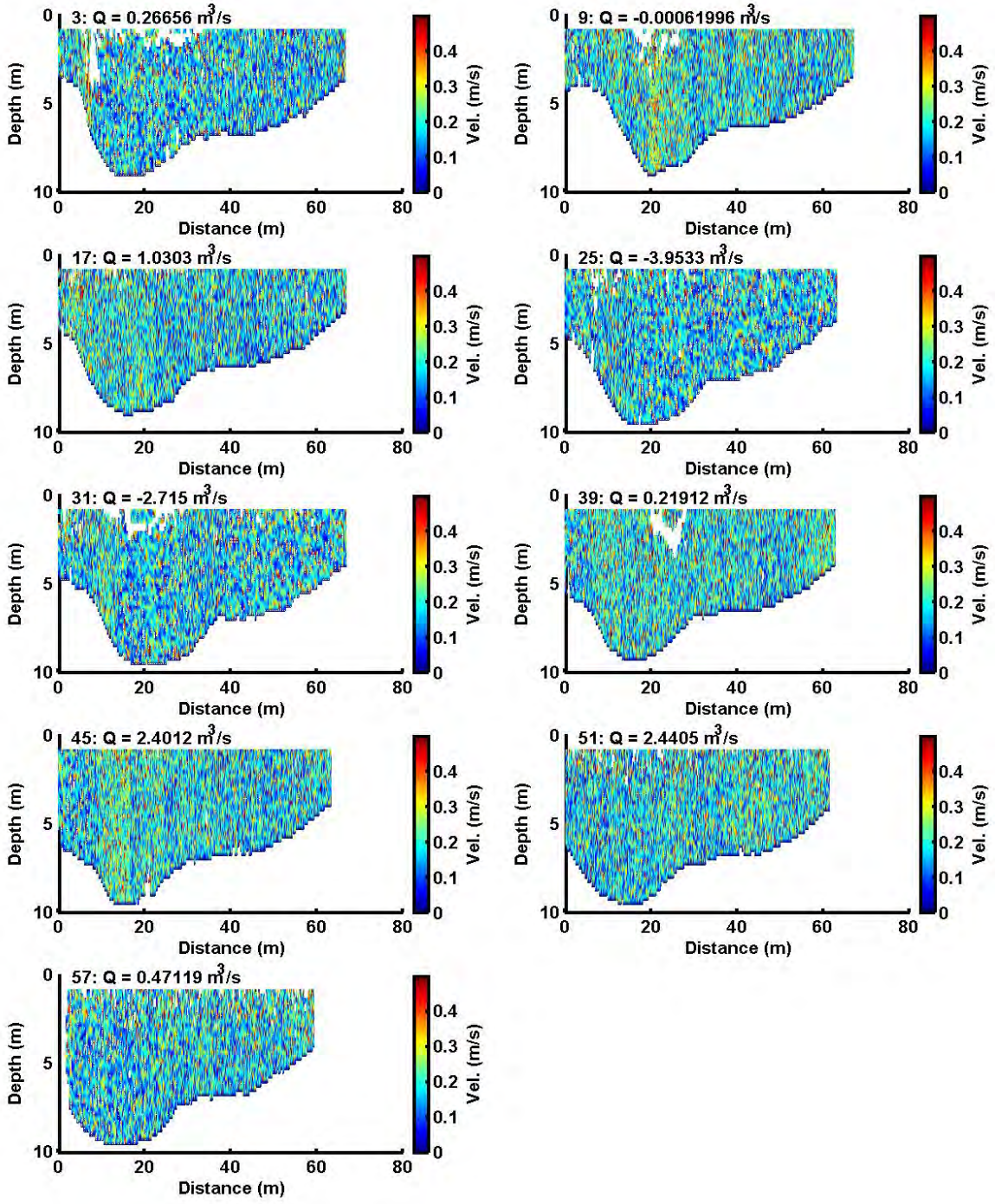


**Figure 12. Cross sectional velocity magnitude (m/s) profiles recorded along survey line #3 (see Figure 1) on 4 and 5 June 2013. The flow rate, Q, calculated from each transect is given at the top of each panel alongside each transect number.**

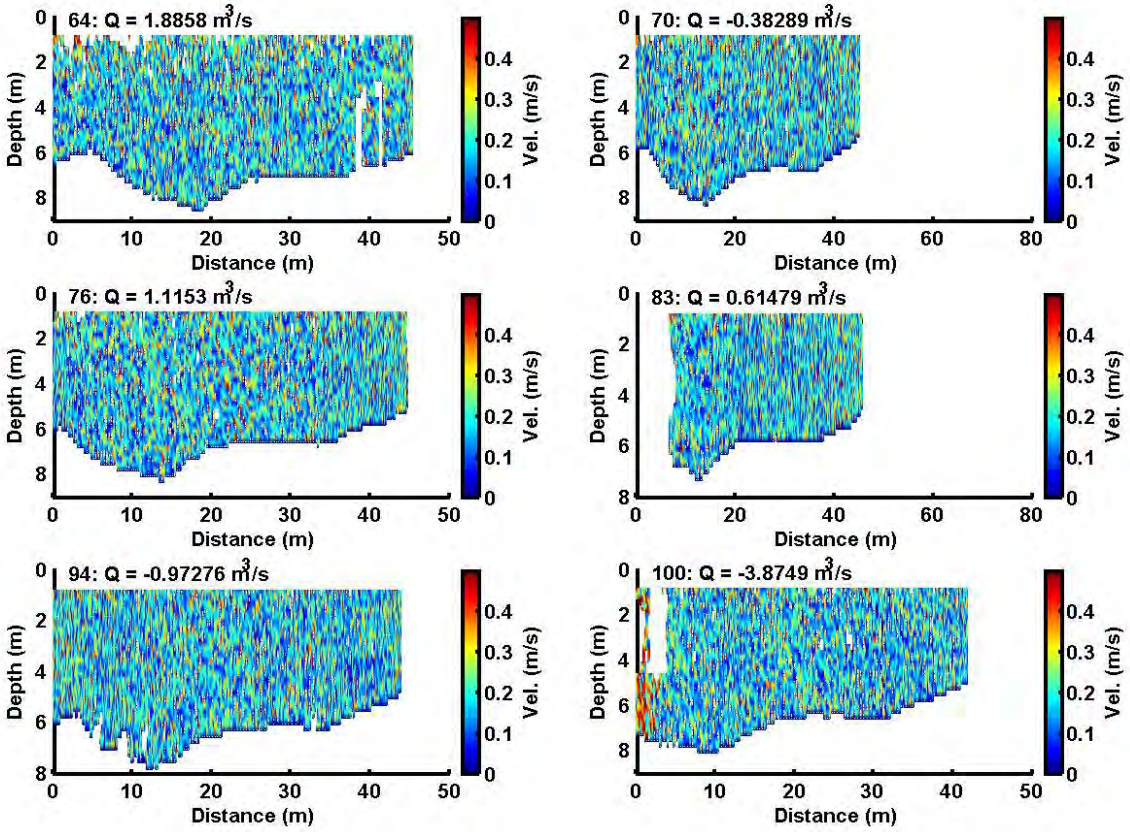


**Figure 13. Cross sectional velocity magnitude (m/s) profiles recorded along survey line #3 (see Figure 1) on 8 and 9 July 2013. The flow rate, Q, calculated from each transect is given at the top of each panel alongside each transect number.**

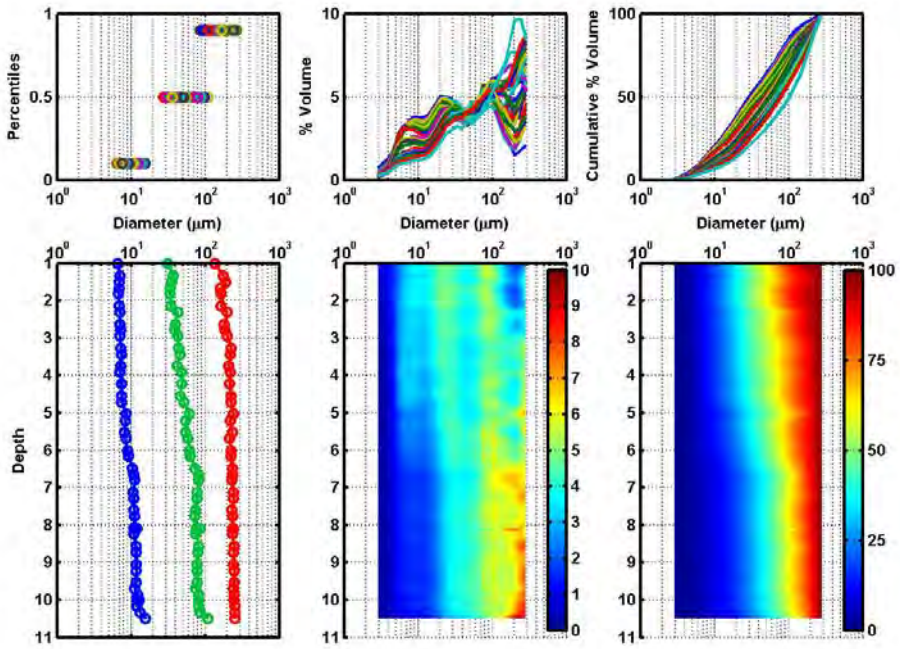


**Figure 14. LISST data collected on 4 June 2013 at 12:27 at ADCP Platform #1. Left: $d_{10}$ (blue), $d_{50}$ (green), and $d_{90}$ (red); Middle: Particle size distribution; and Right: Cumulative particle size distribution. The upper row panels are stackplots of all data collected during the downcast and the lower row panels show the downcast vertical profile.**

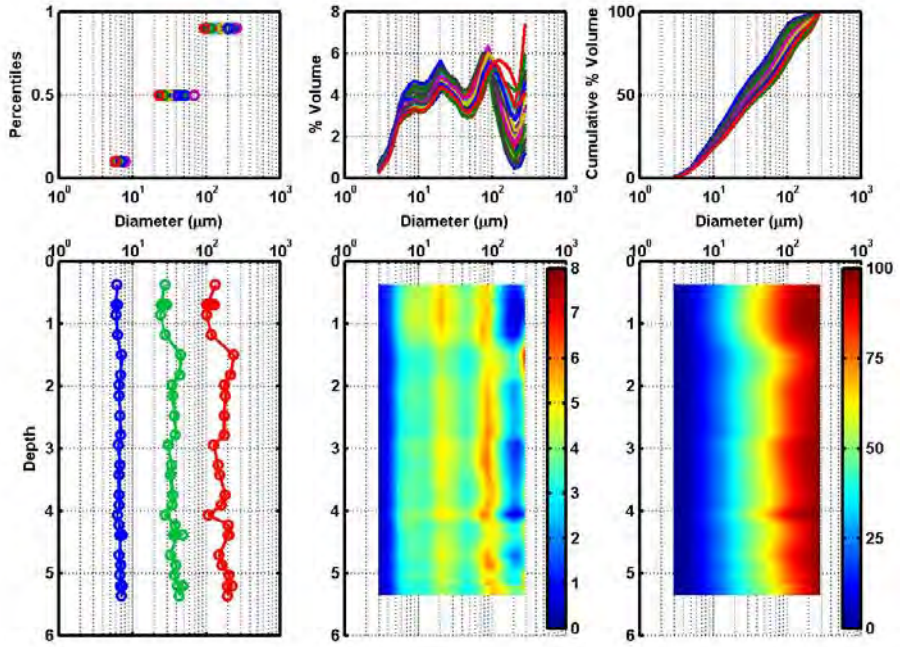


**Figure 15. Same as Figure 14 caption but for LISST data collected on 4 June 2013 at 13:26 at ADCP Platform #2. The increase in PSD at larger sizes may be due to optical interference.**

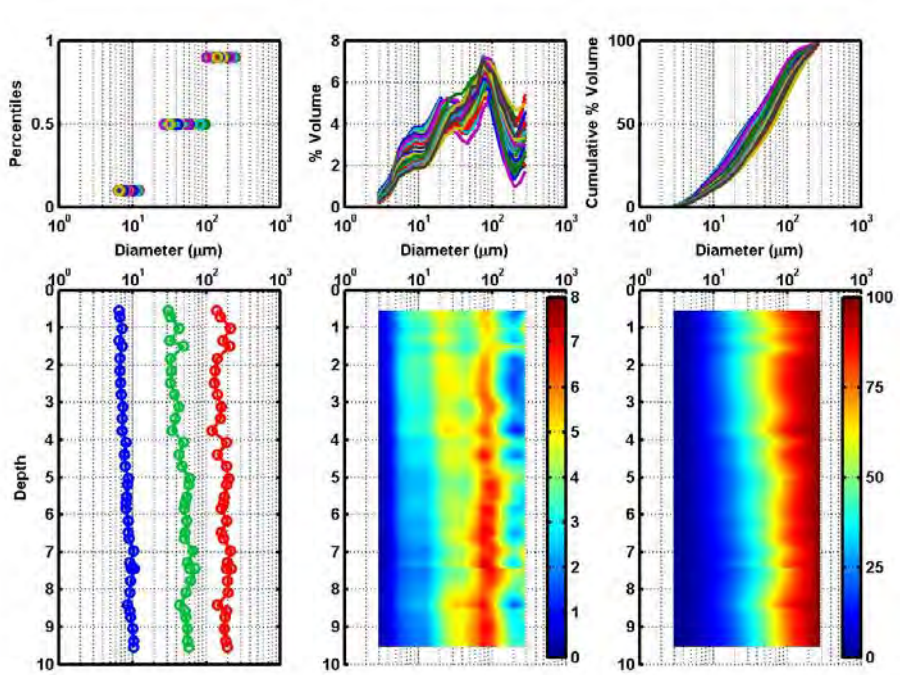


**Figure 16. Same as Figure 14 caption but for LISST data collected on 4 June 2013 at 14:24 at ADCP Platform #1.**

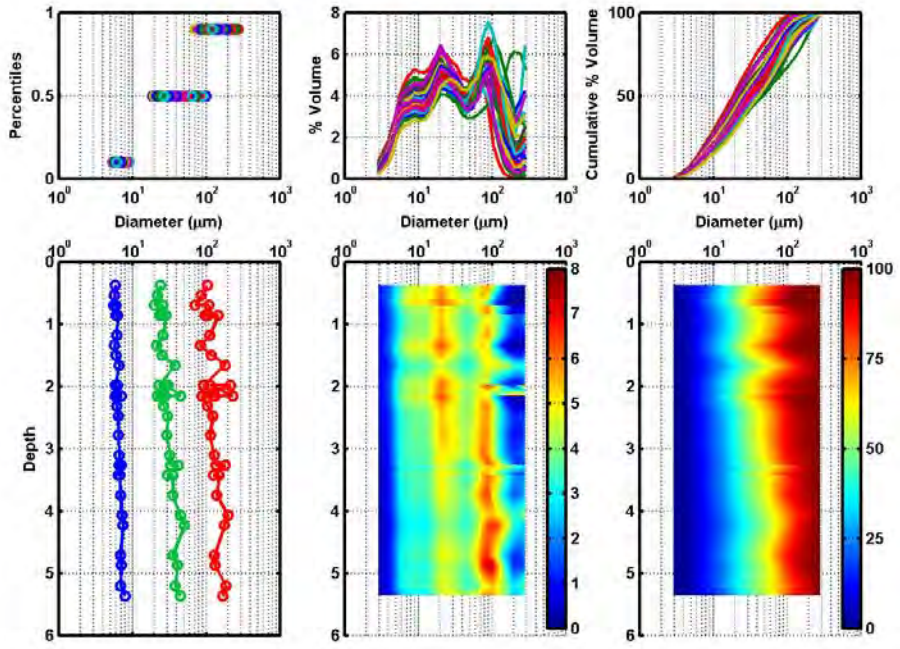


**Figure 17. Same as Figure 14 caption but for LISST data collected on 4 June 2013 at 15:05 at ADCP Platform #2.**

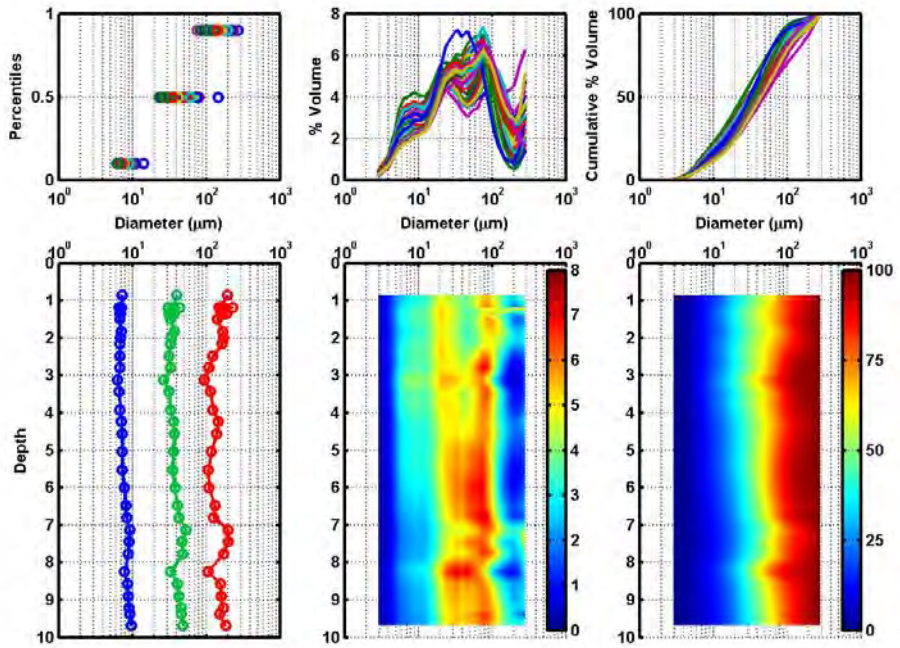


**Figure 18. Same as Figure 14 caption but for LISST data collected on 4 June 2013 at 15:46 at ADCP Platform #1.**

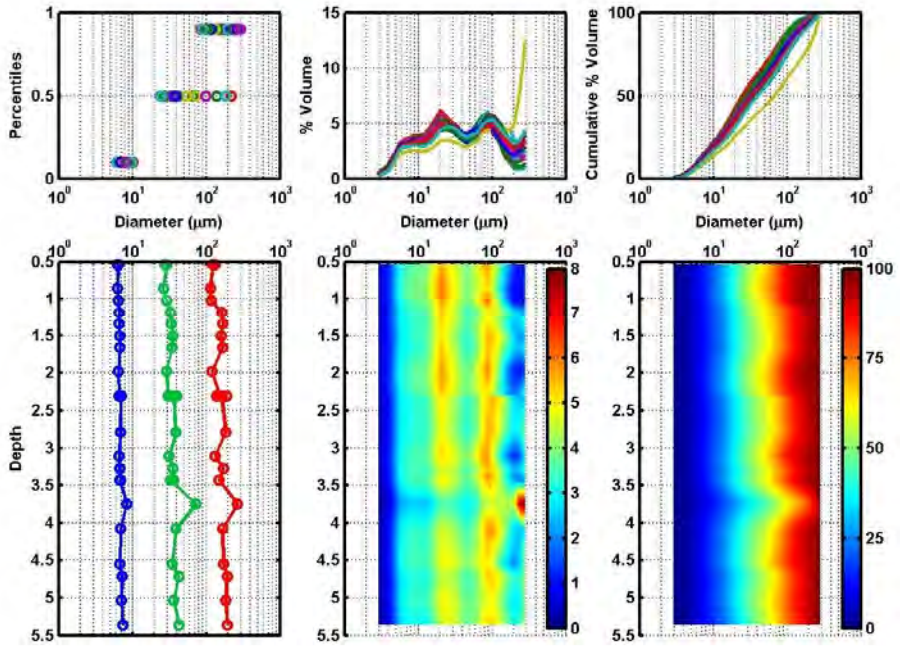


**Figure 19. Same as Figure 14 caption but for LISST data collected on 4 June 2013 at 16:42 at ADCP Platform #2. The increase in PSD at larger sizes may be due to optical interference.**

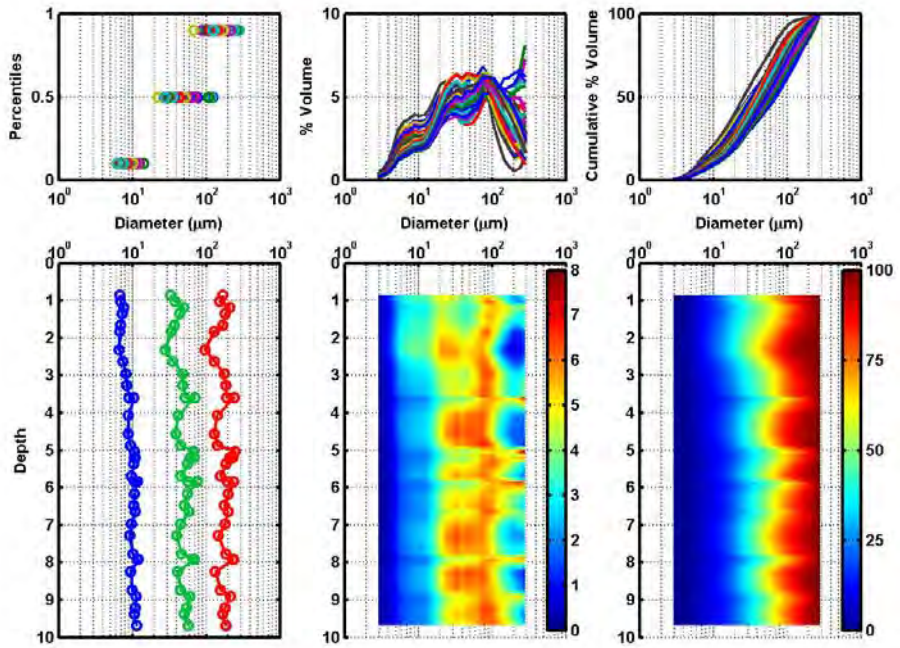


**Figure 20. Same as Figure 14 caption but for LISST data collected on 4 June 2013 at 17:57 at ADCP Platform #1.**

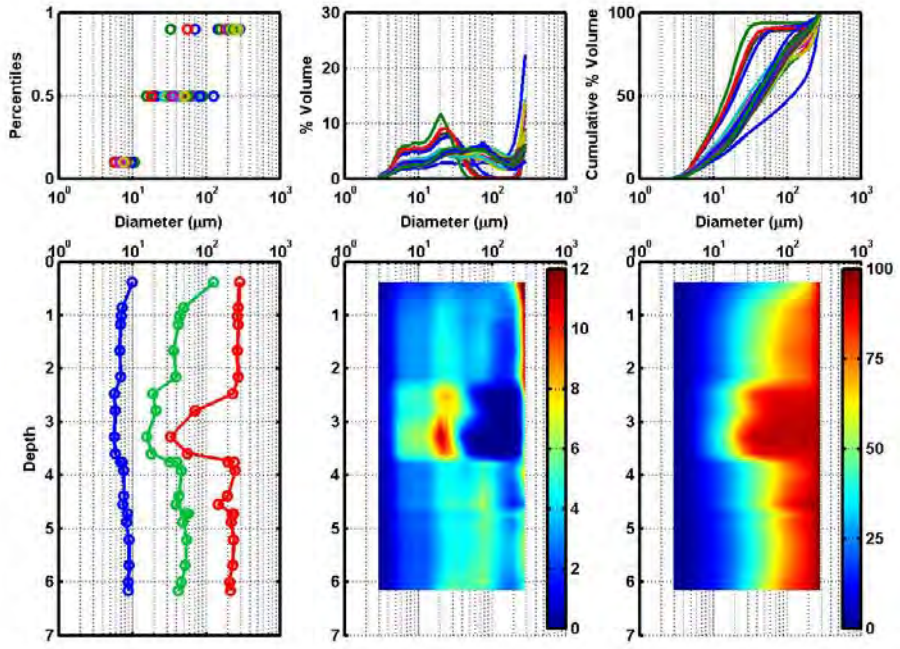


**Figure 21. Same as Figure 14 caption but for LISST data collected on 4 June 2013 at 18:24 at ADCP Platform #2. The increase in PSD at larger sizes may be due to optical interference.**

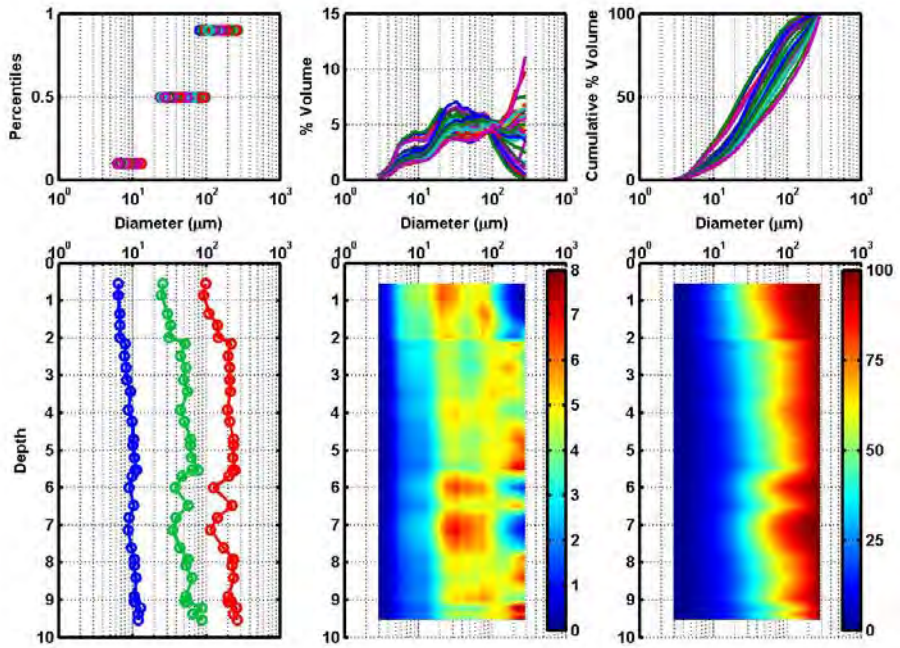


**Figure 22. Same as Figure 14 caption but for LISST data collected on 4 June 2013 at 18:44 at ADCP Platform #1. The increase in PSD at larger sizes may be due to optical interference.**

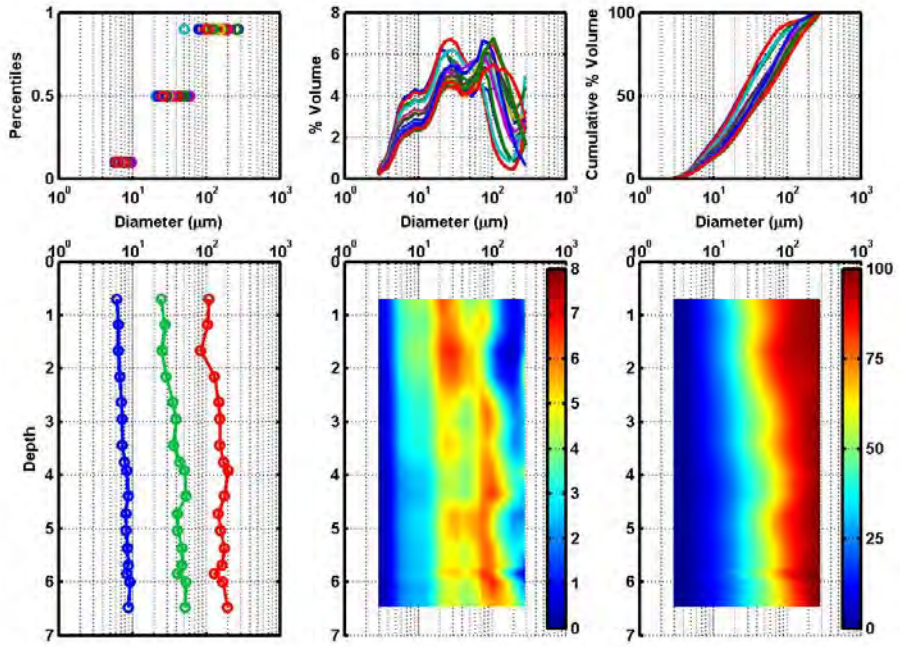


**Figure 23. Same as Figure 14 caption but for LISST data collected on 4 June 2013 at 19:13 at ADCP Platform #2.**

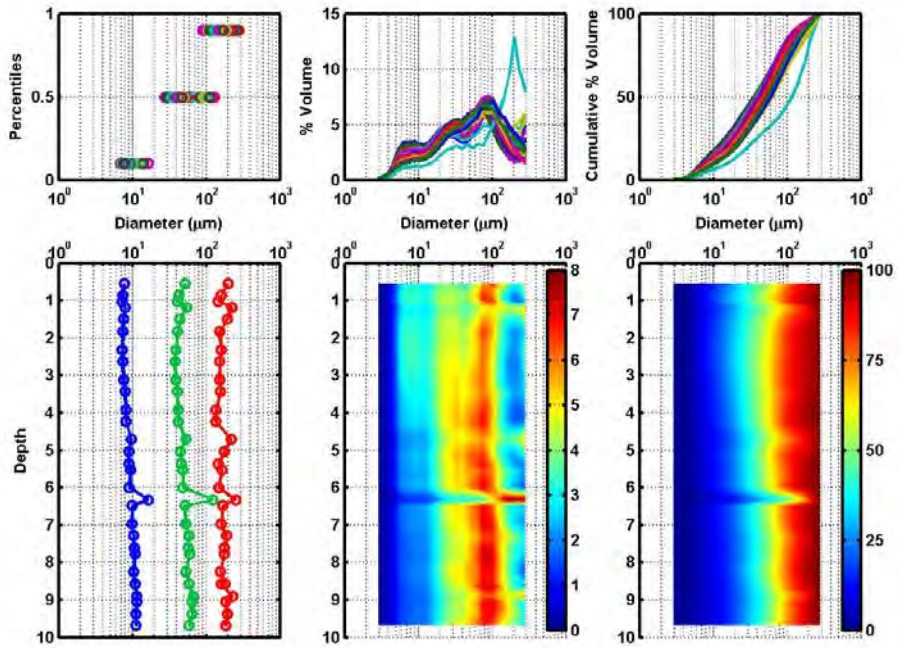


**Figure 24. Same as Figure 14 caption but for LISST data collected on 5 June 2013 at 08:48 at ADCP Platform #1.**

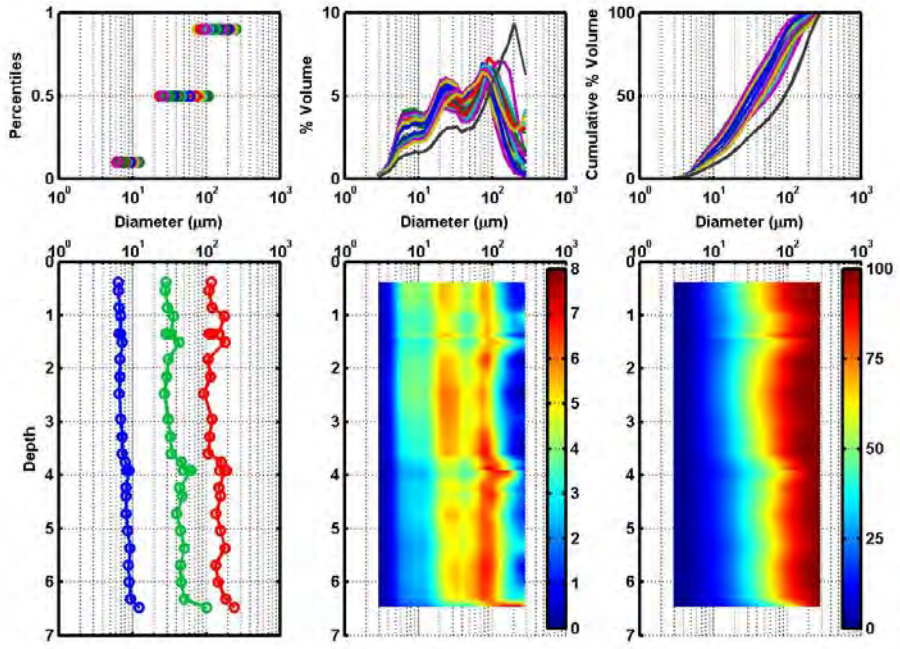


**Figure 25. Same as Figure 14 caption but for LISST data collected on 5 June 2013 at 09:37 at ADCP Platform #2.**

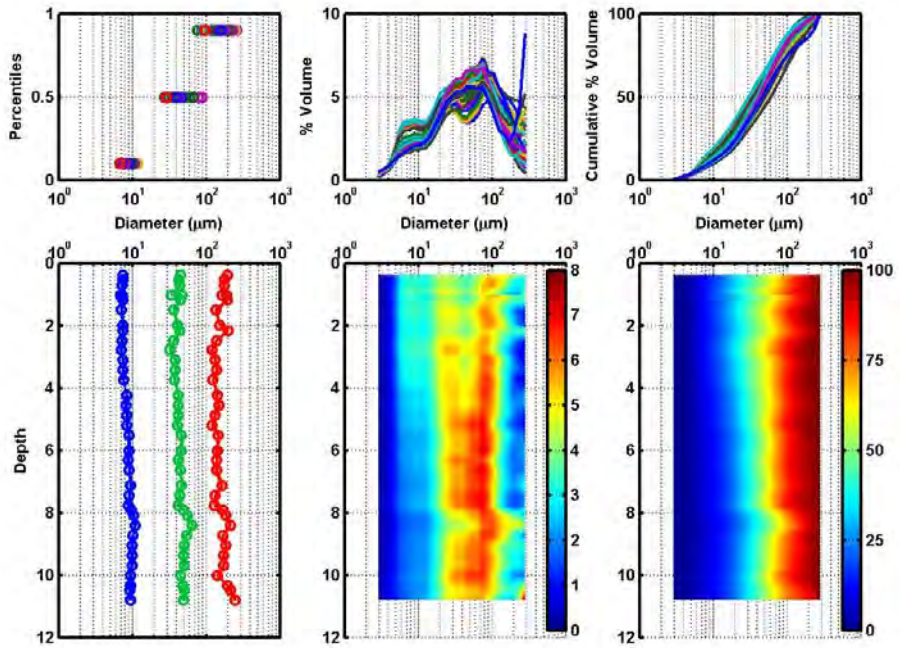


**Figure 26. Same as Figure 14 caption but for LISST data collected on 5 June 2013 at 10:13 at ADCP Platform #1. The increase in PSD at larger sizes may be due to optical interference.**

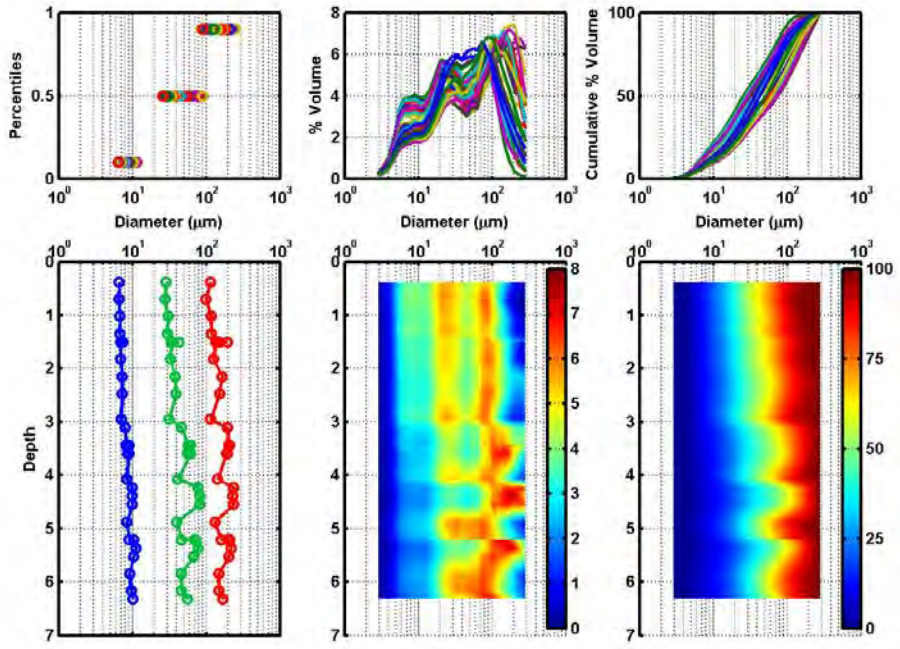


**Figure 27. Same as Figure 14 caption but for LISST data collected on 5 June 2013 at 10:48 at ADCP Platform #2.**

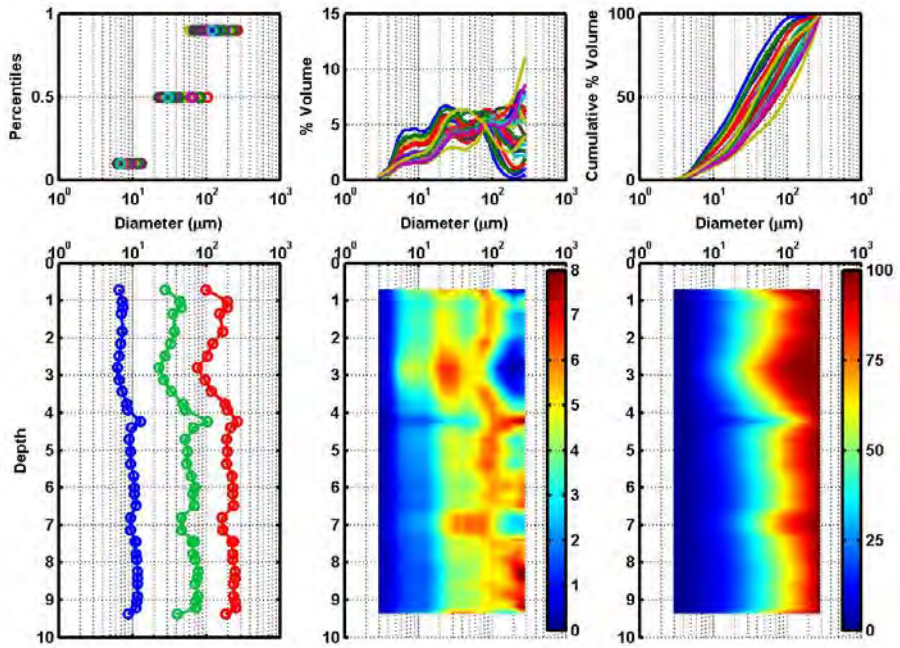


**Figure 28. Same as Figure 14 caption but for LISST data collected on 5 June 2013 at 12:48 at ADCP Platform #1.**

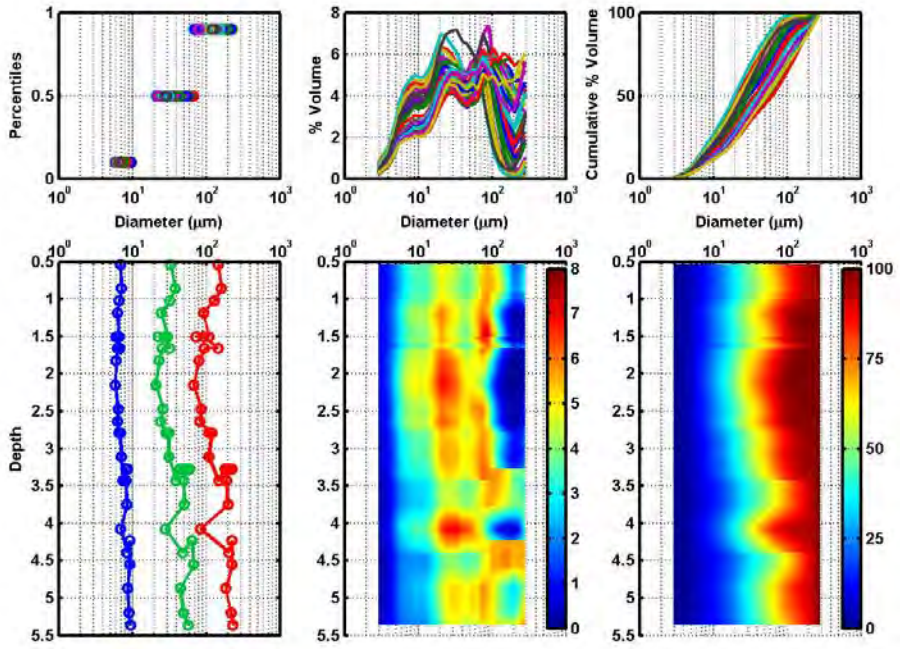


**Figure 29. Same as Figure 14 caption but for LISST data collected on 5 June 2013 at 13:42 at ADCP Platform #2.**

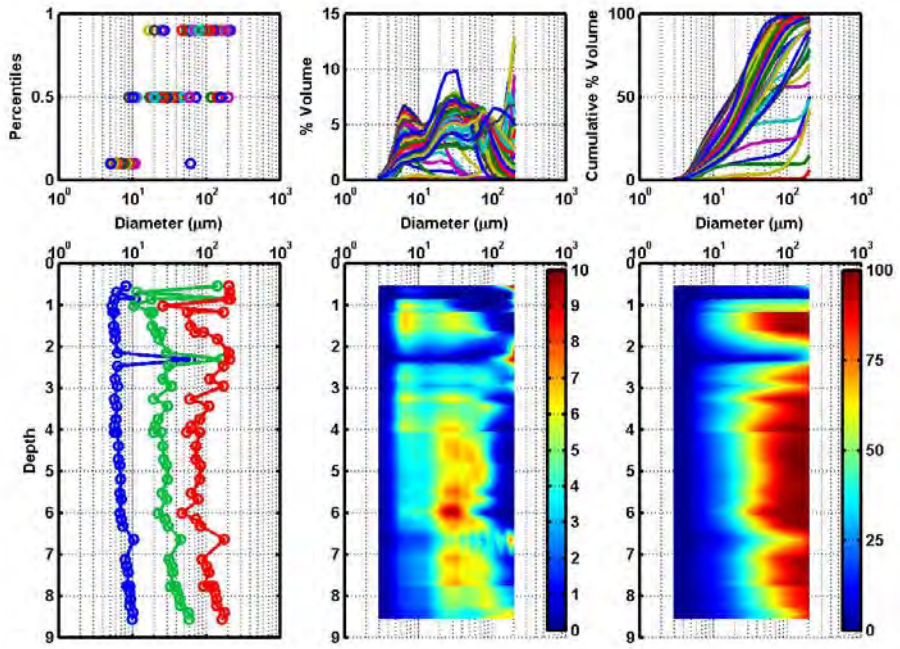


**Figure 30. Same as Figure 14 caption but for LISST data collected on 8 July 2013 at 14:55 at ADCP Platform #1. The increase in PSD at larger sizes may be due to optical interference.**

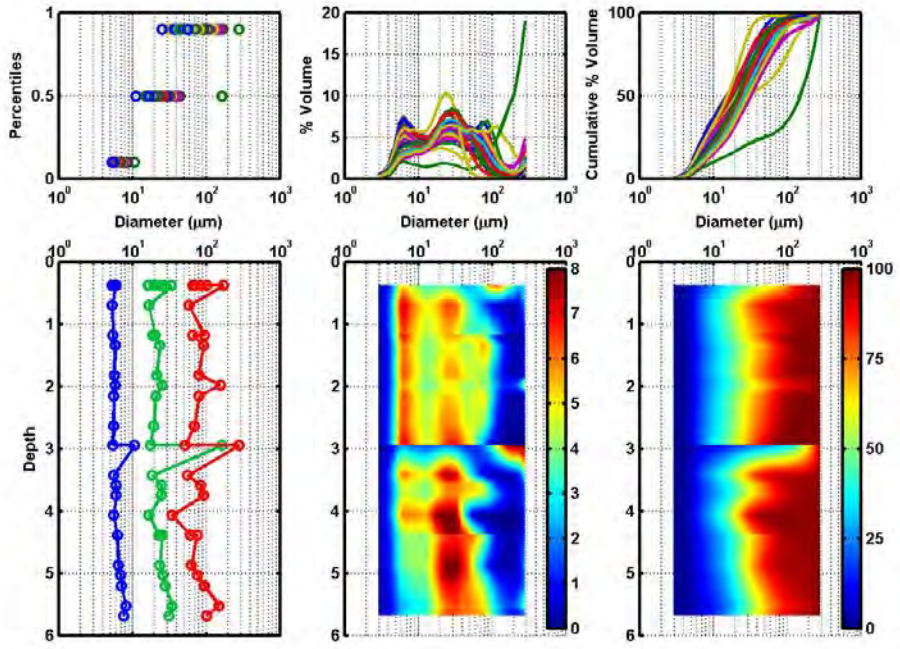


**Figure 31. Same as Figure 14 caption but for LISST data collected on 8 July 2013 at 15:31 at ADCP Platform #2. The increase in PSD at larger sizes may be due to optical interference.**

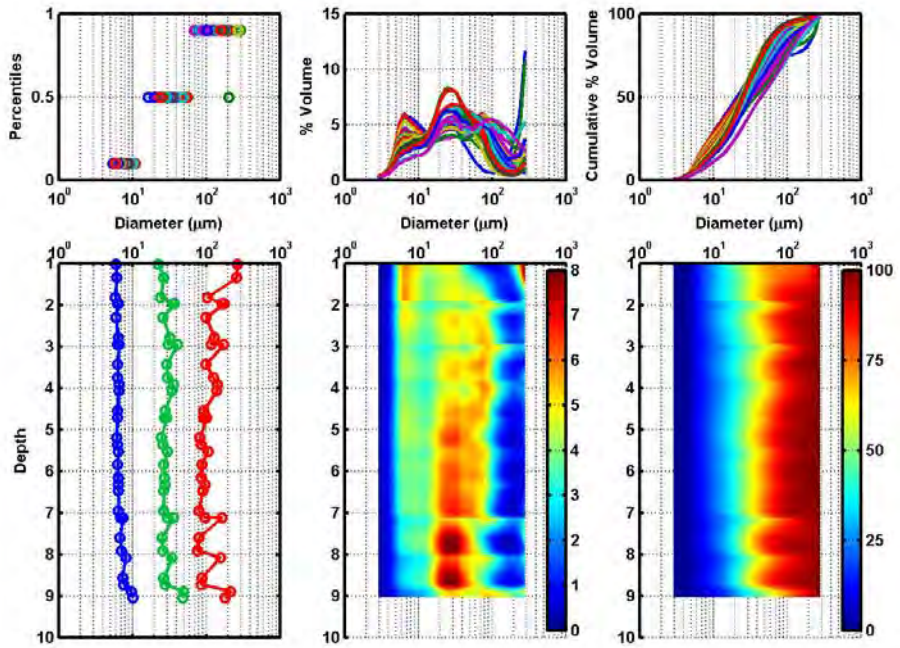


**Figure 32. Same as Figure 14 caption but for LISST data collected on 8 July 2013 at 15:56 at ADCP Platform #1. The increase in PSD at larger sizes may be due to optical interference.**

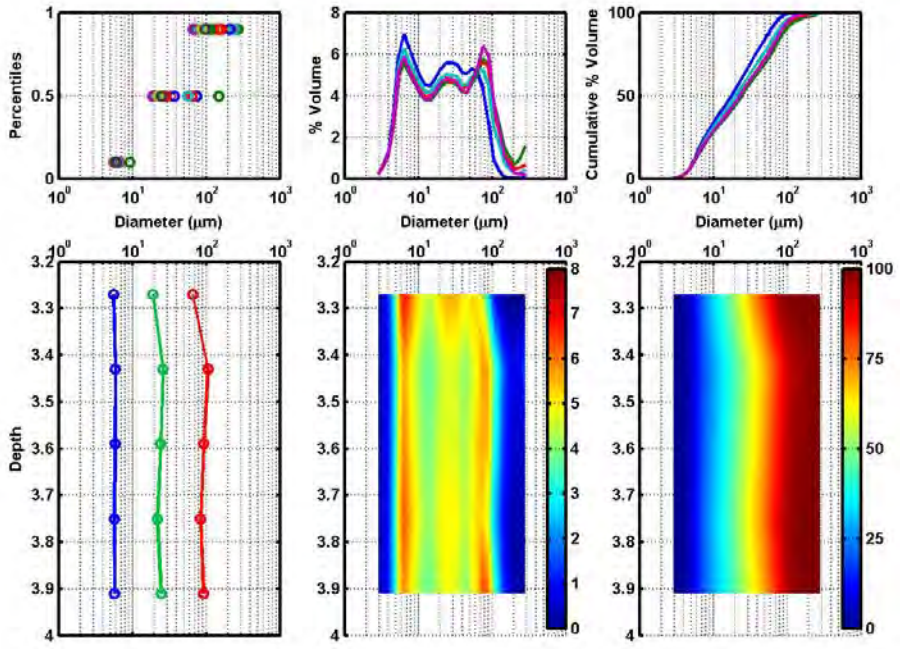


**Figure 33. Same as Figure 14 caption but for LISST data collected on 8 July 2013 at 16:28 at ADCP Platform #2.**

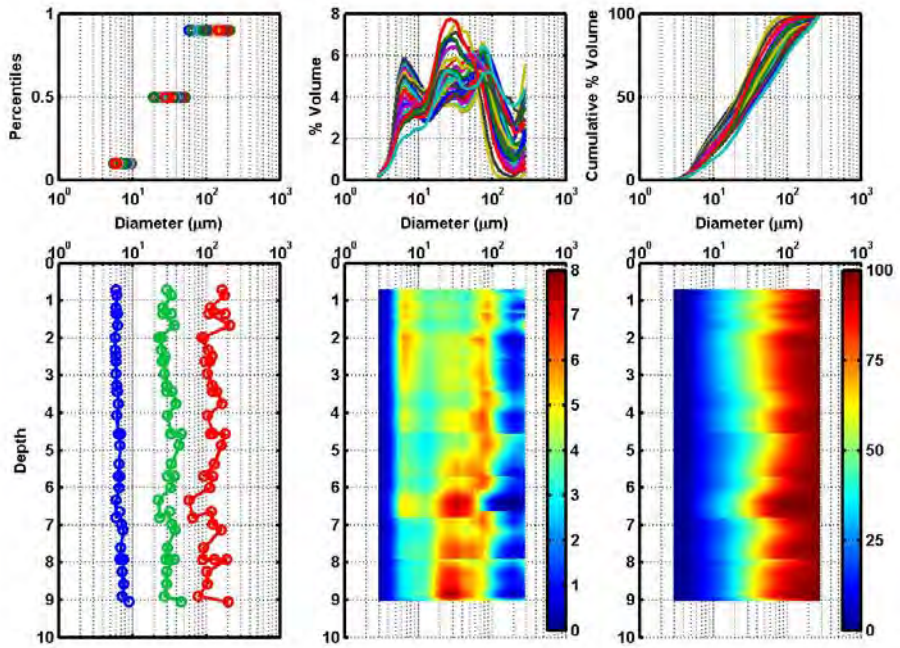


**Figure 34. Same as Figure 14 caption but for LISST data collected on 8 July 2013 at 16:54 at ADCP Platform #1.**

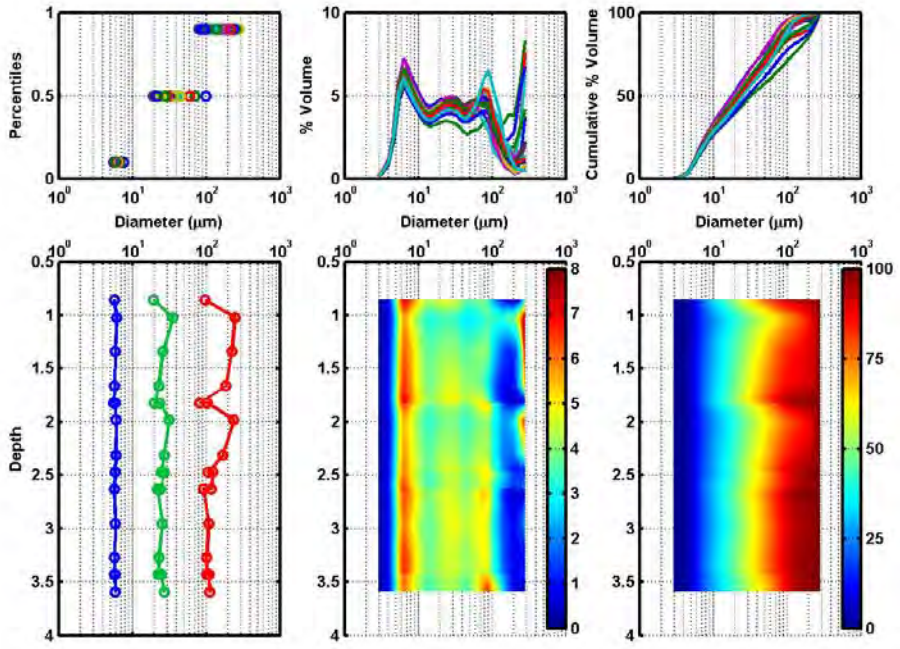


**Figure 35. Same as Figure 14 caption but for LISST data collected on 8 July 2013 at 17:35 at ADCP Platform #2.**

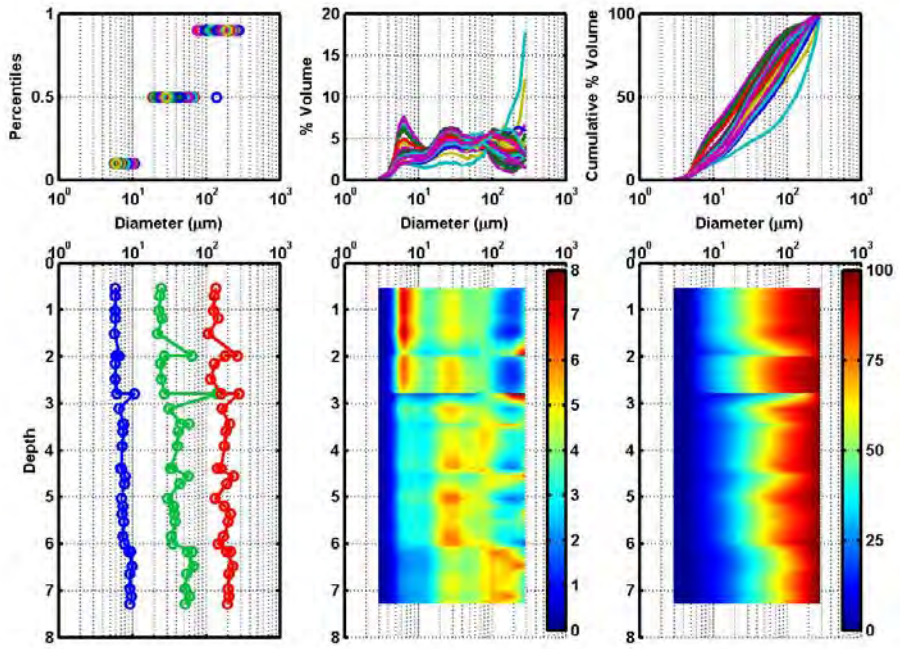


**Figure 36. Same as Figure 14 caption but for LISST data collected on 9 July 2013 at 08:21 at ADCP Platform #1.**

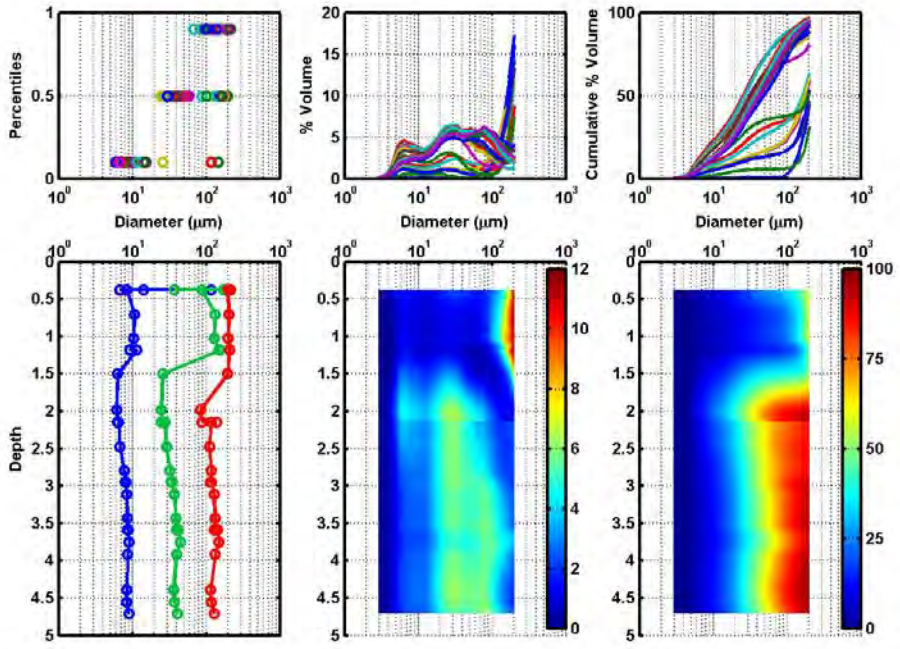


**Figure 37. Same as Figure 14 caption but for LISST data collected on 9 July 2013 at 08:53 at ADCP Platform #2.**

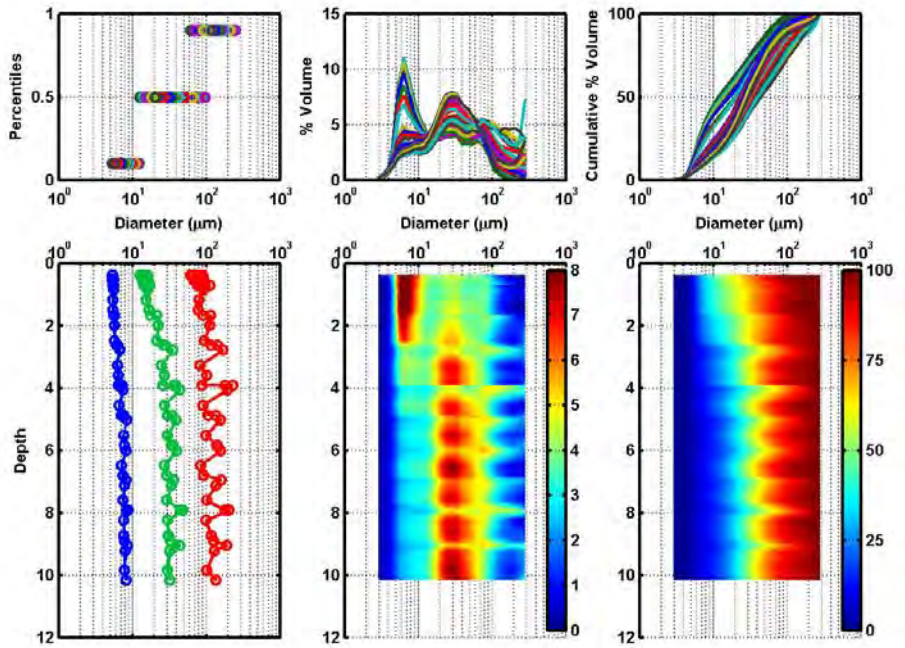


**Figure 38. Same as Figure 14 caption but for LISST data collected on 9 July 2013 at 09:23 at ADCP Platform #1.**

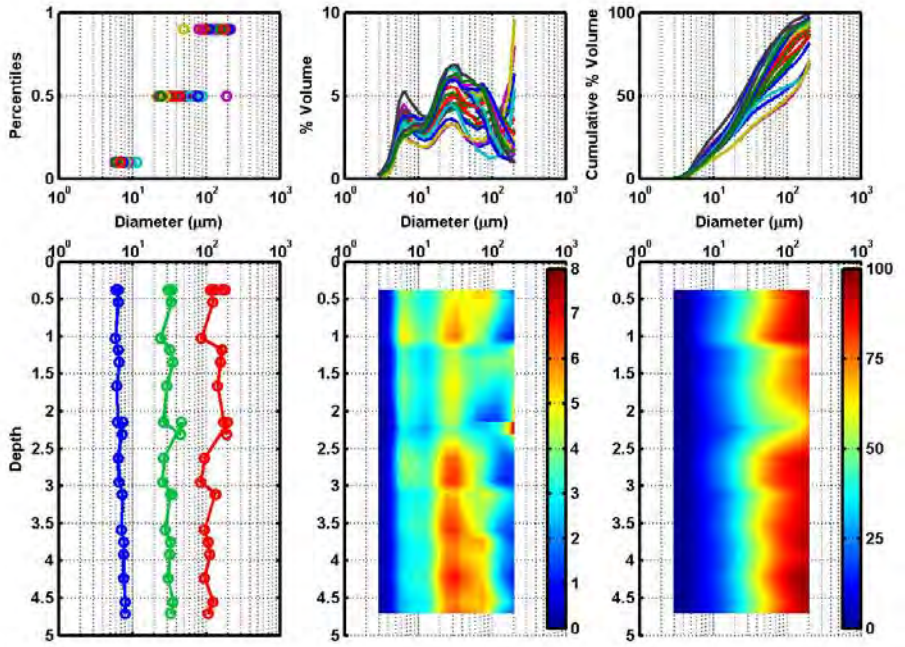


**Figure 39. Same as Figure 14 caption but for LISST data collected on 9 July 2013 at 09:40 at ADCP Platform #2.**

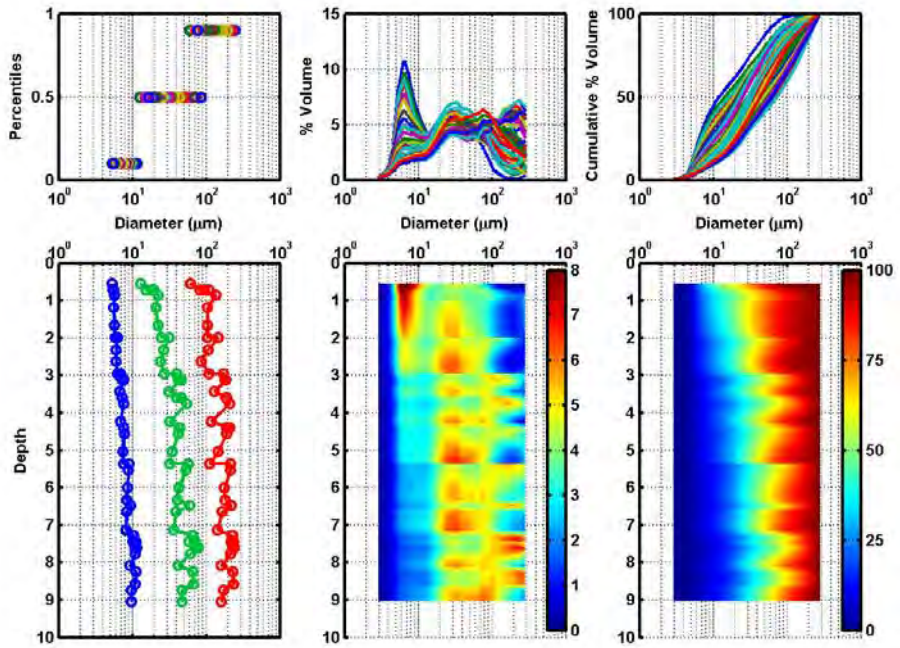


**Figure 40. Same as Figure 14 caption but for LISST data collected on 9 July 2013 at 09:58 at ADCP Platform #1.**

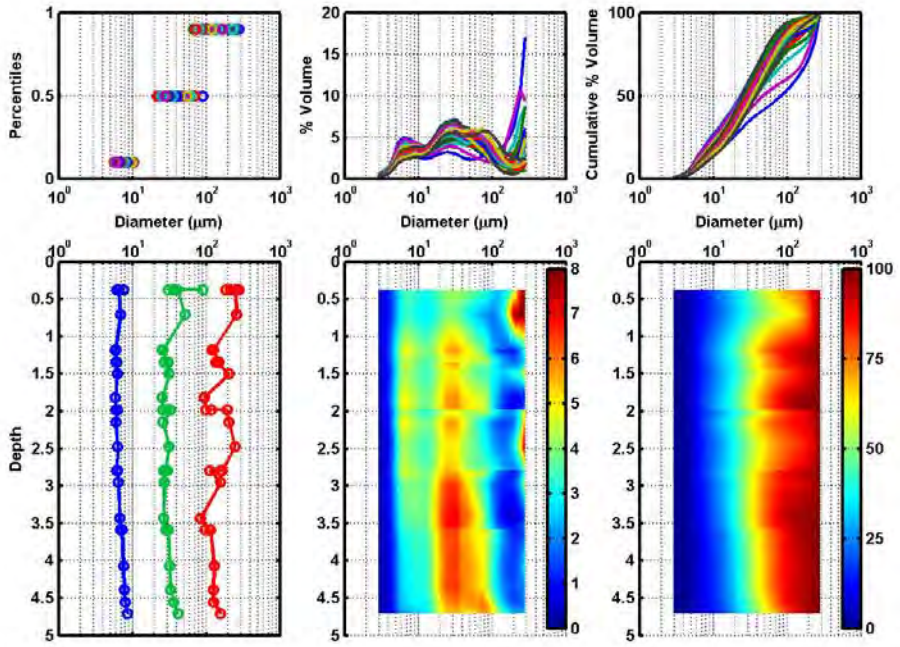


**Figure 41. Same as Figure 14 caption but for LISST data collected on 9 July 2013 at 10:25 at ADCP Platform #2.**

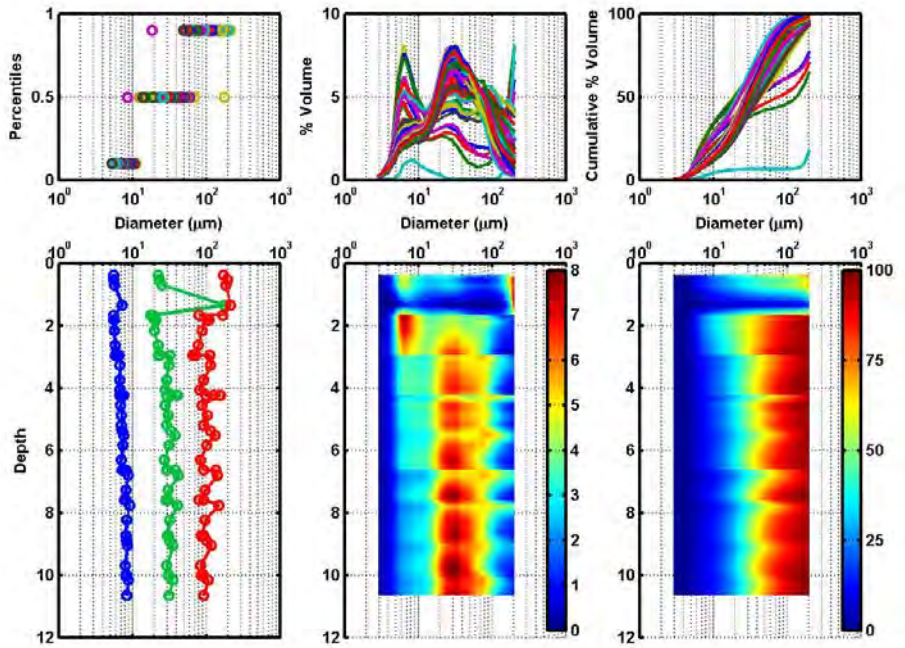


**Figure 42. Same as Figure 14 caption but for LISST data collected on 9 July 2013 at 10:41 at ADCP Platform #1.**

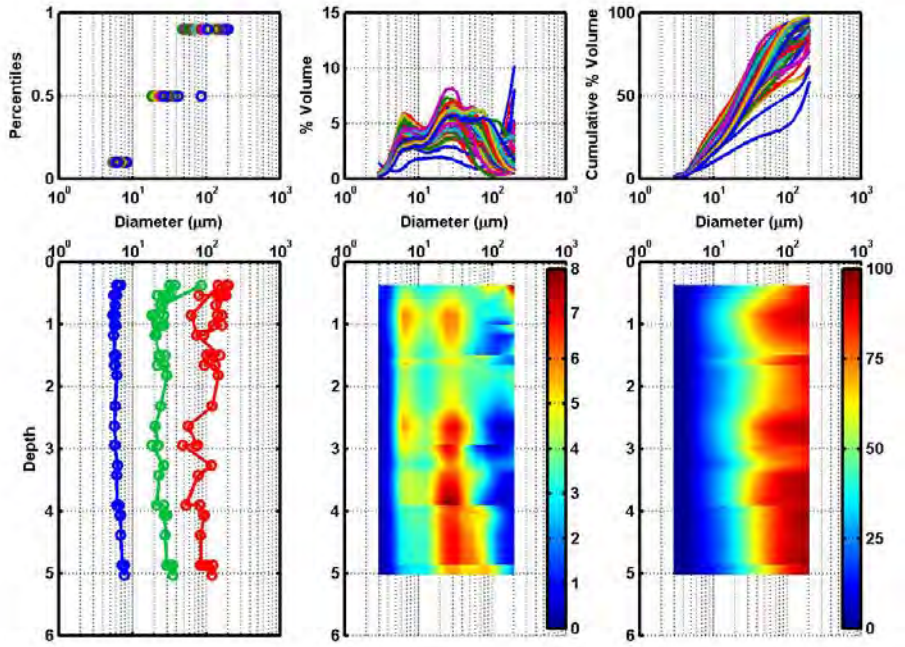


**Figure 43. Same as Figure 14 caption but for LISST data collected on 9 July 2013 at 11:04 at ADCP Platform #2.**

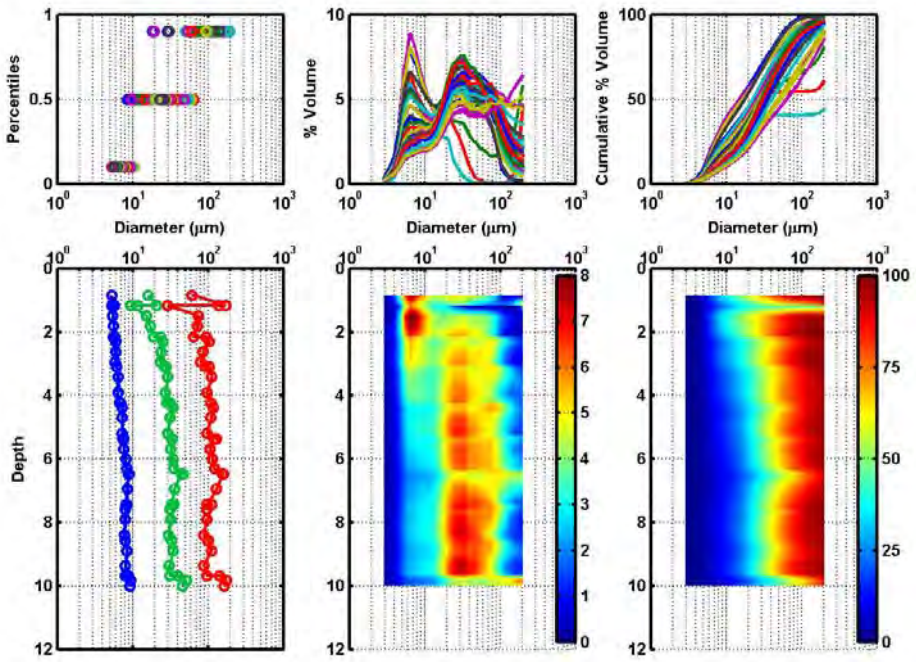


**Figure 44. Same as Figure 14 caption but for LISST data collected on 9 July 2013 at 11:20 at ADCP Platform #1.**

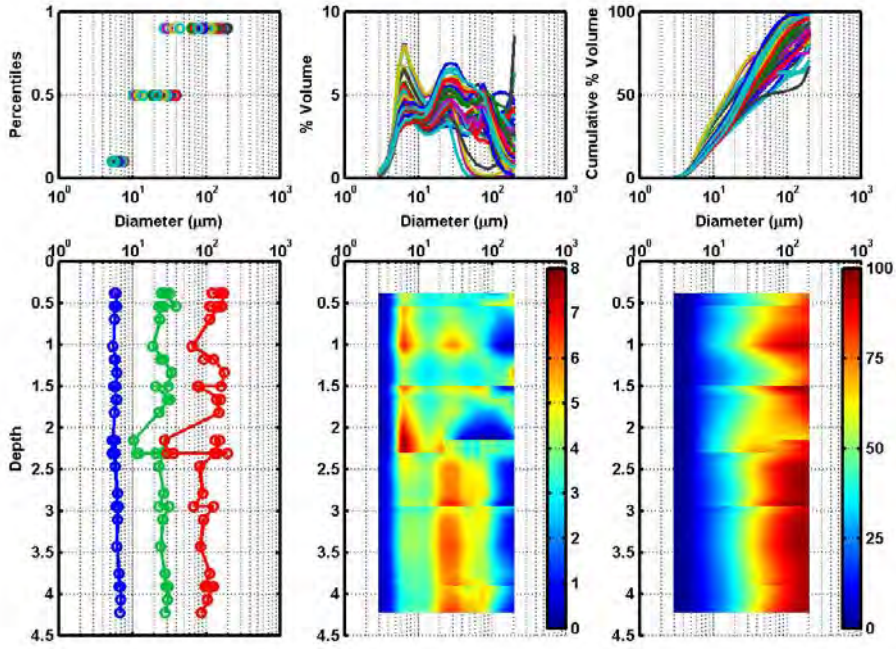


**Figure 45. Same as Figure 14 caption but for LISST data collected on 9 July 2013 at 11:36 at ADCP Platform #2.**

*Total Suspended Solids Concentration (TSS)*

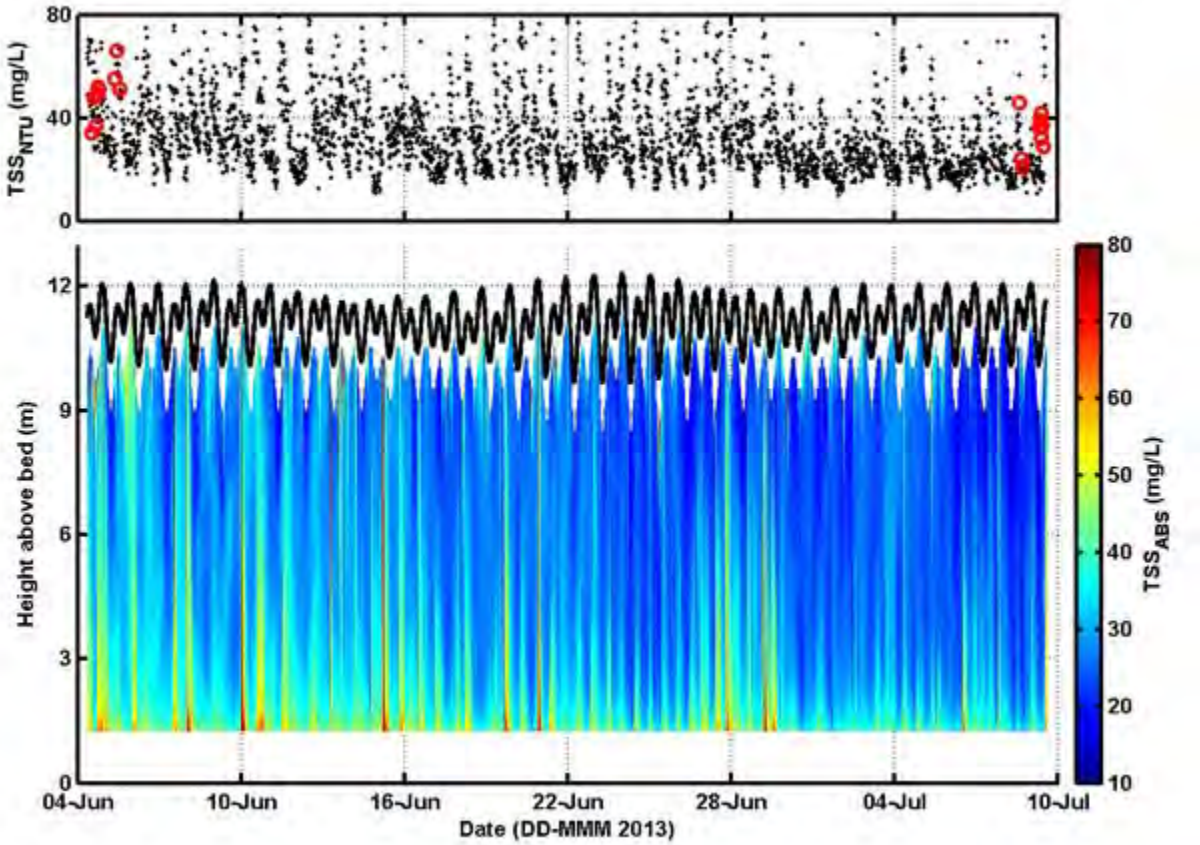


**Figure 46. Top: Time series of TSS derived from optical turbidity. The red circles represent TSS derived from water sample data. Bottom: Time and depth resolved TSS derived from ADCP acoustic backscatter. Data are from ADCP Platform #1.**

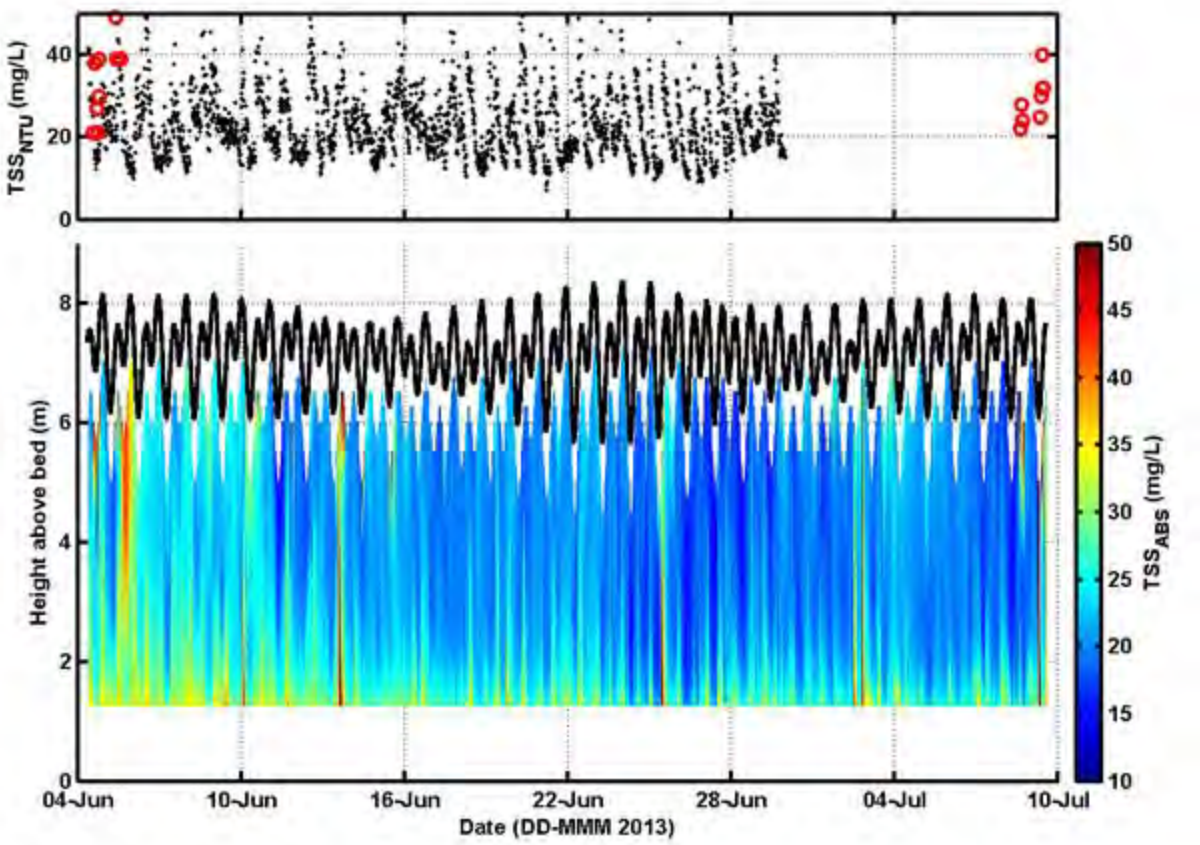


**Figure 47. Top: Time series of TSS derived from optical turbidity. Data are biofouled after 30 June 2013. The red circles represent TSS derived from water sample data. Bottom: Time and depth resolved TSS derived from ADCP acoustic backscatter. Data are from ADCP Platform #2.**

# Appendix B. PARTRAC Sediment Tracking Study

PARTRAC

Sea Engineering, Inc.

# Heckathorn Superfund Site:

# Lauritzen Channel Sediment Tracking Study

*Final Draft*

September 2013

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## EXECUTIVE SUMMARY

Transport Pathway Evaluation (TPE) is a method in which a sediment transport pathway is visualised using a mass of uniquely labelled fluoro-magnetic (tracer) particles. Tracer particles are released into the environment and subsequent capture of these particles in space and/or time provides information on the localised transport direction and rate.

Partrac Ltd were contracted by SEA Engineering Inc. (Santa Cruz) to undertake a TPE study and provide sediment tracking services at the Heckathorn Superfund Site in the Lauritzen Channel, Port of Richmond ,California, to assess the fate of silt bottom sediments impacted by high mean flows and turbulence associated with local propeller wash.

This report presents information on the tracer specification and testing, method of tracer introduction and sampling design, and tracer analysis and enumeration methods. Results (tracer material dry mass in grammes) from testing of all samples are reported. No interpretation is provided in this report.

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# 1. INTRODUCTION

## 1.1 Background

Contaminated sediments are found in numerous ports and harbour environments world-wide, where they comprise legacy deposits from historical industrial activities as well as more recent deposits from on-going contamination. Management approaches directed towards decontamination of contaminated seabed sediments require information on the range of processes governing the transport and fate of the contamination.

Partrac Ltd were contracted by Sea Engineering, Inc (Santa Cruz) to provide sediment tracking services for the Heckathorn Superfund Site in the Lauritzen Channel, Port of Richmond , California, to assess the fate of silt bottom sediments impacted by high mean flows and turbulence associated with local propeller wash. Partrac developed a dual signature silt tracer of two colours (green and red). 175 kg quantities of each were released in the form of low profile, frozen blocks onto the seabed at two locations in the central region of the Lauritzen Channel. Assessment of the mobilisation and transport was achieved through the use of powerful, *in situ* moorings of permanent magnets and through collection of sediment grabs. This methodology is otherwise known as 'Transport Pathway Evaluation' (TPE).

## 1.2 Transport Pathway Evaluation (TPE) Using Sediment Tracers

*Transport Pathway Evaluation* (TPE) is a method in which a sediment transport pathway is visualised using a mass of uniquely labelled fluoro-magnetic (tracer) particles (White, 1998). Tracer particles are released into the environment and subsequent capture of these particles in space and/or time provides information on the localised transport direction and rate (Black *et al*., 2007). TPE experiments require the manufacture of sediment analogues called 'tracers'; these are particles highly similar to those wishing to be tracked and which therefore behave in a highly similar way as native sediment. Partrac manufacture tracer with two unique signatures associated with every tracer grain – fluorescent colour and magnetic character – in order that they may be both extracted from environmental samples, with the use of powerful (11,000 Gauss) bar type magnets, and identified unequivocally using their fluorescent colour. Rarely are environmental particles found which are both fluorescent in colour *and* magnetic, and this thereby provides a firm foundation for the use of 'dual signature' tracers in tracking the movement of sediments.

The benefits of using powerful *[in situ]* magnets to capture the tracers include:

- Magnets can be left in the field to accumulate tracer (passive sampling);
- Magnets can be used to extract tracer from within a (bottom) sediment sample, thus concentrating tracer for ensuing analysis;
- They are simple to use and require minimal operator time;
- They can encompass a large area very easily thereby allowing a large area to be monitored;
- They immediately indicate the presence/absence of tracer, and can therefore be used to inform adaptive sampling; and
- They generally enable subsequent analysis of tracer particles by mass.

# 2. TRACER DESIGN, MANUFACTURE AND TESTING

## 2.1 Introduction

Discussions with Craig Jones (at Sea Engineering, Inc) distilled a tracer specification for use in the studies. This was:

- size range: coarse-medium silt tracer (ca. 20 – 70 μm).
- density: mineral density (~2300 – 2900 kg $m^{-3}$)
- colour; 2 fluorescent colours (red; green).
- para-magnetic[1] attribute; yes.
- quantity (kg): 175 kg x 2 (red; green).

Partrac manufactured two tracer batches of differing colour (red; green) according to this specification. 175 kg of each colour was made.

In order that the use of sediment analogues to track sediment movement in aquatic systems is valid the tracer used should meet a series of underlying assumptions (see Foster, 2000). These are:

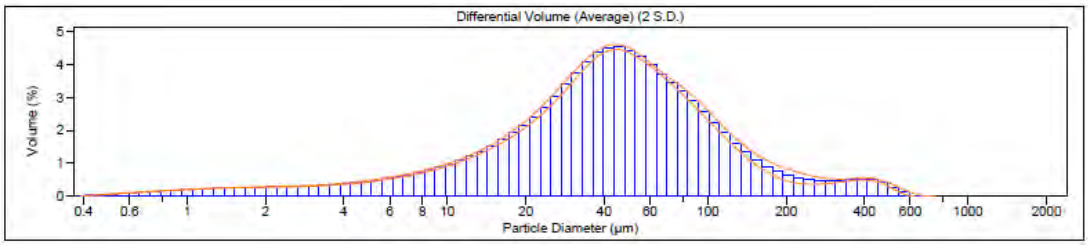
1. The tracer's hydraulic and bio-organic properties mimic those of the sediment of interest, and therefore the tracer is transported in the same fashion as the native sediment.
2. The tracer does not change properties through time (at least over the timescales of interest) and can be monitored.
3. The tracer does not manifestly change the transporting system in any way.

The following sections summarise characterisation tests performed on the tracer and are written in relation to [1] and [2].

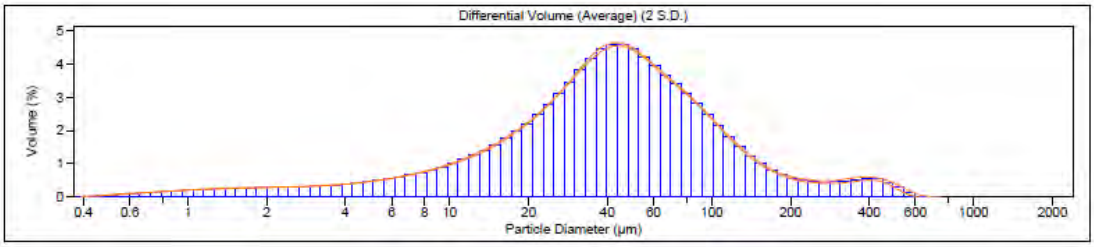
## 2.2 Size Spectra

Since the size range was pre-specified, there was no contractual requirement to determine the size spectra of native sediments by measurement and none were made. However, size spectra measurements were made on two small sub-samples of each tracer colour using Malvern Laser Diffraction instrument at Sea Engineering Inc. Figure  presents data from these analyses which demonstrate that the two tracer colours have very similar grain size distributions. The Green tracer material has a $d_{50}$ of 41.89 μm, and the Red has a $d_{50}$ of 45.82 μm. The $d_{10}$ and $d_{90}$ of each colour of tracer material are also very similar.

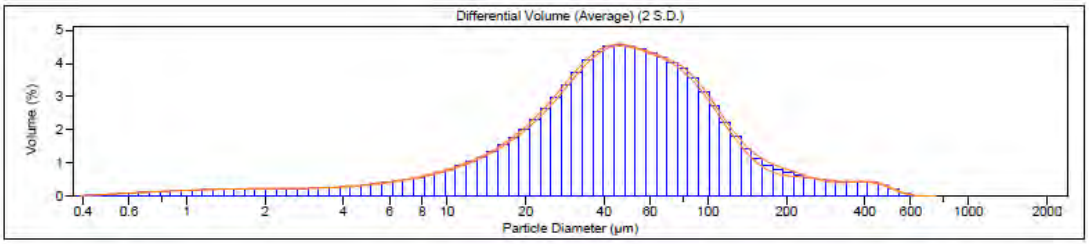
[1] Paramagnetism is a form of magnetism whereby the paramagnetic material is only attracted when in the presence of an externally applied magnetic field.



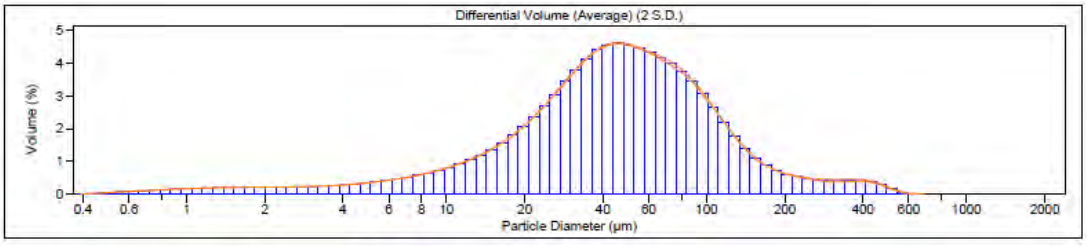

Green Tracer Material Run 1




Green Tracer Material Run 2




Red Tracer Material Run 1




Red Tracer Material Run 2

**Figure 2 Particle size spectra of the red and green tracer materials (2 runs of each colour on a Beckman Coulter LS Particle Size Analyser).**

## 2.3 Particle Density

On a similar basis there was no contractual necessity to measure density of the native sediments as the tracer particles are coated, quartzitic mineral particles and understood to be of a sufficiently similar density. However, direct measures of the density were made using a standard volumetric methodology (BS 1377: 1990 Part 2: 8.2). This gave a density of 2,332 kg $m^{-3}$ for the red tracer (1 sample tested) and a density of 2,354 ± 115 kg $m^{-3}$ (3 samples tested) for the green tracer.

## 2.4 Para-Magnetic Attribute

Particles with para-magnetic attributes were required, in order that magnets could be used both within field sampling and to achieve magnetic separation (i.e. separation of magnetic particles [including tracer]) from non-magnetic sediments). Para-magnetism can be quantitatively confirmed using a specific laboratory test which measures directly the geological mass/volume-specific magnetic susceptibility ($\lambda$) of a tracer. This provides an index of the relative ease of which a soil or sediment sample can acquire magnetic attributes in the presence of an applied, low frequency (100 $\mu$T) alternating magnetic field. Ferruginous (i.e. iron rich) materials possess a greater propensity to acquire a magnetic attribute, and therefore display relatively high values for $\lambda$, whereas largely non-ferrous materials do not. These tests were not undertaken, but a general assessment using the permanent magnets was made to confirm para-magnetic properties for each tracer batch.

## 2.5 Fluorescent Colour

A sub-sample of each tracer colour was inspected under a fluorescence microscope to determine the integrity of the fluorescent-magnetic coating and the % of coated particles (Figure 3). These tests indicated 100% of particles are coated.

**Figure 3: Photograph of both the red and green tracer under black light (UV-A ~ 400nm).**

### 2.5.1 Spectral Characteristics

Each tracer colour possesses spectral characteristics which are a function of the dye incorporated onto particle surfaces during the coating process. The analysis of dye concentration during the tracer enumeration procedure relies upon transmission of light of a specific wavelength - which optimally stimulates the dye to fluoresce (this is known as the 'excitation' wavelength, $\lambda_{ex}$) – and measurement of the intensity of light emitted specifically at the wavelength at which the dye is known to fluoresce (this is known as the 'emission' wavelength, $\lambda_{em}$). If these values are known then the measurement of dye concentration (and hence in this context tracer dry mass, $M$) is also optimised.

Figure 4 shows the excitation and emission spectra of the **green** tracer (code: BSR-CH227). The fluorescence excitation spectrum (dark blue line) is obtained by fixing the fluorescence detector wavelength at 523 nm and then scanning the excitation wavelengths. This provides a fluorescence induction spectrum, which is, in effect, an absorption spectrum of the particles. Inversely, the

fluorescence emission spectrum was obtained by fixing the excitation wavelength at 485nm and then scanning the emission wavelengths.

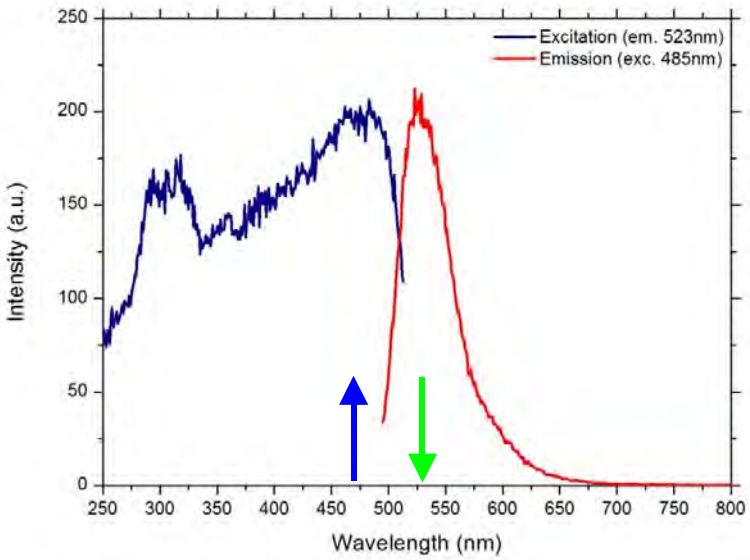



**Figure 4 Emission – excitation spectra for the green tracer pigment. The blue and green lines indicate the specific wavelengths at which the analytical fluorimeter stimulates the tracer to fluoresce, and records the resulting fluorescence intensity, respectively.**

The spectral characteristics of the red tracer (code: BSR-RD213) are presented in Figure 5. These particles show a similar broad excitation spectrum to the green tracer, but extending from the UV to around 600nm. Fluorescence emission is centred at 610nm. The Unilux instrument commissioned for the red tracer work uses a (LED) light source with output centred at 530nm and detects fluorescence emission centred at 625nm.

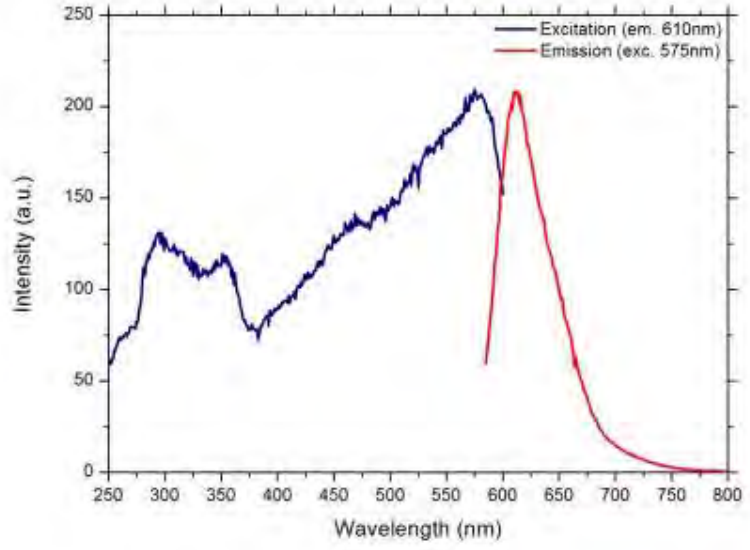



**Figure 5 Excitation and emission spectra of red tracer.**

The excitation and emission wavelengths for each tracer colour are given in Table 1.

**Table 1: Excitation and emission wavelengths for each tracer colour.**

| Tracer Colour | Excitation Wavelength $\lambda_{ex}$ (µm) | Emission Wavelength $\lambda_{ex}$ (µm) |
|---|---|---|
| **Red** | 530 | 625 |
| **Green** | 470 | 530 |

## 2.6 Summary

Table 2 provides a summary of the characteristics of each tracer colour.

**Table 2: Summary of the characteristics of each tracer colour.**

| Colour | Quantity (kg) | $d_{10}$ (µm) | $d_{50}$ (µm) | $d_{90}$ (µm) | Particle Density kg $m^{-3}$ | Particles Fluorescent % |
|---|---|---|---|---|---|---|
| Green | 175 | 8.47 | 41.89 | 129.55 | 2354 | 100 |
| Red | 175 | 11.2 | 45.82 | 128 | 2332 | 100 |

Notes: $d_{10}$ = 10% of particles by weight are smaller than this figure; $d_{50}$ = 50% of particles by weight are smaller than this figure; $d_{90}$ = 90% of particles by weight are smaller than this figure.

# 3. PREPARATORY WORK

## 3.1 Tracer Freezing

The tracer was delivered to SEI's office in 25 kg batches in moist form. During manufacture ~10-15% by mass seawater was added to each batch; this is principally to reduce in advance surface active effects associated with the tracer, and this substantially simplifies tracer deployment. It also saves time in the field as it means that the tracer batches, as delivered, can be frozen directly without intervention or addition of additional seawater. All delivered tracer was frozen for 2.5 days at 9 °F in a nearby fisheries storage facility.

During this time small sub-samples of tracer were taken as archive samples.

## 3.2 Background Data Collection

A 'background' site survey is undertaken as part of the TPE/sediment tracking methodology. The purpose of the background survey is to establish several issues:

- The nature, and typical mass, of naturally magnetic (but non-fluorescent) particulates in the water column; this information is of generic use in regard to the use of suspended magnets to collect magnetic tracer material naturally magnetic (but non-fluorescent) particulates in the
- The nature, and typical mass, of naturally magnetic (but non-fluorescent) particulates in the bedded sediments; this information is of generic use in regard to the analytical methodology used to determine tracer dry mass in sediment samples
- The abundance, if any, of naturally occurring magnetic *and* fluorescent particulates at the site.
- The need to collect sediment material for use in preparation of standard curves within the analytical methodology.

In order to support this a suspended magnet was deployed close to Site M09 on the afternoon of Tuesday 11th June, and 2 bottom sediment grab samples G05 and G06 (1 upstream of the tracer drop zone, 1 downstream) were obtained prior to deployment of tracer on 13th June.

**Table 3: Background sample collection 13th June 2013 (*t*=0; M = Magnet; G = Sediment Grab).**

| Sample Location | Date &Time Sampled |
|---|---|
| **M09** | 13th June 2013: 10:30 |
| **G05** | 13th June 2013: 10:45 |
| **G06** | 13th June 2013: 11:00 |

# 4. ON SITE SURVEY WORK

## 4.1 GPS Position Recording

All positional detail was recorded and provided by Frank Spada (SEI). This included fixes for:

- each magnet mooring, including the background magnet mooring;
- the location of 'drift magnet' samples;
- the location where the two tracer colours were deployed, and
- all the sediment grabs collected, i.e. background samples, post-deployment QA samples, and sampling interval samples.

A table of the navigational fix data for the above is provided in the Appendix.

## 4.2 Deployment of Tracer

On 13th June 2013, each batch of the tracer was deployed using a workboat provided by SEI. Frozen tracer blocks were rolled onto a tarpaulin sheet and wrapped up by rolling the sheet over the block several times (this minimised contact of the block with seawater on the way to the seabed); two operators then attached ropes to eyelets at the corners of the tarpaulin and gently and slowly lowered the block to the seabed. Once it was on the seabed the tarpaulin was then unrolled slowly leaving the block to slide onto the surface of the seabed. The tarpaulin sheet was then slowly recovered.

The locations for each of the patches of the tracer deployed are presented in Figure 6.

**Figure 6: Location for the Red and Green tracer material drop zones in the Lauritzen Channel.**

### 4.3 Deployment of Magnets

Powerful cylindrical rare earth element (REE) magnets, either short 0.3 m (1 foot) or long 0.6 m (2 feet) in length, were utilised in this experiment (Figure 7). These were encapsulated in plastic sheaths with end caps and integrated in a mooring line which could be suspended in the estuary water e.g. from a piece of infrastructure. Following plumbing of the depth of the bed, at each of the magnet mooring locations, the moorings were positioned so that they would sample ~1 m and ~ 2 m above the bed; for 8 (of the 12) of the magnet moorings a long magnet (0.6 m) was positioned lowermost, and a short magnet positioned ~ 1 m above this; for the remaining 4 (of the 12) two short magnets were connected for the lowermost position. Altogether 12 magnet moorings were deployed attached to items of infrastructure largely around the periphery of the Lauritzen Channel (locations shown in Figure 8). The peripheral locations of the magnet moorings, while not preferred from a sampling standpoint, were necessitated so as to not interfere with potential vessel traffic during the study.

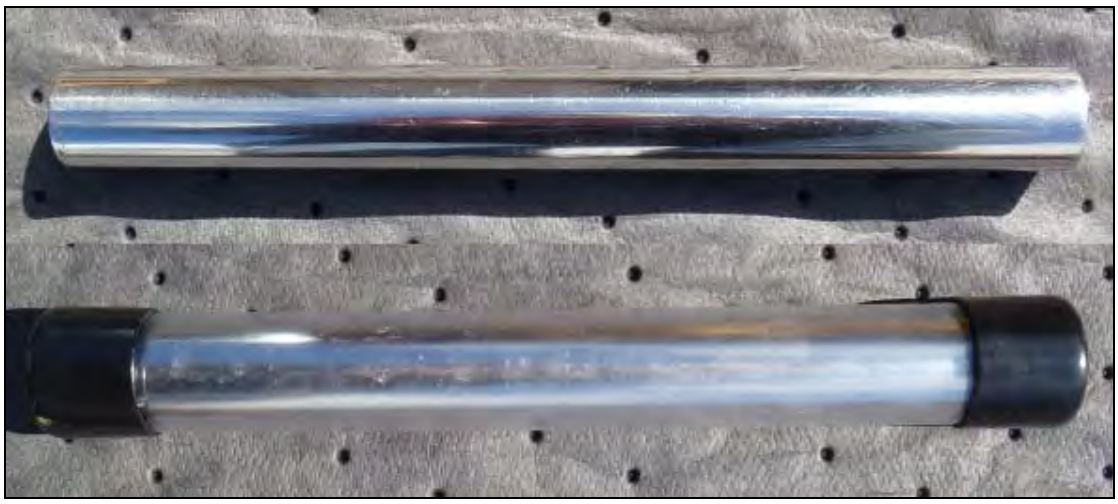


**Figure 7 One of the powerful, permanent REE magnets used in this study (top) and housed in the sheath with endcaps (bottom).**

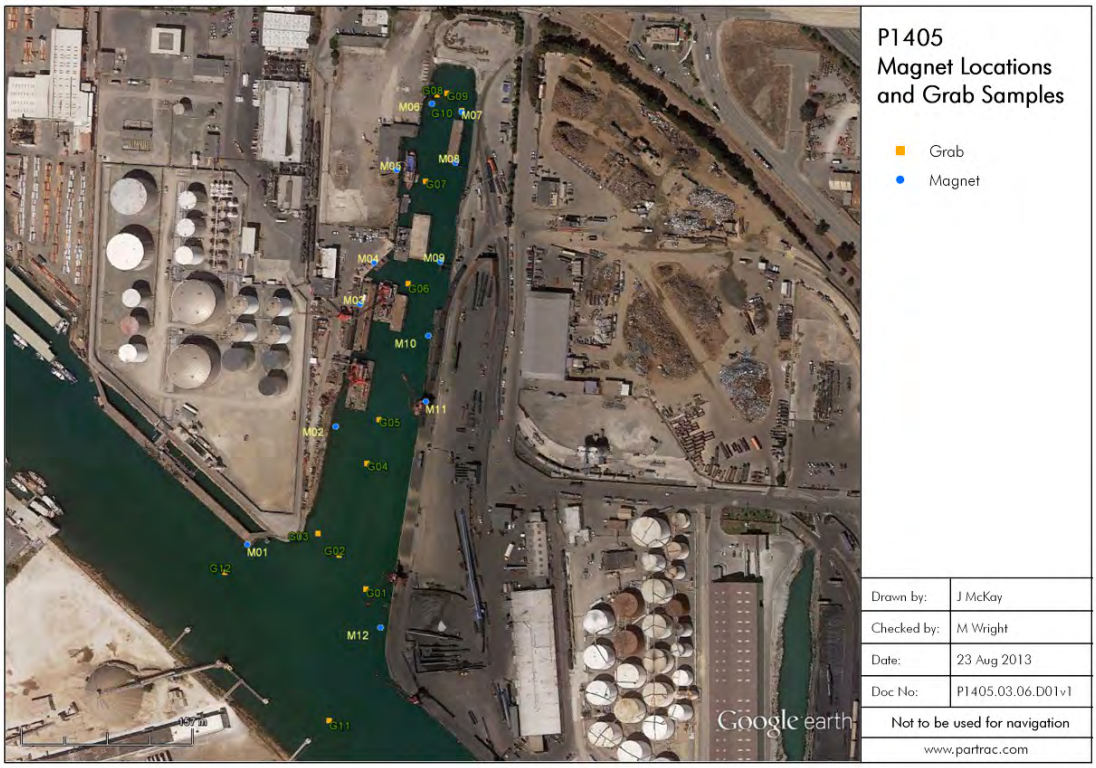



**Figure 8: Magnet moorings and grab sampling locations**

## 4.4 Sampling

Sampling was divided into that associated with Day 0 ($t$=0; 13th June, 2013) the tracer deployment day, and then successive, post-introduction sampling. For the latter sampling was undertaken on:

- Day 1 ($t$=~24 hours; 14th June, 2013);
- Day 2 ($t$=~48 hours; 15th June, 2013);
- Day 4 ($t$=~76 hours; 17th June, 2013);
- Day 6 ($t$=~120 hours; 19th June, 2013); and
- Day 14 ($t$=~336 hours; 19th June, 2013).

On each of the above occasions all the magnets were serviced and grabs of bed sediment at a series of pre-ordained locations (as designated by SEI see Figure 8) were collected. Servicing of the magnets involved recovery of the mooring line, careful removal of the sheath of each magnet and transfer of the sheath to a sample bag, followed by installation of a new clean sheath. The magnet moorings were recovered from the water on Day 14.

Grabs samples of bed sediment were collected with a small petit-ponar-style grab; upon recovery each sample was inspected to assess that the suitable sample had been retrieved and the surface material [of the grab sampler] to a depth of 2-3 cm was scooped off with a stainless steel spoon or spatula, and transferred to a labelled sample bag.

### 4.4.1 Post-Deployment (*t*=0 hours; Day 0) QA Sampling (13th June, 2013)

Two bottom grabs were collected, one ~50 m upstream of the tracer drop zone and approximately on the channel axis, and a second ~50 m downstream of the tracer drop zone and similarly on the tidal axis. The aim of these samples is to provide a simple check on the spread and deposition – if any – of tracer into the surrounding seabed area in the hours immediately following introduction.

This was supported by the collection of 3 magnet drift samples; a magnet was suspended on a wire at approximately mid-depth as the survey vessel drifted across the drop zone areas for a distance of ~50 – 100 m. As above, the aim of the process is to check for the presence of any residual tracer that might be in suspension immediately following tracer introduction.

**Table 4: Samples collected following tracer deployment on 13th June 2013 (*t*=0; Drift M = drift magnet sample M = Magnet; G = Sediment Grab).**

| Sample Location | Date &Time Sampled |
|---|---|
| **Drift M01** | 13th June 2013: 13:10 – 13:18 |
| **Drift M01** | 13th June 2013: 16:09 – 16:15 |
| **Drift M01** | 13th June 2013: 17:32 – 17:38 |
| **G05** | 13th June 2013: 18:36 |
| **G06** | 13th June 2013: 18:48 |

The objective of the use of frozen block method for tracer introduction is to emplace the tracers onto the seabed quickly, in a localised area and with minimal dispersion of tracer as possible. These samples effectively form a useful quality assurance on the success of the tracer deployment.

### 4.4.2 Day 1 (+24 hours after tracer deployment)

Table 5 shows the order and timing of the magnet and grab samples collected on Day 1 (14th June 2013)

**Table 5: Order and timing of sample collection on Day 1, 14th June 2013 (M = Magnet; G = Sediment Grab).**

| Sample Location | Date &Time Sampled |
|---|---|
| **G11** | 14th June 2013: 09:39 |
| **G12** | 14th June 2013: 09:52 |
| **G01** | 14th June 2013: 10:01 |
| **G02** | 14th June 2013: 10:08 |
| **G03** | 14th June 2013: 10:15 |
| **G04** | 14th June 2013: 10:18 |
| **G05** | 14th June 2013: 10:22 |
| **G06** | 14th June 2013: 10:28 |
| **G07** | 14th June 2013: 10:32 |
| **G08** | 14th June 2013: 10:37 |
| **G09** | 14th June 2013: 10:40 |
| **G10** | 14th June 2013: 10:45 |
| **M01** | 14th June 2013: 10:54 |
| **M02** | 14th June 2013: 11:10 |

| Sample Location | Date &Time Sampled |
|---|---|
| **M03** | 14th June 2013: 11:27 |
| **M04** | 14th June 2013: 11:37 |
| **M05** | 14th June 2013: 11:52 |
| **M06** | 14th June 2013: 12:07 |
| **M07** | 14th June 2013: 12:24 |
| **M08** | 14th June 2013: 12:30 |
| **M09** | 14th June 2013: 12:38 |
| **M10** | 14th June 2013: 12:55 |
| **M11** | 14th June 2013: 09:39 |
| **M12** | 14th June 2013: 09:39 |

### 4.4.3 **Day 2 (+48 hours after tracer deployment)**

Table 6 shows the order and timing of the magnet and grab samples collected on Day 2 (15th June 2013).

**Table 6: Order and timing of sample collection on Day 2, 15th June 2013 (M = Magnet; G = Sediment Grab).**

| Sample Location | Date &Time Sampled |
|---|---|
| **M07** | 15th June 2013: 09:38 |
| **G10** | 15th June 2013: 09:51 |
| **M08** | 15th June 2013: 09:57 |
| **M09** | 15th June 2013: 10:11 |
| **M10** | 15th June 2013: 10:22 |
| **M12** | 15th June 2013: 10:37 |
| **M11** | 15th June 2013: 10:55 |
| **M01** | 15th June 2013: 11:07 |
| **M02** | 15th June 2013: 11:16 |
| **M03** | 15th June 2013: 11:38 |
| **M04** | 15th June 2013: 11:46 |
| **M05** | 15th June 2013: 12:04 |
| **M06** | 15th June 2013: 12:18 |
| **G08** | 15th June 2013: 12:29 |
| **G09** | 15th June 2013: 12:41 |
| **G07** | 15th June 2013: 12:49 |
| **G06** | 15th June 2013: 12:56 |
| **G05** | 15th June 2013: 13:02 |
| **G04** | 15th June 2013: 13:08 |
| **G03** | 15th June 2013: 13:11 |
| **G02** | 15th June 2013: 13:28 |
| **G01** | 15th June 2013: 13:36 |
| **G12** | 15th June 2013: 13:41 |
| **G11** | 15th June 2013: 13;47 |

### 4.4.1 **Day 4 (+72 hours after tracer deployment)**

Table 7 shows the order and timing of the magnet and grab samples collected on Day 4 (17th June 2013).

**Table 7: Order and timing of sample collection on Day 4, 17th June 2013 (M = Magnet; G = Sediment Grab).**

| Sample Location | Date &Time Sampled |
|---|---|
| **M06** | 17th June 2013: 09:38 |
| **G08** | 17th June 2013: 09:51 |
| **M07** | 17th June 2013: 09:57 |
| **G10** | 17th June 2013: 10:11 |
| **M08** | 17th June 2013: 10:22 |
| **M09** | 17th June 2013: 10:37 |
| **M10** | 17th June 2013: 10:55 |
| **M11** | 17th June 2013: 11:07 |
| **M12** | 17th June 2013: 11:16 |
| **M02** | 17th June 2013: 11:38 |
| **M03** | 17th June 2013: 11:46 |
| **M04** | 17th June 2013: 12:04 |
| **M05** | 17th June 2013: 12:18 |
| **G09** | 17th June 2013: 12:29 |
| **G07** | 17th June 2013: 12:41 |
| **G06** | 17th June 2013: 12:49 |
| **G05** | 17th June 2013: 12:56 |
| **G04** | 17th June 2013: 13:02 |
| **M01** | 17th June 2013: 13:08 |
| **G12** | 17th June 2013: 13:11 |
| **G03** | 17th June 2013: 13:28 |
| **G02** | 17th June 2013: 13:36 |
| **G01** | 17th June 2013: 13:41 |
| **G11** | 17th June 2013: 13;47 |

### 4.4.1 **Day 6 (+120 hours after tracer deployment)**

Table 8 shows the order and timing of the magnet and grab samples collected on Day 6 (19th June 2013).

**Table 8: Order and timing of sample collection on Day 6, 19th June 2013 (M = Magnet; G = Sediment Grab)**

| Sample Location | Date &Time Sampled |
|---|---|
| **M06** | 19th June 2013: 08:15 |
| **G08** | 19th June 2013: 08:21 |
| **M07** | 19th June 2013: 08:25 |
| **G10** | 19th June 2013: 08:35 |
| **G09** | 19th June 2013: 08:39 |
| **M08** | 19th June 2013: 08:45 |
| **M05** | 19th June 2013: 08:50 |
| **G07** | 19th June 2013: 09:01 |
| **M09** | 19th June 2013: 09:09 |
| **G06** | 19th June 2013: 09:18 |
| **M04** | 19th June 2013: 09:24 |
| **M03** | 19th June 2013: 09;32 |
| **M10** | 19th June 2013: 09:41 |
| **M11** | 19th June 2013: 09:47 |
| **G05** | 19th June 2013: 09:55 |
| **M02** | 19th June 2013: 09:57 |
| **G04** | 19th June 2013: 10:03 |
| **M12** | 19th June 2013: 10:07 |
| **G01** | 19th June 2013: 10:17 |
| **G02** | 19th June 2013: 10:22 |
| **G03** | 19th June 2013: 10:25 |
| **M01** | 19th June 2013: 10:29 |
| **G12** | 19th June 2013: 10:38 |
| **G11** | 19th June 2013: 10:38 |

# 5. TRACER ENUMERATION

## 5.1 Introduction

A method known as *spectrofluorimetry* was used to determine the dry mass of tracer (in grammes) within a sample. A fluorimeter is a device used to measure parameters of fluorescence: its intensity and wavelength distribution of emission spectrum after excitation by a certain spectrum of light. These parameters can be used to identify the presence and the amount of specific dye molecules in a fluid medium. Modern fluorimeters are capable of detecting fluorescent molecule concentrations as low as 1 part per trillion. This approach offers a means with which to obviate the additional mass due to the presence of magnetic but non-fluorescent particulates[2] simply and directly. It also provided a very high analytic resolution which would facilitate detection of very low (mg quantities) tracer mass. The fluorimeter signal output can be empirically related to tracer mass (kg or g) through a series of tracer (colour) specific, reference standards.

## 5.2 Unilux™ Fluorimeters

The analyses were carried out using two specially manufactured high performance, miniature Unilux™ fluorimeters from Chelsea Technologies Group (one for each tracer colour analysis). The sensors comprise a small (26.5 mm) diameter housing with a single window geometry (Figure 8). The front lens of the fluorimeter is designed to refract the output from the 6 LEDs so that it converges in the solution approximately 7 mm in front of the lens, forming an evenly illuminated spot approximately 5 mm in diameter. Any fluorescence generated is then collected by the same lens and directed down the central axis of the instrument to the detector. High quality filters are used to select the specific excitation and emission wavelengths required (see Table 1).

**Figure 8: The CTG Unilux miniature laboratory fluorimeter (right) and the measurement cell (left); note the fluorimeter shines from beneath during acquisition of data.**

The Unilux series are especially suited to the present task as they are small, highly stable, possess a high ambient light rejection capability and have low noise-high sensitivity attributes. The general technical specification of the Unilux instrument is provided in Appendix I.

2 Magnetic (but non-fluoresent) particles would be expected in relatively high abundance in an industrialised port environment.

### 5.3 Methodology

A detailed **Standard Operating Procedure** for the analysis is given in Appendix II. The method in general terms, for situations where two tracer colours may be found in the same sample, involves a series of steps:

1. drying and weighing of the sample (sieving if necessary);
2. dissolution of the fluorescent pigment into a special solvent for a period of 168 hours (7 days);
3. centrifugation if necessary (to remove all particulates);
4. dilution to a known level using analytical grade solvent;
5. analysis of the fluorescence intensity of the dye solution using both Unilux™ sensors (sampling frequency 1 Hz, duration 30-40 s); and then
6. derivation of tracer particle dry mass (*M*) using calibration functions (dose response curves) for each Unilux for each dye colour.

By testing each sample with both fluorimeters, and using data obtained from the dose response curves for each sensor in both dyes (Section 5.3.1), there are two simultaneous equations with two unknowns:

$$SignalF = SlopeFG \times [Green] + SlopeFP \times [Red] + OffsetF \quad 1.$$

and

$$SignalR = SlopeRG \times [Green] + SlopeRP \times [Red] + OffsetR \quad 2.$$

Where:

SignalF : is the sample signal from the Fluorescein UniLux (measured).
SlopeFG : is the slope of the Green Dye response on the Fluorescein UniLux (known).
SlopeFP : is the slope of the Red Dye response on the Fluorescein UniLux (known).
OffsetF : is the solvent blank signal (known).

and

SignalP : is the sample signal from the Rhodamine UniLux (measured).
SlopePG : is the slope of the Green Dye response on the Rhodamine UniLux (known).
SlopeRP : is the slope of the Red Dye response on the Rhodamine UniLux (known).
OffsetR : is the solvent blank signal (known).

These two simultaneous equations can be solved (using matrix algebra) to give the two unknown concentrations for both dyes. As the fluorimeter calibrations are established using solutions based on a known dry mass of tracer particle, the mass ratio for particles in the unknown sample solution is simply the ratio of the calculated concentrations.

### 5.3.1 **Standard (Dose Response) Curves**

Eluted dye solutions for both tracer colours were prepared by adding a known dry mass of tracer particles ($10^{-1}$ g) to 40ml of acetone in an Eppendorf tube, mixing and then allowing the solution to equilibrate for 168 hours (7 days). This time period has been established as optimal for maximal extraction of the pigment into the acetone. 200µl of the eluted dye solution was then mixed with 2ml of analytical grade acetone (dilution of 1 in 10) to create a stock solution. Dose response curves were obtained by filling the calibration cell with 75 ml of analytical grade acetone, recording a baseline reading and then adding sequential 20 µl aliquots of the stock solution, mixing and recording further readings. Approximately 20 seconds worth of raw data was recorded for each measurement using a 1 second sampling rate. Average and standard deviation values were calculated for the 20 sequential readings from each of the data sets. Due to the (significant) non-fluorescent magnetic background material present at the site dose response curves were prepared with just tracer present and tracer and ~ 1g (the average of the dry mass of all samples) of non-fluorescent native magnetic material present to effectively measure the quenching effects of the native sediment. Dose response curves were prepared as follows:

1. 0.1g tracer; no background material, sequential readings through to 1g (both tracer colours); and
2. 0.1g tracer; ~ 1.0g background native material (average background material concentration) sequential readings through to 1g (both tracer colours).

Least-squares regression analysis (Fowler *et al*., 1998) was performed on the data to generate calibration functions.

### 5.3.2 **Quality Assurance**

An analytical quality control/assurance methodology was developed in tandem with development with the fluorimetric method. This involved inclusion of the following within the laboratory testing strategy:

1. Periodic testing of blanks (1 in every 7 tests);
2. Periodic testing of blind samples (i.e. tracer masses unknown to the technician);
    a. 4 samples tested.
3. Evaluation of Unilux sensor drift (temporal stability); and
4. Evaluation of Unilux sensor bias (accuracy and precision).

### 5.3.3 **Visual Observations**

Prior to fluorimetric analysis all samples were routinely visually inspected under UV illumination to assess tracer presence. Qualitative descriptions were developed as follows:

- Trace
- Low
- Intermediate
- High
- Very high

Note:- Due to quenching effects of the background non-fluorescent, magnetic material and the low wavelength of a standard UV-A inspection lamp (~ 400nm), and since not all the sample is examined in depth, the probability exists *of a negative visual inspection and a positive fluorimetric result*. Cross-comparison of qualitative descriptions with fluorimetric data should accordingly be undertaken with caution.

Quenching is any process that decreases the fluorescent intensity of a sample (Lakowicz, 2006).

# 6. RESULTS

## 6.1 Dose Response (Calibration) Functions

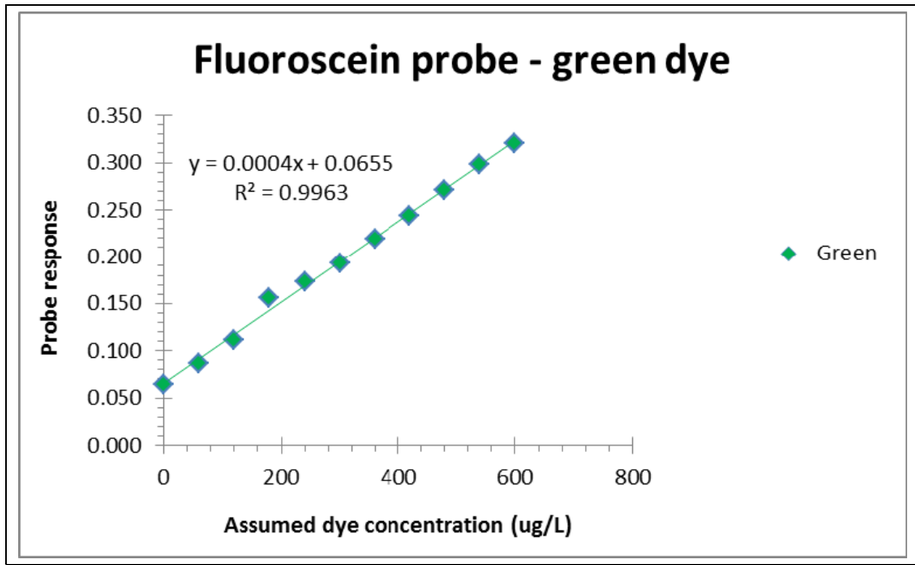
Standard (dose response) curves were developed to relate fluorimetric measurements (probe reading in volts) to tracer dye concentration over the range of dry masses (0 – 1 g, as follows: (0.0g; 0.1g; 0.2g; 0.3g; 0.4g; 0.5g; 0.6g; 0.7g; 0.8g; 0.9g and 1g) (Figure 9). Since there is a probability of both tracer colours occurring in a given sample, functions were generated for both sensors in both dyes (note the weak but linear responses of the probes in contrary dyes, which is expected). Since there is a non-fluorescent, magnetic background (non-tracer) fraction in most samples, this was repeated for the dose response curves prepared with tracer and 1 g of the non-fluorescent, magnetic background material (the average mass for this fraction across all samples collected). Least squares regression analysis on the data provides 4 transfer functions for use in data analysis (Table 9). Consistently high coefficients of determination ($r^2$) are found. The practical, minimum resolvable tracer mass (MRM) is $10^{-3}$ g (i.e 1 mg).

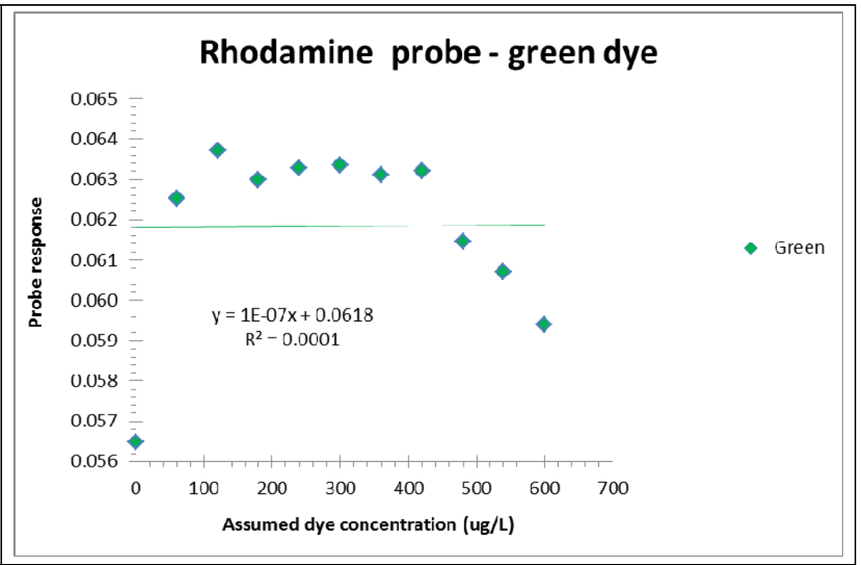
**Table 9: Summary of standard (dose response) equations for the fluorescein and rhodamine sensors for both dyes with no background (magnetic, non-fluorescent) material present.**

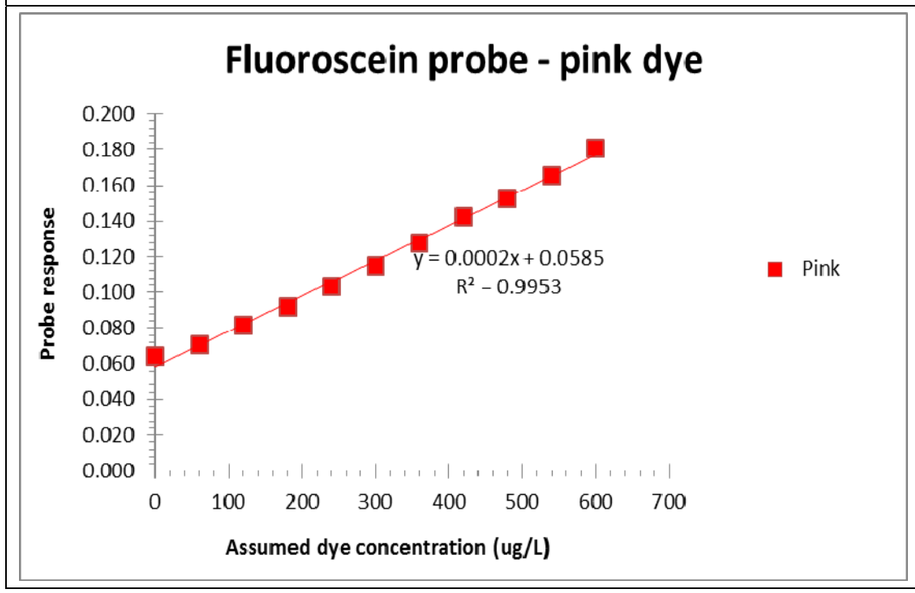
| Probe | Dye | Slope | Intercept | $r^2$ |
|---|---|---|---|---|
| Fluorescein | Green | 0.0004 | +0.0655 | 0.99 |
| Rhodamine | Red | 0.0006 | +0.0506 | 0.99 |
| Fluorescein | Red | 0.0002 | +0.0585 | 0.99 |
| Rhodamine | Green | $1x10^{-7}$ | +0.0618 | 0.00 |

**Table 10: Summary of standard (dose response) equations for the fluorescein and rhodamine sensors for both dyes with1 g of background (magnetic, non-fluorescent) material present.**

| Probe | Dye | Slope | Intercept | $r^2$ |
|---|---|---|---|---|
| Fluorescein | Green | 0.0003 | +0.0489 | 0.9916 |
| Rhodamine | Red | -2E-05 | +0.0607 | 0.7748 |
| Fluorescein | Red | 7E-05 | +0.0538 | 0.9942 |
| Rhodamine | Green | -1E-05 | +0.06 | 0.7380 |



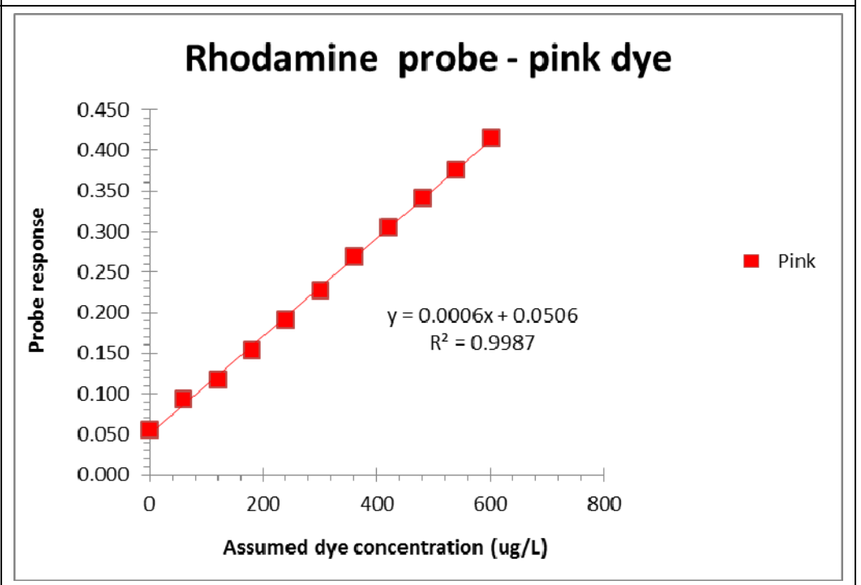
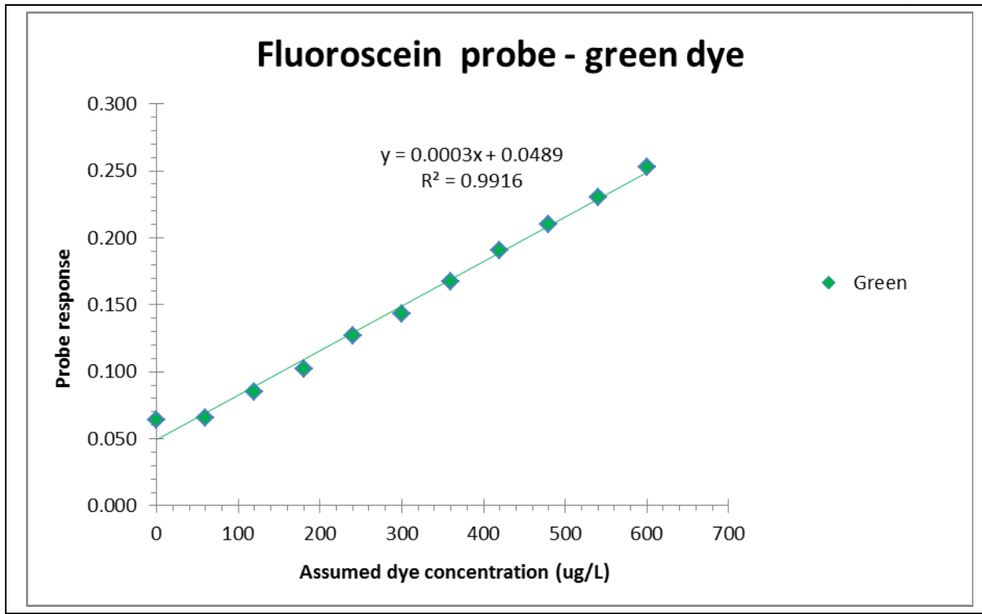
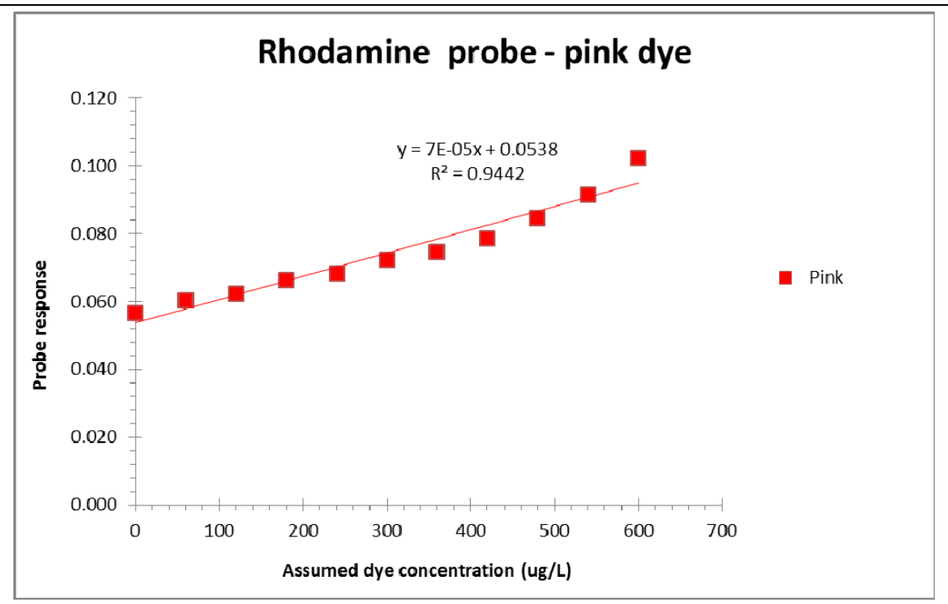
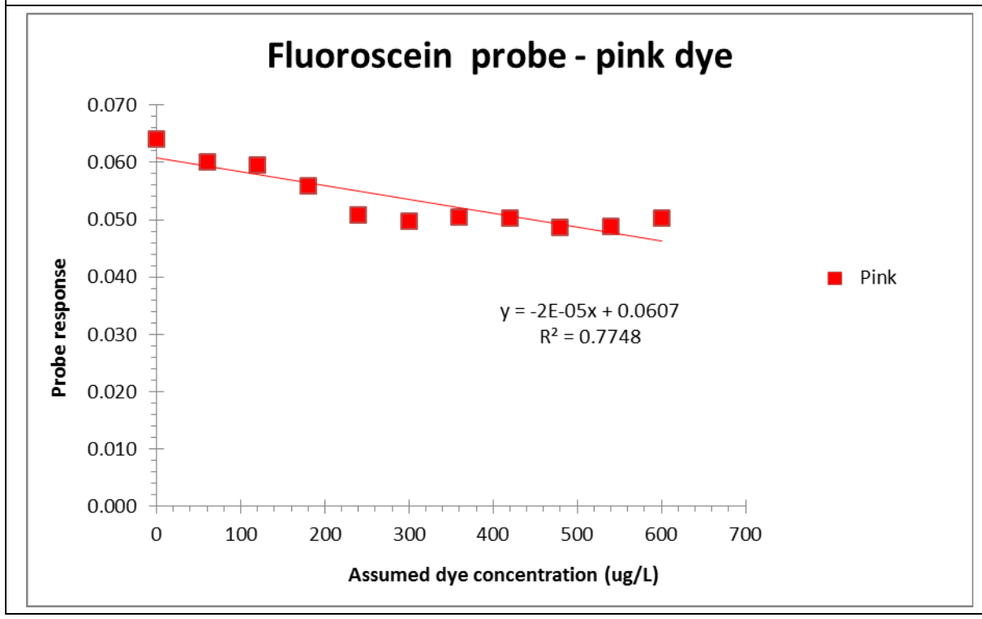




**Figure 9: Dose response curves – neat tracer only (no background non-fluorescent, magnetic material). In practise the point concentration values on the x-axis are interchangeable with the tracer dry masses (0.0g; 0.1g; 0.2g; 0.3g; 0.4g; 0.5g; 0.6g; 0.7g; 0.8g; 0.9g and 1g).**



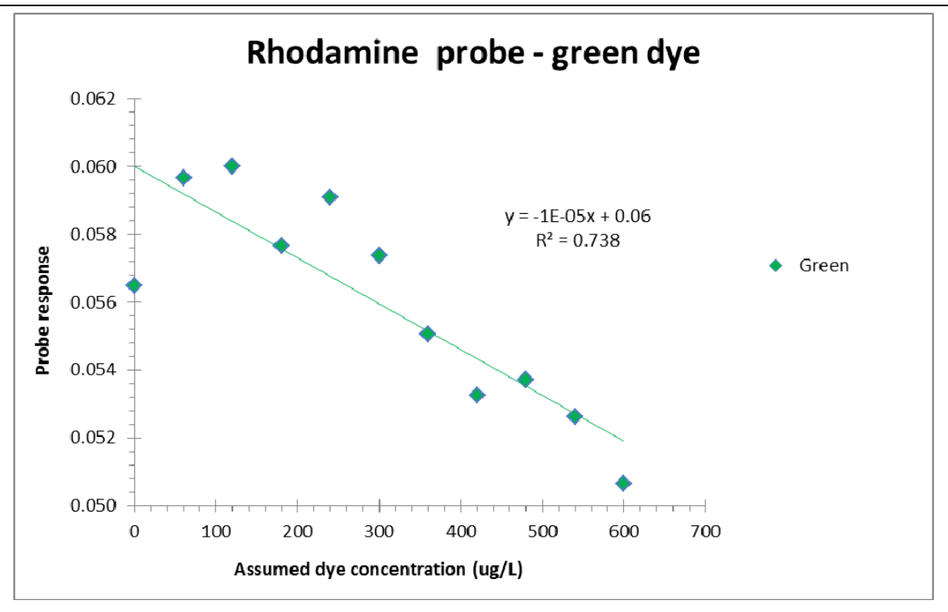




**Figure 10: Dose response (calibration) functions for both Unilux fluorimeters for both dyes inclusive of 1 g of non-fluorescent, magnetic background material. In practise the point concentration values on the x-axis are interchangeable with the tracer dry masses (0.0g; 0.1g; 0.2g; 0.3g; 0.4g; 0.5g; 0.6g; 0.7g; 0.8g; 0.9g and 1g).**

## 6.2 QC Data – Periodic Testing of Blanks

A check on the performance of the fluorimetric analytical procedure is made through periodic testing of blanks. Blanks are solutions made up in entirely the same manner as samples but without inclusion of a sediment/tracer sample. Note due to the use of a solvent (rather than water) zero values were not recorded (the fluorescein Unilux returns raw values ~0.064; the rhodamine Unilux 0.056; these are the y-axis intercepts in Figure 9 and 10). However, a value of zero for the *derived* tracer mass (Table 11) confirms proper functioning of the fluorimeters.

**Table 11: Periodic testing of laboratory blanks for mono-colour dyes (i.e. green tracer, red tracer).**

| Sample # | Measured Blank Tracer Mass $M_{blank}$ g |
|---|---|
| 1 | 0.000 |
| 2 | 0.000 |
| 3 | 0.000 |
| 4 | 0.000 |
| 5 | 0.000 |
| 6 | 0.000 |
| 7 | 0.000 |
| 8 | 0.000 |
| 9 | 0.000 |
| 10 | 0.000 |

## 6.3 QC Data – Periodic Testing of Blind Samples (Methodological Accuracy)

In order to establish the fluorimetric analytical procedure together with operator efficiency function as desired, periodic blind samples were submitted for testing to the laboratory. These provide information on the methodological accuracy, which is the degree of closeness of measurements of a quantity to that quantity's actual (true) value. Blind samples are prefabricated mono-colour sediment samples within which the tracer dry mass is unknown to the analyst. Table 12 summarises results from testing of four samples. The results are good (within 16% of true value) in terms of analytical accuracy and reasonably consistent over the range of tracer masses tested.

**Table 12: Periodic testing of blind samples (green tracer).**

| Sample # | Doped Tracer Mass $M_{dop}$ (g) | Measured Tracer Mass $M$ (g) | Mean Error (%) |
|---|---|---|---|
| 1 | 0.151 | 0.165 | 9 |
| 2 | 1.250 | 1.111 | 12 |
| 3 | 0.165 | 0.146 | 12 |
| 4 | 0.016 | 0.019 | 16 |

## 6.4 QC Data – Unilux Sensor Precision

The precision of a measurement system, also called reproducibility or repeatability, is the degree to which repeated measurements under unchanged conditions show the same results. The precision of the Unilux fluorometer instrument was tested by carefully preparing a series of known tracer dry masses, eluting into the solvent and then collecting 10 consecutive (repeat) fluorescence intensity measurements from the solutions (Table 13). These data show relatively low standard deviation values, which indicates a relatively high precision for the methodology.

**Table 13 Assessment of method precision.**

| Tracer Mass (g) | *Fluorimeter Response (Raw Data) ± standard deviation* |
|---|---|
| 0.025 | 0.190 ± 5% |
| 0.100 | 0.216 ± 6% |
| 0.200 | 0.284 ± 5% |
| 0.500 | 0.443 ± 6% |
| 0.750 | 0.684 ± 9% |
| 1.000 | 0.790 ± 12% |

## 6.5 Tracer Dry Mass

Table 14 presents results for all samples tested. Background samples (i.e. collected before any tracer was deployed), and samples of the seabed immediately following tracer introduction, are found at the top of the table. Qualitative visual descriptions (inspection under black light) are given for every sample (note the general use of caution in Section 6.3.3 if cross-referencing these to fluorimetric data is undertaken). A reference number is also given for a digital photograph for each sample (photographs are not provided in this report).

*N.B. All data has been reported however caution should be exercised with any reported tracer mass data that is at or below ~0.005g*

**Table 14 Summary of tracer dry mass (g) for all samples. Data omissions are where samples were either not collected or the results of the analyses were not considered to be sensible/reliable.**

| Day - Date - Sample Number<br>Day 1 (13th June 2013) | Visual Description under Black Light | Photo Number | Mass of Red Tracer (g) | Mass of Green Tracer (g) |
|---|---|---|---|---|
| **Background Magnet (M09)** | no tracer present (prior to deployment) | 5167 | 0.000 | 0.000 |
| **Post Deployment Grab (G05)** | trace: green | 5022 | 0.267 | 0.062 |
| **Post Deployment Grab (G06)** | no tracer present | 5171 | 0.031 | 0.122 |
| **Drift Magnet 01** | no tracer present | - | 0.000 | 0.000 |
| **Drift Magnet 02** | no tracer present | - | 0.000 | 0.000 |
| **Drift Magnet 03** | no tracer present | - | 0.000 | 0.000 |

| Day 2 (14th June 2013)<br>Sample Number | Visual Description under Black Light | Photo Number | Mass of Red Tracer (g) | Mass of Green Tracer (g) |
|---|---|---|---|---|
| **M01A** | no tracer present | 5166 | 0.000 | 0.000 |
| **M01B** | no tracer present | 5157 | 0.000 | 0.000 |
| **M02A** | no tracer present | 5165 | 0.000 | 0.000 |
| **M02B** | no tracer present | 5164 | 0.000 | 0.000 |
| **M02C** | no tracer present | 5163 | 0.000 | 0.000 |
| **M03A** | no tracer present | 5162 | 0.000 | 0.000 |
| **M03B** | No Sample recovered | | | |
| **M03C** | no tracer present | 5160 | 0.000 | 0.000 |
| **M04A** | no tracer present | 5159 | 0.000 | 0.000 |
| **M04B** | no tracer present | 5158 | 0.000 | 0.000 |
| **M04C** | no tracer present | 5155 | 0.000 | 0.000 |

| Day 2 (14th June 2013) Sample Number | Visual Description under Black Light | Photo Number | Mass of Red Tracer (g) | Mass of Green Tracer (g) |
|---|---|---|---|---|
| **M05A** | no tracer present | 5154 | 0.000 | 0.000 |
| **M05B** | no tracer present | 5153 | 0.000 | 0.000 |
| **M05C** | no tracer present | 5152 | 0.000 | 0.000 |
| **M06A** | no tracer present | 5151 | 0.000 | 0.000 |
| **M06B** | no tracer present | 5150 | 0.000 | 0.000 |
| **M07A** | no tracer present | 5149 | 0.000 | 0.000 |
| **M07B** | no tracer present | 5148 | 0.005 | 0.000 |
| **M08A** | no tracer present | 5147 | 0.000 | 0.000 |
| **M08B** | no tracer present | 5146 | 0.000 | 0.000 |
| **M09A** | no tracer present | 5145 | 0.000 | 0.000 |
| **M09B** | no tracer present | 5143 | 0.000 | 0.019 |
| **M10A** | no tracer present | 5142 | 0.000 | 0.000 |
| **M10B** | no tracer present | 5141 | 0.000 | 0.094 |
| **M11A** | no tracer present | 5139 | 0.000 | 0.132 |
| **M11B** | no tracer present | 5138 | 0.000 | 0.087 |
| **M12A** | no tracer present | 5137 | 0.000 | 0.144 |
| **M12B** | no tracer present | 5140 | 0.000 | 0.036 |
| **G01** | no tracer present | 5201 | 0.012 | 0.052 |
| **G02** | no tracer present | 5202 | 0.000 | 0.000 |
| **G03** | no tracer present | 5200 | 0.211 | 0.075 |
| **G04** | no tracer present | 5205 | 0.000 | 0.000 |
| **G05** | no tracer present | 5203 | 0.026 | 0.027 |
| **G06** | no tracer present | 5207 | 0.000 | 0.068 |
| **G07** | no tracer present | 5209 | 0.038 | 0.057 |
| **G08** | no tracer present | 5206 | 0.246 | 0.102 |

| Day 2 (14th June 2013) Sample Number | Visual Description under Black Light | Photo Number | Mass of Red Tracer (g) | Mass of Green Tracer (g) |
|---|---|---|---|---|
| **G09** | no tracer present | 5204 | 0.060 | 0.000 |
| **G10** | no tracer present | 5208 | 0.174 | 0.000 |
| **G11** | no tracer present | 5199 | 0.020 | 0.000 |
| **G12** | no tracer present | 5198 | 0.035 | 0.363 |

| Day 3 (15th June 2013) Sample Number | Visual Description under Black Light | Photo Number | Mass of Red Tracer (g) | Mass of Green Tracer (g) |
|---|---|---|---|---|
| **M01A** | no tracer present | 5136 | 0.000 | 0.134 |
| **M01B** | no tracer present | 5135 | 0.000 | 0.076 |
| **M02A** | no tracer present | 5134 | 0.000 | 0.063 |
| **M02B** | no tracer present | 5133 | 0.000 | 0.015 |
| **M02C** | no tracer present | 5132 | 0.000 | 0.155 |
| **M03A** | no tracer present | 5131 | 0.000 | 0.116 |
| **M03B** | no tracer present | 5130 | 0.000 | 0.066 |
| **M03C** | no tracer present | 5129 | 0.000 | 0.243 |
| **M04A** | no tracer present | 5128 | 0.000 | 0.000 |
| **M04B** | no tracer present | 5127 | 0.017 | 0.345 |
| **M04C** | no tracer present | 5126 | 0.000 | 0.031 |
| **M05A** | no tracer present | 5125 | 0.000 | 0.476 |
| **M05B** | no tracer present | 5124 | 0.121 | 0.205 |
| **M05C** | no tracer present | 5123 | 0.000 | 0.027 |
| **M06A** | no tracer present | 5122 | 0.196 | 0.047 |
| **M06B** | no tracer present | 5121 | 0.000 | 0.065 |
| **M07A** | no tracer present | 5120 | 0.000 | 0.088 |
| **M07B** | no tracer present | 5119 | 0.035 | 0.147 |

| Day 3 (15th June 2013) Sample Number | Visual Description under Black Light | Photo Number | Mass of Red Tracer (g) | Mass of Green Tracer (g) |
|---|---|---|---|---|
| **M08A** | no tracer present | 5118 | 0.000 | 0.216 |
| **M08B** | no tracer present | 5117 | 0.018 | 0.197 |
| **M09A** | no tracer present | 5116 | 0.159 | 0.015 |
| **M09B** | Unreliable Analysis Result | | | |
| **M10A** | no tracer present | 5114 | 0.102 | 0.170 |
| **M10B** | Unreliable Analysis Result | | | |
| **M11A** | no tracer present | 5112 | 0.000 | 0.250 |
| **M11B** | no tracer present | 5110 | 0.000 | 0.145 |
| **M12A** | no tracer present | 5109 | 0.000 | 0.403 |
| **M12B** | no tracer present | 5111 | 0.081 | 0.223 |
| **G01** | no tracer present | 5174 | 0.050 | 0.000 |
| **G02** | no tracer present | 5175 | 0.000 | 0.000 |
| **G03** | no tracer present | 5176 | 0.010 | 0.050 |
| **G04** | no tracer present | 5177 | 0.002 | 0.000 |
| **G05** | no tracer present | 5178 | 0.010 | 0.000 |
| **G06** | low: green | 5182 | 0.000 | 0.140 |
| **G07** | no tracer present | 5181 | 0.360 | 0.237 |
| **G08** | no tracer present | 5184 | 0.017 | 0.080 |
| **G09** | no tracer present | 5185 | 0.000 | 0.063 |
| **G10** | no tracer present | 5179 | 0.192 | 0.049 |
| **G11** | no tracer present | 5180 | 0.023 | 0.000 |
| **G12** | no tracer present | 5183 | 0.000 | 0.101 |

| Day 4 (17th June 2013) Sample Number | Visual Description under Black Light | Photo Number | Mass of Red Tracer (g) | Mass of Green Tracer (g) |
|---|---|---|---|---|
| **M01A** | no tracer present | 5108 | 0.000 | 0.056 |
| **M01B** | no tracer present | 5107 | 0.000 | 0.000 |
| **M02A** | No Sample Recovered | | | |
| **M02B** | no tracer present | 5106 | 0.000 | 0.053 |
| **M02C** | no tracer present | 5105 | 0.000 | 0.000 |
| **M03A** | no tracer present | 5104 | 0.000 | 0.000 |
| **M03B** | no tracer present | 5103 | 0.004 | 0.012 |
| **M03C** | no tracer present | 5102 | 0.000 | 0.066 |
| **M04A** | no tracer present | 5101 | 0.000 | 0.014 |
| **M04B** | no tracer present | 5100 | 0.001 | 0.048 |
| **M04C** | no tracer present | 5099 | 0.000 | 0.000 |
| **M05A** | no tracer present | 5098 | 0.055 | 0.000 |
| **M05B** | no tracer present | 5097 | 0.000 | 0.018 |
| **M05C** | no tracer present | 5096 | 0.000 | 0.065 |
| **M06A** | no tracer present | 5095 | 0.011 | 0.190 |
| **M06B** | no tracer present | 5094 | 0.000 | 0.000 |
| **M07A** | no tracer present | 5093 | 0.000 | 0.000 |
| **M07B** | no tracer present | 5092 | 0.000 | 0.000 |
| **M08A** | no tracer present | 5091 | 0.000 | 0.000 |
| **M08B** | Unreliable Analysis Result | | | |
| **M09A** | no tracer present | 5089 | 0.000 | 0.000 |
| **M09B** | no tracer present | 5088 | 0.000 | 0.000 |
| **M10A** | no tracer present | 5087 | 0.000 | 0.000 |
| **M10B** | no tracer present | 5086 | 0.000 | 0.000 |
| **M11A** | no tracer present | 5085 | 0.000 | 0.000 |

| Day 4 (17th June 2013) Sample Number | Visual Description under Black Light | Photo Number | Mass of Red Tracer (g) | Mass of Green Tracer (g) |
|---|---|---|---|---|
| **M11B** | no tracer present | 5084 | 0.906 | 0.000 |
| **M12A** | no tracer present | 5083 | 0.000 | 0.000 |
| **M12B** | no tracer present | 5082 | 0.000 | 0.000 |
| **G01** | no tracer present | 5217 | 0.035 | 0.081 |
| **G02** | no tracer present | 5212 | 0.028 | 0.000 |
| **G03** | no tracer present | 5221 | 0.035 | 0.037 |
| **G04** | no tracer present | 5220 | 0.008 | 0.108 |
| **G05** | Unreliable Analysis Result | | | |
| **G06** | no tracer present | 5211 | 0.231 | 0.190 |
| **G07** | no tracer present | 5210 | 0.000 | 0.087 |
| **G08** | no tracer present | 5216 | 0.361 | 0.061 |
| **G09** | no tracer present | 5213 | 0.177 | 0.171 |
| **G10** | no tracer present | 5214 | 0.098 | 0.109 |
| **G11** | no tracer present | 5219 | 0.000 | 0.022 |
| **G12** | no tracer present | 5215 | 0.000 | 0.066 |

| Day 6 (19th June 2013) Sample Number | Visual Description under Black Light | Photo Number | Mass of Red Tracer (g) | Mass of Green Tracer (g) |
|---|---|---|---|---|
| **M01A** | no tracer present | 5081 | 0.000 | 0.000 |
| **M01B** | no tracer present | 5079 | 0.000 | 0.000 |
| **M02A** | no tracer present | 5078 | 0.000 | 0.000 |
| **M02B** | no tracer present | 5077 | 0.000 | 0.000 |
| **M02C** | no tracer present | 5076 | 0.000 | 0.000 |
| **M03A** | no tracer present | 5075 | 0.002 | 0.000 |
| **M03B** | no tracer present | 5074 | 0.000 | 0.000 |

| Day 6 (19th June 2013) Sample Number | Visual Description under Black Light | Photo Number | Mass of Red Tracer (g) | Mass of Green Tracer (g) |
|---|---|---|---|---|
| **M03C** | no tracer present | 5073 | 0.000 | 0.000 |
| **M04A** | no tracer present | 5072 | 0.000 | 0.142 |
| **M04B** | no tracer present | 5071 | 0.000 | 0.000 |
| **M04C** | no tracer present | 5070 | 0.000 | 0.000 |
| **M05A** | no tracer present | 5069 | 0.000 | 0.000 |
| **M05B** | no tracer present | 5068 | 0.000 | 0.000 |
| **M05C** | no tracer present | 5067 | 0.000 | 0.000 |
| **M06A** | no tracer present | 5066 | 0.000 | 0.000 |
| **M06B** | no tracer present | 5065 | 0.000 | 0.000 |
| **M07A** | no tracer present | 5064 | 0.000 | 0.000 |
| **M07B** | no tracer present | 5063 | 0.000 | 0.000 |
| **M08A** | no tracer present | 5062 | 0.000 | 0.000 |
| **M08B** | no tracer present | 5059 | 0.000 | 0.000 |
| **M09A** | no tracer present | 5061 | 0.000 | 0.000 |
| **M09B** | no tracer present | 5058 | 0.000 | 0.000 |
| **M10A** | no tracer present | 5057 | 0.000 | 0.000 |
| **M10B** | no tracer present | 5169 | 0.000 | 0.000 |
| **M11A** | no tracer present | 5170 | 0.000 | 0.000 |
| **M11B** | no tracer present | 5168 | 0.000 | 0.000 |
| **M12A** | no tracer present | 5055 | 0.000 | 0.000 |
| **M12B** | no tracer present | 5054 | 0.000 | 0.000 |
| **G01** | no tracer present | 5224 | 0.030 | 0.157 |
| **G02** | no tracer present | 5226 | 0.014 | 0.258 |
| **G03** | no tracer present | 5223 | 0.019 | 0.051 |
| **G04** | no tracer present | 5225 | 0.000 | 0.162 |

| Day 6 (19th June 2013) Sample Number | Visual Description under Black Light | Photo Number | Mass of Red Tracer (g) | Mass of Green Tracer (g) |
|---|---|---|---|---|
| **G05** | no tracer present | 5229 | 0.005 | 0.047 |
| **G06** | trace: green | 5227 | 0.000 | 0.255 |
| **G07** | no tracer present | 5222 | 0.021 | 0.083 |
| **G08** | no tracer present | 5233 | 0.000 | 0.000 |
| **G09** | Unreliable Analysis Result | | | |
| **G10** | no tracer present | 5230 | 0.000 | 0.000 |
| **G11** | no tracer present | 5231 | 0.000 | 0.065 |
| **G12** | no tracer present | 5232 | 0.000 | 0.000 |

| Day 14 (27th June 2013) Sample Number | Visual Description under Black Light | Photo Number | Mass of Red Tracer (g) | Mass of Green Tracer (g) |
|---|---|---|---|---|
| **M01A** | no tracer present | 5053 | 0.000 | 0.000 |
| **M01B** | no tracer present | 5052 | 0.000 | 0.000 |
| **M02A** | no tracer present | 5051 | 0.000 | 0.000 |
| **M02B** | no tracer present | 5050 | 0.000 | 0.000 |
| **M02C** | no tracer present | 5049 | 0.000 | 0.000 |
| **M03A** | No Sample Recovered | | | |
| **M03B** | no tracer present | 5048 | 0.000 | 0.000 |
| **M03C** | no tracer present | 5047 | 0.000 | 0.011 |
| **M04A** | no tracer present | 5046 | 0.000 | 0.000 |
| **M04B** | no tracer present | 5045 | 0.000 | 0.000 |
| **M04C** | no tracer present | 5044 | 0.000 | 0.056 |
| **M05A** | no tracer present | 5041 | 0.000 | 0.046 |
| **M05B** | no tracer present | 5042 | 0.000 | 0.000 |
| **M05C** | no tracer present | 5040 | 0.010 | 0.105 |

| Day 14 (27th June 2013) Sample Number | Visual Description under Black Light | Photo Number | Mass of Red Tracer (g) | Mass of Green Tracer (g) |
|---|---|---|---|---|
| **M06A** | no tracer present | 5039 | 0.000 | 0.155 |
| **M06B** | no tracer present | 5038 | 0.000 | 0.076 |
| **M07A** | no tracer present | 5037 | 0.094 | 0.124 |
| **M07B** | no tracer present | 5036 | 0.000 | 0.000 |
| **M08A** | no tracer present | 5035 | 0.000 | 0.002 |
| **M08B** | no tracer present | 5034 | 0.000 | 0.028 |
| **M09A** | trace: green | 5033 | 0.082 | 0.150 |
| **M09B** | no tracer present | 5032 | 0.000 | 0.047 |
| **M10A** | no tracer present | 5031 | 0.054 | 0.170 |
| **M10B** | no tracer present | 5030 | 0.000 | 0.000 |
| **M11A** | No Sample Recovered | | | |
| **M11B** | no tracer present | 5029 | 0.055 | 0.133 |
| **M12A** | no tracer present | 5027 | 0.000 | 0.173 |
| **M12B** | no tracer present | 5024 | 0.000 | 0.083 |
| **G01** | no tracer present | 5187 | 0.018 | 0.203 |
| **G02** | no tracer present | 5188 | 0.000 | 0.154 |
| **G03** | no tracer present | 5192 | 0.446 | 0.220 |
| **G04** | no tracer present | 5193 | 0.187 | 0.226 |
| **G05** | no tracer present | 5190 | 0.000 | 0.114 |
| **G06** | no tracer present | 5189 | 0.004 | 0.119 |
| **G07** | low: green | 5194 | 0.033 | 0.151 |
| **G08** | no tracer present | 5196 | 0.123 | 0.215 |
| **G09** | no tracer present | 5195 | 0.091 | 0.331 |
| **G10** | no tracer present | 5197 | 0.118 | 0.369 |
| **G11** | no tracer present | 5186 | 0.047 | 0.080 |

| Day 14 (27th June 2013) Sample Number | Visual Description under Black Light | Photo Number | Mass of Red Tracer (g) | Mass of Green Tracer (g) |
|---|---|---|---|---|
| **G12** | no tracer present | 5191 | 0.000 | 0.058 |
| **Eastdrop 1** | no tracer present | 5172 | 0.000 | 0.000 |
| **Eastdrop2** | no tracer present | 5173 | 0.080 | 0.000 |

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# 8. APPENDIX I GENERAL TECHNICAL SPECIFICATION OF THE UNILUX

**SPECIFICATION**

The UniLux is calibrated over the following ranges:

**Performance**

Wavelength Option Dynamic Range* Limit of Detection
Chlorophyll a 0 to 100 µg/L <0.01 µg/L
Fluorescein 0 to 100 µg/L <0.005 µg/L
Rhodamine WT 0 to 100 µg/L <0.02 µg/L
Phycoerythrin Cyanobacteria 0 to 100 µg/L <0.02 µg/L
Phycocyanin Cyanobacteria 0 to 100 µg/L <0.01 µg/L
Turbidity 0 to 100 FTU <0.02 FTU
* User configurable up to 500 µg/L

**Mechanical**

Size: 26.5mm dia. x 105mm (140mm including connector)
Weight in air: 100g
Pressure housing: Acetal C
Depth rating: 600 metres
Connector: MCBH-6-MP-SS
Electrical
Input voltage: 11 to 25Vdc
Data output: Digital RS232 and analogue 0 to 5Vdc (RS422 and SDI-12 options)
Power requirements: <1Watt @ 12 volt

## 9. APPENDIX II SPECTROFLUORIMETRIC ANALYSIS OF SEDIMENT SAMPLES (STANDARD OPERATING PROCEDURE)

**Objectives**: Determination of the weight of tracer particles within a sample that contains naturally magnetic but non-fluorescent particles, using a miniature, low cost multi-wavelength fluorimeter (Unilux).

**Scientific Background**: Partrac Ltd has developed a series of fluorescent-magnetic particulate tracers which are used on a commercial basis for tracking the movement of particulates in aquatic environments. The tracer possesses two signatures which are used to unequivocally identify tracer in samples within studies: fluorescent colour and para-magnetic character. The inclusion of para-magnetism in each particle means that permanent magnetism can be used to separate the tracer from the environment whilst in the environment. The fluorescence colour is used as a second signature to unequivocally identify tracer in samples. An inherent drawback of the magnetic particle methodology is that there are a variety of naturally magnetic (i.e. ferrous rich), but non-fluorescent particles in nature. In the methodology used these particles are included within samples, and this effectively constitutes 'noise' in data. The overall objective for samples is to derive the dry mass of tracer within samples, and the presence of magnetic but non-fluorescent particles constitutes additional mass.

**Sample Analysis Methodology (SoP)**:

1. Record the dry weight of the sample and place in a labelled vial that is able to withstand exposure to acetone.
2. Formulate a blank sample (i.e. use an ashed sand or silt, independently tested to be pigment free).
3. Visually inspect dry sample using a handheld fluorescent lamp to establish tracer presence.
4. Add a known volume of analytical grade acetone (90%) to the vial containing the sediment. The volume of acetone is dependent on the amount of sediment, but should adequately cover the sample. The volume chosen *must* remain the same through a given sample batch run.
5. Place the samples in a fridge for 24 hours.
6. Remove the extractant for flourimetric analysis. Samples should be filtered if particles are in suspension.
7. Each sample should be analysed using the appropriate CTG Unilux probe for the tracer dye, or using both probes for mixed colour studies.
8. Most samples will require dilution (e.g. 1 in 100 or 1 in 1000) before being analysed. Each sample should be diluted in analytical grade acetone, using a pipette and volumetric flask for accuracy.
9. Measure the blank (i.e. volume of acetone).
10. Place approximately 100ml of diluted sample into a glass measuring beaker and place under the Unilux probe. Allow the probe to measure the sample for approximately 20 seconds.
11. Remove the sample and wash the probe with distilled water before placing the next sample underneath.
12. A continuing calibration blank should be run at the beginning, after every 10 samples, and at the end of each run.
13. Wash and rinse all glassware with acetone and distilled water between samples.
14. Routinely run blanks and spiked samples as part of methodology QA.
15. Routinely assess sensor drift and reproducibility (bias).

**Calibration Methodology**: Calibration experiments should be performed for each batch of samples run, and these standards should be processed regularly to check the performance of the Unilux. Calibration must be completed individually for each tracer pigment that will be determined, and jointly where there are or might be two tracers in the same sample. Decide on the calibration range needed, which is typically determined based on the typical concentrations observed in the sample extracts and the desire to establish that the calibration is linear throughout the working range. The lowest concentration standard is at or less than the practical quantification limit. Ideally, in order for a calibration to be acceptable, the correlation coefficient for the linear regression should be greater than 0.990. However, this will depend on a number of factors such as degree of coating, particle size distribution, solvent and dye properties. Have 3-5 replicate samples per calibration weight and analyse as described above.

Calibration samples are made up by adding a known dry mass of tracer particles to 5ml of acetone in an Eppendorf tube, mixing and then allowing the solution to equilibrate for 24h hours. 100µl of the eluted dye solution is then mixed with 1ml of analytical grade acetone (dilution of 1 in 10) to create a stock solution. Dose response curves are obtained by filling the calibration cell with 75 ml of analytical grade acetone, recording a baseline reading and then adding sequential 50 µl aliquots of the stock solution, mixing and recording further readings. Approximately 20 seconds worth of raw data is recorded for each measurement using a 1 second sampling rate. An average and standard deviation was calculated for 20 sequential readings from each of the data sets. This procedure is continued for another 3 times or for as many points required on the calibration curve.

## 10. APPENDIX III: NAVIGATION FIX DATA FOR TRACER MATERIAL SAMPLING DEPLOYMENT AND LOCATIONS

| Location | Latitude (Digital Degrees) | Longitude (Digital Degrees) |
|---|---|---|
| Centre of GREEN Tracer deployment area | 37.922741 | -122.367279 |
| Centre of RED Tracer deployment area | 37.922229 | -122.366994 |
| M01 | 37.92058817 | -122.3685177 |
| M02 | 37.92160255 | -122.3676715 |
| M03 | 37.92262179 | -122.3674927 |
| M04 | 37.92296956 | -122.3673701 |
| M05 | 37.92374312 | -122.3671938 |
| M06 | 37.92430278 | -122.3668711 |
| M07 | 37.92425325 | -122.3665549 |
| M08 | 37.92383306 | -122.3665889 |
| M09 | 37.92301071 | -122.3666834 |
| M10 | 37.92239548 | -122.3667615 |
| M11 | 37.92185367 | -122.3667468 |
| M12 | 37.91997169 | -122.3670779 |
| G01 | 37.9202833 | -122.36725 |
| G02 | 37.92055 | -122.36755 |
| G03 | 37.9207167 | -122.3677833 |
| G04 | 37.9213167 | -122.3673167 |
| G05 | 37.9216833 | -122.3672167 |
| G06 | 37.9228167 | -122.367 |
| G07 | 37.9236667 | -122.3668833 |
| G08 | 37.9243833 | -122.3668167 |
| G09 | 37.9244 | -122.3667167 |
| G10 | 37.9242667 | -122.36655 |
| G11 | 37.9191833 | -122.36755 |
| G12 | 37.92035 | -122.3687333 |

# Appendix C. Sedflume Analysis

# United Heckathorn Sedflume Analysis
# Richmond Harbor, CA
# August 2013

Prepared for:

CH2M HILL

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# Executive Summary

Morphological bed changes in any aquatic system are dictated by complex and dynamically linked relationships between biological activity, hydrodynamic forcing, and sediment characteristics. When analyzing the sediment transport occurring within a system, numerous variables must be considered; one key aspect is the erosion properties and stability of a site's sediments. Sea Engineering, Inc. (SEI) conducted a Sediment Erosion at Depth Flume (Sedflume) analysis on 10 sediment cores obtained from Richmond Harbor, CA in the Lauritzen Channel. The Lauritzen channel is part of the United Heckathorn Superfund Site. The cores were collected in water depths ranging between 5.8 m to 7.9 m. The primary goal of this work was to characterize the erosion properties and physical characteristics of the sites sediments. The Sedflume analysis determined sediment erosion rates, critical shear stresses, particle sizes and bulk densities at specific down-core depth intervals.

Critical shear stress is a difficult parameter to quantify; for Sedflume analysis it is typically defined as the shear stress required to erode sediment at a rate of $10^{-4}$centimeter per second (cm/s) (Roberts et al. 1998). To reduce uncertainty, critical shear stresses were estimated by combining a power law regression analysis with critical shear stress thresholds based on direct erosion rate measurements. Calculated critical shear stresses ranged from 0.1 Pa to 1.28 Pa.

The presence of detritus, pebbles and shells had a noticeable effect on erosion. The Sedflume analysis provided a quantification of the overall effect of each of these constituents on sediment erosion. Although erosion rates fluctuated between intervals, core sediments generally stiffened with depth. This trend is common for sites with cohesive sediments. Cohesive sediments will often compact due to the weight of the overlying material. Compaction reduces the potential for sediment mobility. However, Sedflume results must be analyzed in conjunction with other system characteristics, such as hydrodynamic forcing, to assess overall site stability and sediment transport trends.

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# Section 1
# Introduction to Sedflume

## 1.1 Introduction

Morphological bed changes in any aquatic system are dictated by complex and dynamically linked relationships between biological activity, hydrodynamic forcing, and sediment characteristics. When analyzing the sediment transport occurring within a system, numerous variables must be considered; one key aspect is the erosion properties and stability of a site's sediments. Sea Engineering, Inc. (SEI) conducted a Sediment Erosion at Depth Flume (Sedflume) analysis on 10 sediment cores obtained from Richmond Harbor, CA in the Lauritzen Channel. The Lauritzen channel is part of the United Heckathorn Superfund Site. The cores were collected in water depths ranging between 5.8 m to 7.9 m. The primary goal of this work was to characterize the erosion rates and physical properties of the sediments within the study area. The cores were eroded during the Sedflume analysis to determine erosion rates as a function of shear stress and depth. In addition, each core was sub-sampled to determine sediment bulk density and particle size distribution at specific depths within the core. Critical shear stresses were also deduced for five vertical intervals in each core (unless otherwise stated).The following report outlines the procedures used in the Sedflume analysis, presents the measured data, and provides a description and analysis of the results.

## 1.2 Core Collection

Ten sediment cores were collected by SEI personnel on July10 and 11, 2013. At each coring location, a differential global positioning system (DGPS) was used to position a vessel at pre-determined fixed sampling stations in the Lauritzen Channel. The 10 coring locations are shown in Figure 1, where the white squares represent the coring locations. A pole was attached with clamps to the 10 cm by 15 cm rectangular core. The core tube was lowered into the water and positioned perpendicular to the sediment bed. Pressure was applied by hand until at least 30 cm (approximately) and no more than 60 cm of the core tube penetrated into the sediment bed. A valve affixed to the top of the core tube was temporally closed to provide suction when the core was pulled out of the sediment bed. The sediment bed near the mouth of the channel (SF08, SF04, SF05, SF03 and SF09) was stiff and required additional force from a fence-post hammer to achieve core penetration; smaller than 30 cm cores were kept if several core attempts were made at a location and each lead to recoveries less than 30 cm.

After cores reached the water surface, they were visually inspected for length and quality. Undisturbed cores were capped and secured to minimize sediment disturbance from sloshing water and vessel/vehicle motion. Cores were then transferred from the vessel to land, and packed in secure Sedflume core shipping boxes. The cores were then driven by SEI personnel to SEI's Sedflume laboratory in Santa Cruz, California. Upon arrival, the cores were again visually inspected to ensure sediment structure and surface had been

preserved. The cores were then placed in an ambient water bath for preservation until processing.

**Table 1. Sedflume core extraction coordinates, time and date, and water depth.**

| Core ID | Lat (°N) | Long (°W) | Coring Date | Time (PST) | Depth (m)* |
|---|---|---|---|---|---|
| SF01 | 37.92442 | -122.36678 | 7/10/2013 | 12:45 | 5.8 |
| SF02 | 37.92442 | -122.36668 | 7/10/2013 | 13:45 | 5.8 |
| SF03 | 37.92237 | -122.36730 | 7/10/2013 | 17:15 | 7.6 |
| SF04 | 37.92167 | -122.36747 | 7/11/2013 | 10:20 | 6.1 |
| SF05 | 37.92187 | -122.36742 | 7/11/2013 | 12:35 | 7.3 |
| SF06 | 37.92395 | -122.36668 | 7/10/2013 | 14:40 | 7.3 |
| SF07 | 37.92353 | -122.36690 | 7/10/2013 | 15:15 | 7.3 |
| SF08 | 37.92127 | -122.36750 | 7/11/2013 | 09:30 | 6.4 |
| SF09 | 37.92267 | -122.36712 | 7/11/2013 | 07:50 | 7.9 |
| SF10 | 37.92308 | -122.36677 | 7/11/2013 | 11:45 | 6.4 |

* Water depths are as recorded during core extractions and are not referenced to any datum.

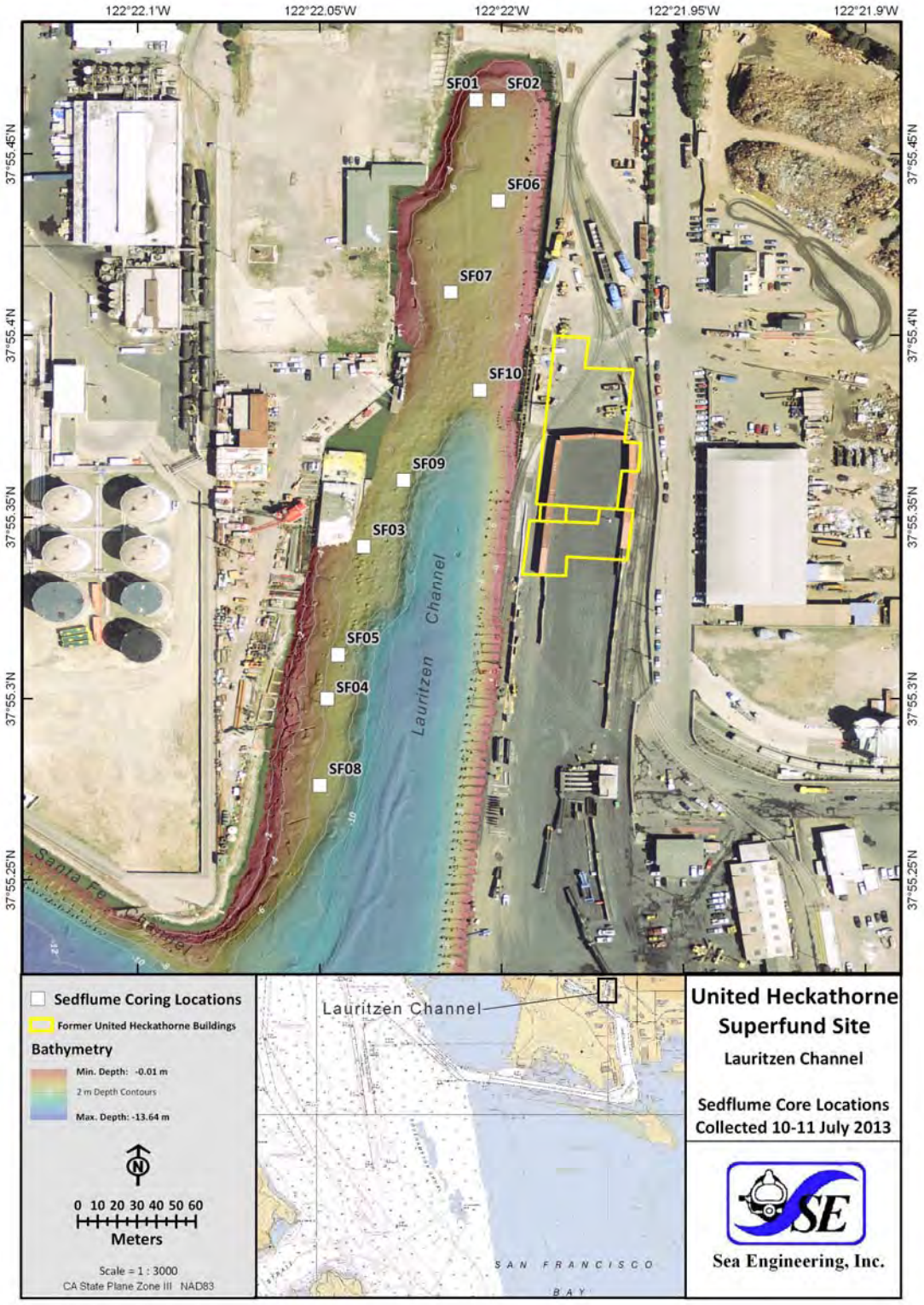


**Figure 1. Map of coring locations in Lauritzen Channel.**

## 1.3 Experimental Procedures

A detailed description of Sedflume analysis and its application are given in McNeil et al. (1996) and Roberts et al. (1998). The following sections supplement those reports with a general description of the Sedflume analysis procedures conducted in this study.

### *1.3.1 Description of Sedflume Setup*

A Sedflume is essentially a straight flume with an open bottom section through which a rectangular cross-section core barrel containing sediment can be inserted (schematic shown in Figure 2). The main components of the flume are the water tank, pump, inlet flow converter (which establishes uniform, fully-developed, turbulent flow), the main duct, test section, hydraulic jack and the core barrel containing sediment (Figure 3). The core barrel, test section, flow inlet section, and flow exit section are made of transparent acrylic so the sediment-water interactions can be observed visually. The core barrel has a rectangular cross-section, 10 cm by 15 cm, and a length of 60 cm.

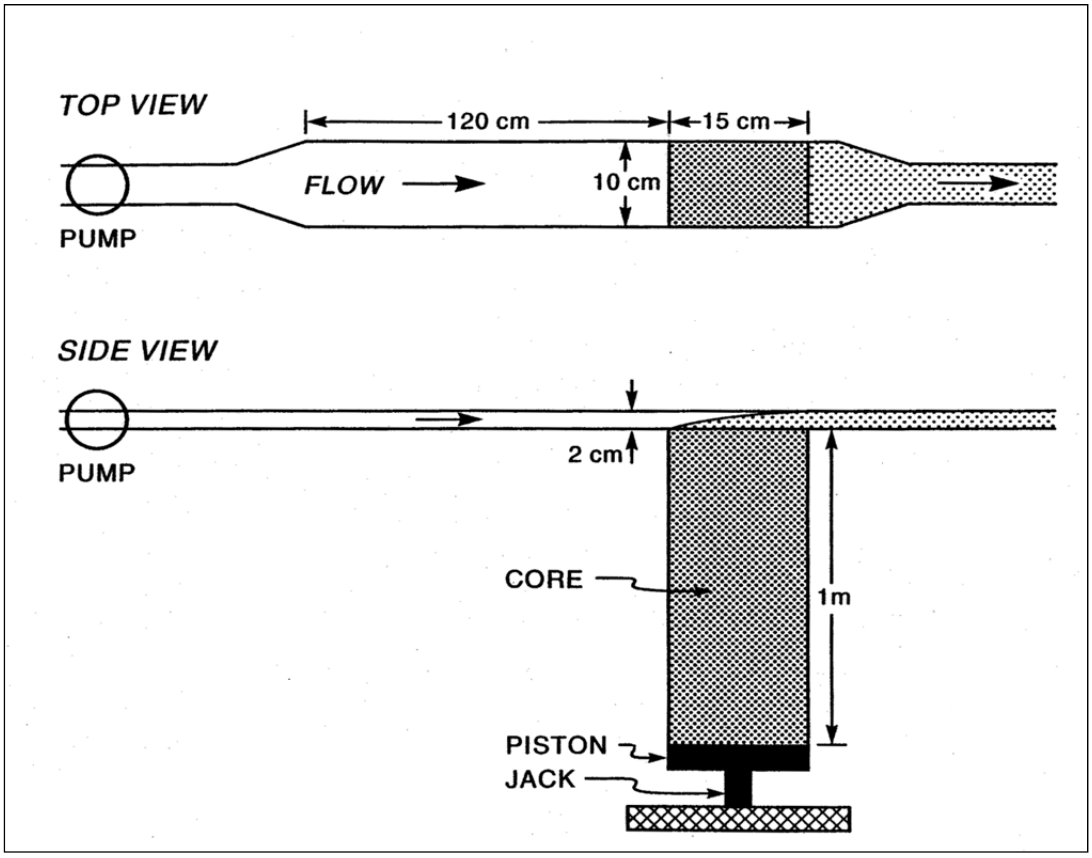


**Figure 2. Schematic of the Sedflume setup showing top and side views.**

Water is pumped through the system from a 300-gallon storage tank, through a 5 cm diameter pipe, and then through the flow converter into the main duct. This duct is

rectangular, 2 cm in height, 10 cm in width, and 120 cm in length; it connects to the test section, which has the same cross-sectional area (2 cm by 10 cm) and is 15 cm long. The flow converter changes the shape of the cross-section from circular to rectangular while maintaining a constant cross-sectional area. A ball valve regulates the amount of water entering the flume so that the flow rates can be carefully controlled. The flume also has a small valve immediately downstream from the test section that is opened to prevent a pressure vacuum from forming and enhancing erosion.

At the start of each test, a core barrel and the sediment it contains are inserted into the bottom of the test section. The sediment surface is aligned with the bottom of the Sedflume channel. When fully enclosed, water is forced through the duct and test section over the surface of the sediment. The shear stress produced by the flow, and imparted on the particles, causes the sediment to erode. As the sediment on the surface of the core erode, the remaining sediments in the core barrel are slowly moved upward so that the sediment-water interface remains level with the bottom of the flume.

An operator moves the sediment upward using a piston that is inside the core barrel and is controlled by a hydraulic jack with a 1m drive stroke. The jack is driven by the release of pressure that is regulated with a switch and valve system. In this manner, the sediments can be raised and made level with the bottom of the test section. The movement of the hydraulic jack can be controlled for measurable increments as small as 0.5 mm.

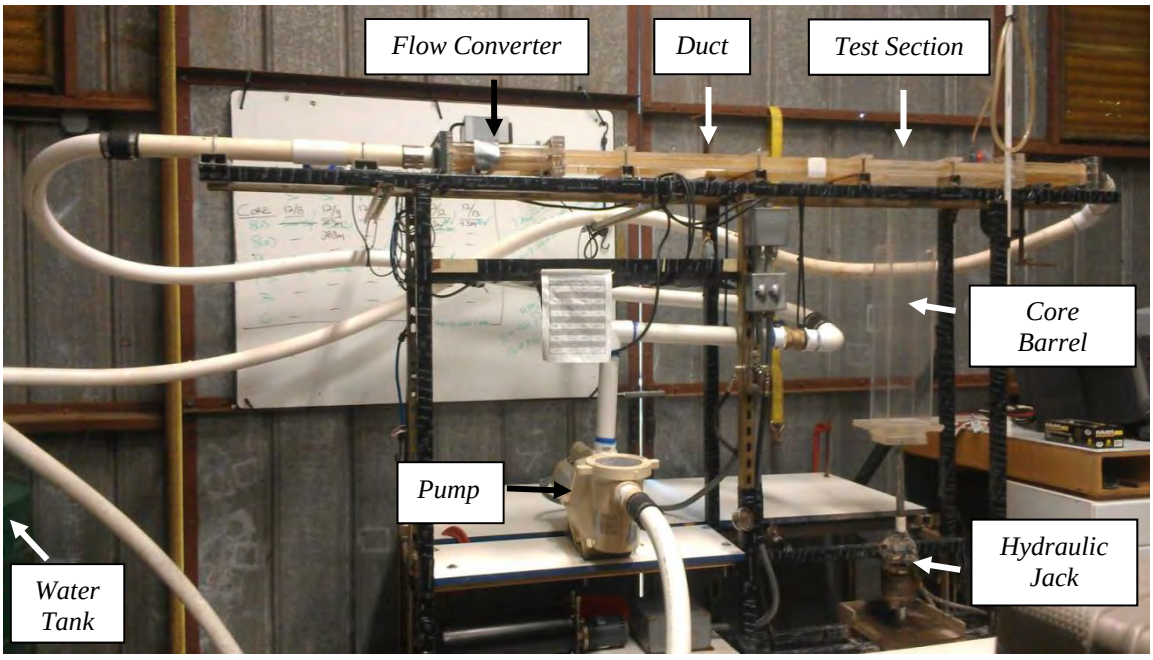


**Figure 3. Sedflume in the Santa Cruz, CA, SEI laboratory.**

### *1.3.2 Measurements of Sediment Erosion Rate*

At the start of each core analysis an initial reference measurement was made of the starting core length. The flume was then operated at a specific flow rate corresponding to a particular shear stress, and sediment was eroded (McNeil et al., 1996). As erosion proceeded, the core was raised if needed to keep the core's surface level with the bottom of the flume. This continued until 10 minutes had passed, or the core had been raised roughly 2 cm. The erosion rate for the applied shear stress was then calculated as:

$$E = \frac{\Delta z}{T} \qquad [1]$$

$E$ = Erosion rate
$\Delta z$ = Amount that the sediment was raised during a particular measurement period
$T$ = Measurement time interval

Because material is eroded and the core structure is broken down, repetitive erosion measurements at a given depth are not possible. To best determine the erosion rate at several different shear stresses and depths using only one core, the following procedures were performed for all cores:

1) The core was inserted into the bottom of the Sedflume test section.
2) The total length of sediment in the core barrel was measured and recorded.
3) Two 5-gram (approximately) subsamples of sediment from the core's surface were collected using a clean spoon. Sediment sampling was constrained to the "downstream" (relative to the Sedflume flow direction) end of surface.
4) Various shear stresses where applied to the cores surface from low to high, and sediment erosion was measured if it occurred (0.5 mm of erosion in 10 minutes was considered quantifiable). Applied shear stresses started at 0.1 Pa, and sequentially doubled until a given shear stress caused roughly 2 cm of erosion in 20 seconds. Each shear stress cycle was applied for a minimum of 20 seconds and a maximum of 10 minutes. To the extent possible, no more than 2 cm of sediment was allowed to erode at a single shear stress.
5) Once the threshold of 2 cm of erosion in 20 seconds was met, a new depth interval was started. Steps 3 and 4 were repeated[1]. Also, if the sediment composition changed noticeably in appearance or erosion properties, the depth interval was stopped, sediment sub-samples were collected, and a new depth interval was started (step 4).
6) Up to five depth intervals were tested per core.

[1] If a particular shear stress did not cause any observable erosion over a 10 minute period for consecutive depth intervals (e.g. less than 0.5 mm eroded in 10 minutes), that shear stress was removed from subsequent testing cycles; higher shear stresses were added, as appropriate, to attempt to measure at least 3 erosion rates.

### *1.3.3 Determination of Critical Shear Stress*

The critical shear stress of a sediment bed, $\tau_{cr}$, is the applied shear stress at which sediment motion is initiated. In this study it is operationally defined as the shear stress required to produce 0.001 mm of erosion in 1 second. This represents an erosion rate of $10^{-4}$ cm/s, or roughly 1 mm of erosion in 15 minutes[2].

Since it is difficult to measure $\tau_{cr}$ exactly at the $10^{-4}$ cm/s threshold, erosion was instead measured over a range of shear stresses designed to bracket the initiation of erosion threshold. The highest applied shear stress where erosion *did not occur* is defined by $\tau_0$; and $\tau_1$ is the lowest applied shear stress where erosion *did occur*.

Using the measured erosion rate data in each depth interval, a power law regression (described below) analysis was employed to determine the shear stress ($\tau_{power}$) required to cause $10^{-4}$ cm/s of erosion. Assimilating the bracketed shear stress values ($\tau_0$ and $\tau_1$) and $\tau_{power}$, the critical shear stress of each interval was then chosen according to the set of criteria described below:

- If $\tau_0 \leq \tau_{power} \leq \tau_1$, then $\tau_{power}$was the selected critical shear stress, $\tau_{cr}$, for the interval
- If $\tau_0 \geq \tau_{power}$, then $\tau_0$ was the selected critical shear stress for the interval
- If $\tau_{power} \geq \tau_1$, then $\tau_1$ was the selected critical shear stress for the interval

where $\tau_0$ and $\tau_1$ are determined directly from the Sedflume measurements. The $\tau_{cr}$ criteria allowed for selection of critical shear stresses using the power law results where the regression analysis was in agreement with measured erosion rate data.

**Power Law Regression**

Following the methods of Roberts et al. (1998), the erosion rate for sediments can be approximated by the power law regression:

$$E = A\tau^n \rho^m \qquad [2]$$

$E$ = erosion rate (cm/s)
$\tau$ = bed shear stress (Pa)
$\rho$ = sediment bulk density (g/cm$^3$)
$A$, $n$ and $m$ = constants that depend on the sediment characteristics

The equation used in the present analysis is an abbreviated variation of Equation 2:

$$E = A\tau^n \qquad [3]$$

[2] Though other definitions of critical shear stress erosion rate thresholds can be argued (and considered valid), the value of $10^{-4}$ cm/s threshold is used here for consistency with previous Sedflume efforts and in order to keep testing times to a practical duration.

where the constant, *A*, is a function of the sediment bulk density and other difficult properties to measure such as sediment geochemistry and biological influences. The variation of erosion rate with density typically cannot be determined for field sediments due to natural variation in other sediment properties (e.g. mineralogy, particle size and electrochemical forces). Therefore, the density term from the equation above, for a particular interval of approximately constant density, is incorporated into the constant *A*.

For each depth interval, the measured erosion rates (*E*) and applied shear stresses ($\tau$) were used to determine the *A* and *n* constants that provide a best fit power law curve to the data for that interval. Good regression fits of these parameters, where they existed, were then used to estimate the critical shear stress for the respective intervals. A coefficient of determination, $r^2$, of 0.80 was used as a criteria threshold for acceptance[3].

### *1.3.4 Measurement of Sediment Bulk Properties*

In addition to measuring erosion rates during the analysis, sediment sub-samples were periodically collected at depth to determine the water content (for wet bulk density), particle size distribution, and loss on ignition of the sediments in each core. Sub-samples were collected from the undisturbed core surface (prior to analysis) as well as the sediment surface at the beginning of each subsequent depth interval.

Wet bulk density was determined by water content analysis using methods outlined in Hakanson and Jansson (2002). This was accomplished, first, by measuring the wet and dry weight of the collected sample to determine the water content (*W)* as described in the ASTM standard 2216-05:

$$W = \frac{M_w - M_d}{M_w} \qquad [4]$$

$W$ = water content
$M_w$ = wet weight of sample
$M_d$ = dry weight of sample

Once the water content was calculated, the wet bulk density, $\rho_b$, was determined from Equation 5:

$$\rho_b = \frac{\rho_w \rho_s}{\rho_w + (\rho_s - \rho_w)W} \qquad [5]$$

$\rho_w$ = density of water (assumed 1 g/cm$^3$)

[3]The coefficient of determination, $r^2$, is a function of the *Pearson's r,* which is a measure of the linear dependence (correlation) between two variables. *Pearson's r* can be positive or negative, and is a value between -1 and +1. The more common usage of the correlation coefficient is to square the *Pearson's r*, $r^2$, and report that value, the coefficient of determination.

$\rho_s$ = density of sediment particle (assumed 2.65 g/cm$^3$)

Particle size distributions were determined using laser diffraction analysis in the SEI laboratory in Santa Cruz, CA. Sediment samples were screened with a 2000 µm sieve to remove large pieces of organic material, then they were dispersed in water and inserted into a Beckman Coulter LS 13 320 laser diffraction analyzer. Each sample was analyzed in three 1-minute intervals and the results of the three analyses were averaged.

Loss on ignition *(LOI)*was determined following ASTM D2974 Version C. Samples were first dried in the SEI Laboratory oven to remove moisture (following ASTM 2216-05 recommendations). Then, the samples were placed in a furnace and ignited at 440° C until the mass remained constant (typically 24 hours). The change in mass before and after indicates the fraction of combustible substances within each sub-sample, and can be used qualitatively to evaluate the organic versus inorganic fraction within each:

$$LOI = \frac{M_d - M_{d,combustion}}{M_d} \qquad [6]$$

$M_d$ = dry weight of sample
$M_{d,\ combustion}$ = dry weight of sample after combustion

The relationships used to determine sediment bulk properties are summarized in Table 2.

**Table 2. Parameters measured and computed during the Sedflume analysis.**

| Measurement | Definition | Units | Detection Limit | Internal Consistency |
|---|---|---|---|---|
| Water Content | $W = \frac{M_w - M_d}{M_w}$ | unit-less | 0.001 g in sample weight ranging from 1 to 50 g | 0 < W < 1 |
| Wet Bulk Density | $\rho_b = \frac{\rho_w \rho_s}{\rho_w + (\rho_s - \rho_w)W}$ | g/cm$^3$ | Same as water content | $\rho_w < \rho_b < 2.6\rho_w$ |
| Particle Size Distribution Below 2000 µm | Distribution of particle sizes by volume percentage using laser diffraction | µm | Method Specific | 1µm<Grain Size<2000µm |
| Loss on Ignition | $LOI = \frac{M_d - M_{d,combustion}}{M_d}$ | unit-less | Same as water content | Wet and dry mass of sample |

*$W_d$ = dry weight of sample*
*Mw = wet weight of sample*
*Md, combustion = dry weight of sample after combustion*

$\rho_w$ = *density of water (assumed 1 g/cm$^3$)*
$\rho_s$ = *density of sediment particle (assumed 2.65 g/cm$^3$)*

### 1.3.5 Intra-core and Inter-core Comparisons

A potentially useful method of comparing sediment characteristics at a specific site is to compute *intra*-core and *inter*-core erosion rates. This method provides a means to quantify the erosion rates within each core (intra-core) as well as the general erosion rates of the cores at the site (inter-core).

**Intra-core Erosion Rate Ratios**

Once the power law regression *A* and *n* coefficients for each depth interval within an individual core were known, the *interval-average* erosion rate for the core was determined using Equation 3 and the logarithmic average of the range of shear stresses tested in the Sedflume analysis[4]. C*ore-average* erosion rates were then computed by:

1) Log-averaging the *A* coefficient values from each depth interval within a core to arrive at an average *A* coefficient for the entire core.
2) Arithmetically averaging the *n* coefficient values from each depth interval within a core to arrive at an average *n* coefficient for the entire core.
3) Solving for the *core-average* erosion rate following Equation 3 and using the log-average of the range of shear stresses applied to the depth interval (1.13 Pa).

An intra-core erosion rate *ratio* was then defined by dividing the *interval-average* erosion rate by the *core-average* erosion rate, providing a quantitative estimation of the relative erosion susceptibility of each depth interval. This method highlights the core intervals that are more or less susceptible to erosion within a particular core, and may indicate layering within a core. Intervals for which the coefficient of determination of the power law regression fit, $r^2$, was less than 0.80 were omitted from the comparison and the corresponding bar plots and tables.

**Inter-core Erosion Rate Ratios**

Two additional ratios were computed to evaluate large-scale spatial erosion susceptibility. An inter-core erosion rate ratio was computed by comparing the individual *core-average* erosion rate with a *site-wideaverage* erosion rate. The *site-wide average* erosion rate was computed by:

1) Log-averaging the *core-averageA* coefficient values from each core to arrive at an average *A* coefficient for the entire site.
2) Arithmetically averaging the *core-averagen* coefficient values in each core to arrive at an average *n* coefficient for the entire site.

[4]The shear stress values averaged were: 0.1, 0.2, 0.4, 0.8, 1.6, 3.2, 6.4 and 12.8 Pa. The logarithmic average of these, used to compute erosion rate ratios, was 1.13 Pa.

3) Solving for the *site-wide average* erosion rate following Equation 3 and using the log-average of the range of shear stresses (1.13 Pa).

The *inter-core* erosion rate ratio computed in this manner provided a qualitative estimate of the erosion susceptibility of each core (as a whole) relative to other cores in the site, potentially indicating spatial locations that are more or less susceptible to erosion than other locations.

# Section 2
# Results

This section of the report contains both qualitative and quantitative findings from the Sedflume analysis. Results will be presented on a core-by-core basis. Although median particle size data are presented here, Appendix A contains additional grain size statistics and distribution plots.

## 2.1 SF01

Core SF01 was collected in 5.8 m of water. Stringy organic material was present in the first 5 cm of the core. A layer of gray and tan sand 0.5 to 2.0 cm thick was present at the core's surface. The remainder of the core was a homogenous, dark gray sediment uniform in color and texture.

A photograph of core SF01 aligned vertically with the corresponding erosion rate is presented in Figure 4. An erosion rate of $10^{-5}$ cm/s is considered incapable of mobilizing sediment (this hold in all erosion rate plots). The sediment surface (depth= 0) is plotted at the top of all graphs with depth into the sediments increasing down the Y-axis. Shear stresses ranging between 0.1 Pa and 6.4 Pa were applied to the core. Vertical profiles of bulk density and median particle size ($d_{50}$) are presented in Figure 5. An average critical shear stress of 0.38 Pa was determined for the entire core.

Erosion rates decreased slightly within the core to a depth of 13.3 cm, and then increased for the final interval. Intra-core erosion rate ratios of tested intervals in SF01 are shown in Figure 6. The numbers plotted on the y-axis of all erosion rate plots represent interval (shear stress cycles) starting depths. The vertical dashed line denotes an erosion rate ratio of 1.0. Ratios to the right of the dashed line indicate intervals that were more susceptible to erosion than ratios to the left, relative to the vertically averaged erosion rate of the entire core. No Intra-Core erosion rate ratio is presented for the third interval because the interval had an $r^2$ value less than 0.8, as shown in Table 3. Bulk densities, medium particle sizes, organic fractions, and relevant shear stress values ($\tau_{power}$, $\tau_{no}$, $\tau_{first}$, and $\tau_{crit}$,) are presented in Table 4, and power law fit parameters are presented in Table 3.

The average median particle size in SF01 was 9.41 µm. The Wentworth Size Classification (Wentworth Size Classification was used in all grain size determination) classifies this sediment as fine silt. Bulk densities ranged from 1.22 g/cm$^3$ at the surface to 1.31 g/cm$^3$ at the bottom of the core. The average bulk density was 1.28 g/cm$^3$. Core SF01 had an average *LOI* of 0.1. Loss on Ignition represents the amount of organic material within the core.

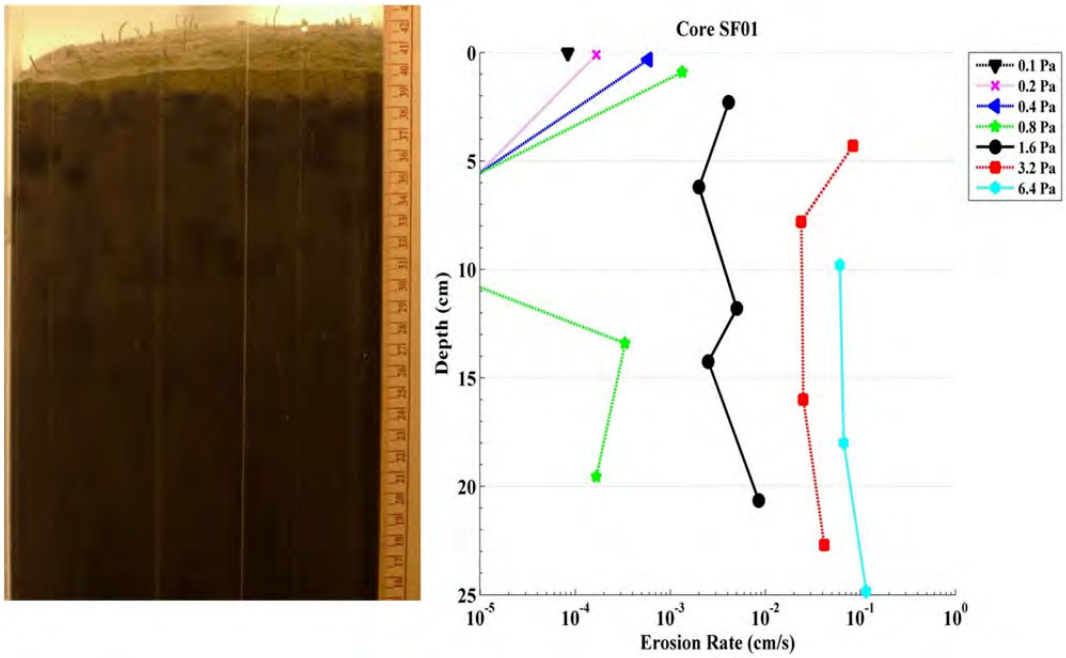


**Figure 4. Photo of core SF01 aligned vertically with the corresponding erosion rates.**

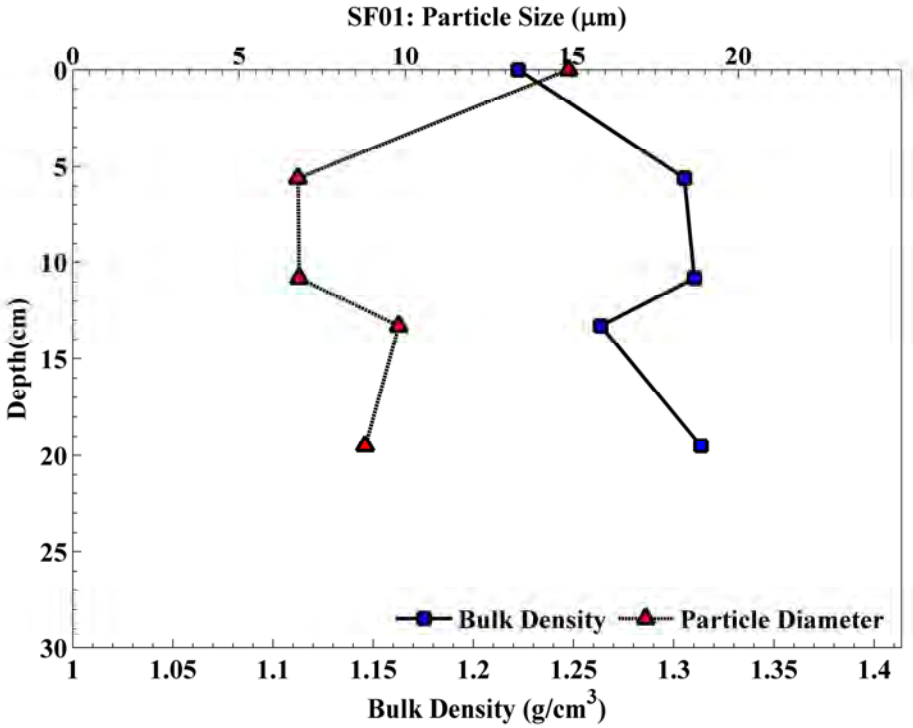


**Figure 5. Bulk density and median particle size ($d_{50}$) with depth for core SF01.**

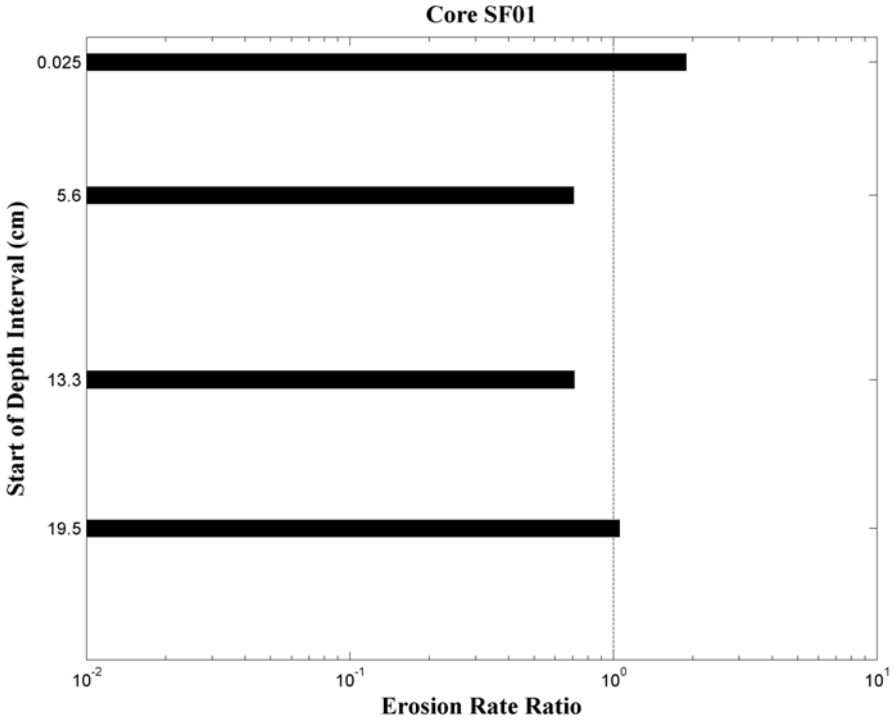


**Figure 6. Intra-core erosion rate ratios for core SF01. The dashed line indicts conditions for the core's average erosion rate (i.e., erosion rate ratio equals 1).**

**Table 3.Power law best-fit variables for specified depth intervals in core SF01.**

| Interval | Depth Start (cm) | Depth Finish (cm) | A | N | $r^2$ |
|---|---|---|---|---|---|
| 1 | 0.00 | 4.30 | 0.00358 | 1.90 | 0.93 |
| 2 | 5.60 | 9.80 | 0.00081 | 2.50 | 0.94 |
| 3 | 10.8 | 11.8 | NA | NA | 0.50 |
| 4 | 13.3 | 18.0 | 0.00072 | 2.60 | 0.98 |
| 5 | 19.5 | 24.9 | 0.00075 | 3.10 | 0.91 |

**Table 4. Median particle size, bulk density, loss on ignition, and critical shear stress with depth for core SF01.**

| Depth (cm) | $d_{50}$ (μm) | $\rho_b$(g/cm$^3$) | *LOI* | Power Law $\tau_{cr}$ (Pa) | $\tau_{no}$ (Pa) | $\tau_{first}$ (Pa) | $\tau_{crit}$ (Pa) |
|---|---|---|---|---|---|---|---|
| 0.00 | 14.9 | 1.22 | 0.11 | 0.15 | NA | 0.10 | 0.10 |
| 5.60 | 6.77 | 1.31 | 0.09 | 0.43 | 0.80 | 1.60 | 0.80 |
| 10.8 | 6.80 | 1.31 | 0.10 | NA | 0.80 | 1.60 | 0.80 |
| 13.3 | 9.80 | 1.26 | 0.09 | 0.47 | 0.40 | 0.80 | 0.47 |
| 19.5 | 8.79 | 1.31 | 0.10 | 0.52 | 0.40 | 0.80 | 0.52 |
| **Mean** | **9.41** | **1.28** | **0.1** | **0.39** | **0.60** | **0.98** | **0.38** |

## 2.2 SF02

Core SF02 was collected in 5.8 m of water. The surface of the core was covered by approximately 10% organic and detritus material. A 1 cm very fine gray, brown sediment layer extended from the surface. A 0.5 cm layer of fine gray material was found below the surface layer, extending to depth of roughly 1.0 to 1.5 cm. The remaining 30 cm was comprised of a homogenous black or dark grey material. Worm tubes were present over roughly the first 10 cm of the core.

A photograph of core SF02 aligned vertically with the corresponding erosion rate data is presented in Figure 7. A total of five intervals were tested, where shear stresses from 0.1 Pa to 3.2 Pa were applied. Erosion rates decreased over the top to the middle of the core, and then increased from the middle to the bottom of the core. Values of Intra-core erosion rates were not plotted in Figure 9 for intervals 2 and 4 because they both had an $r^2$ value less than 0.8. An average critical shear stress of 0.38 Pa was determined for Core SF02.

Median grain sizes were in the medium silt range, averaging to 21 µm. Bulk densities ranged from 1.22 g/cm$^3$ near the surface to 1.32 g/cm$^3$ towards the bottom of the core (Figure 8and Table 6). The average bulk density was 1.27 g/cm$^3$, and the average *LOI* was 0.13.

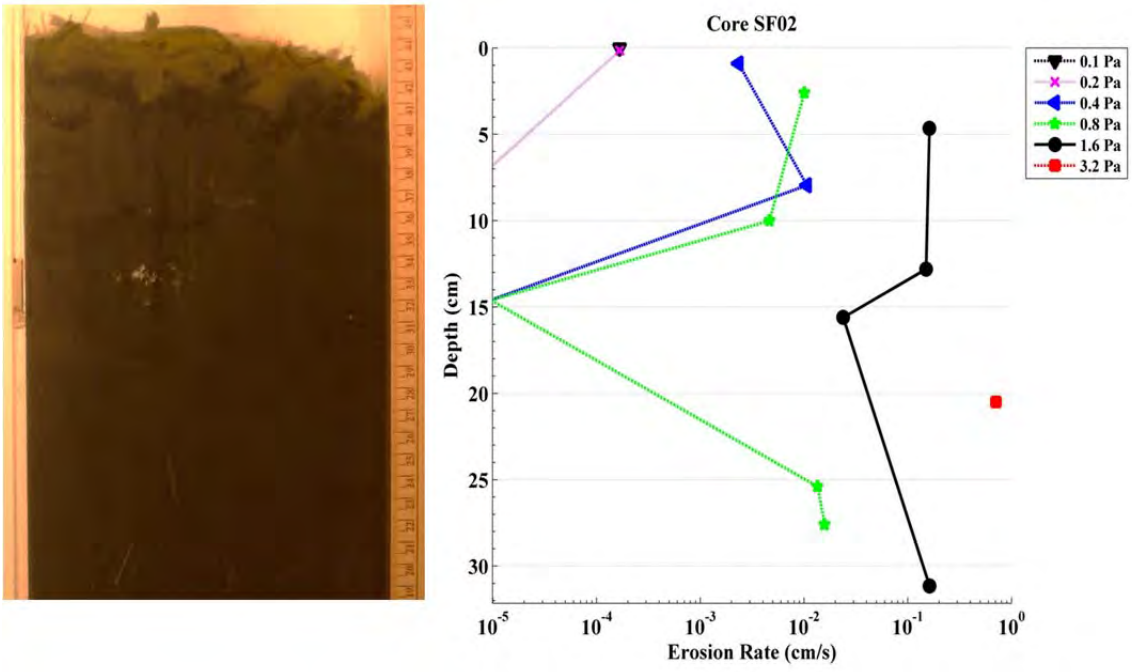


**Figure 7.Photo of core SF02 aligned vertically with the corresponding erosion rates.**

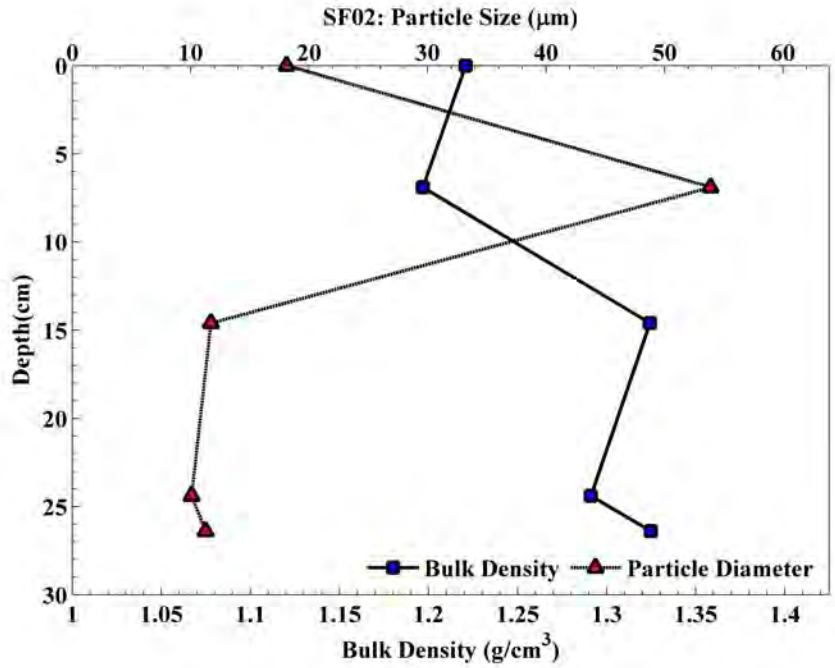


**Figure 8**. **Bulk density and median particle size ($d_{50}$) with depth for core SF02.**

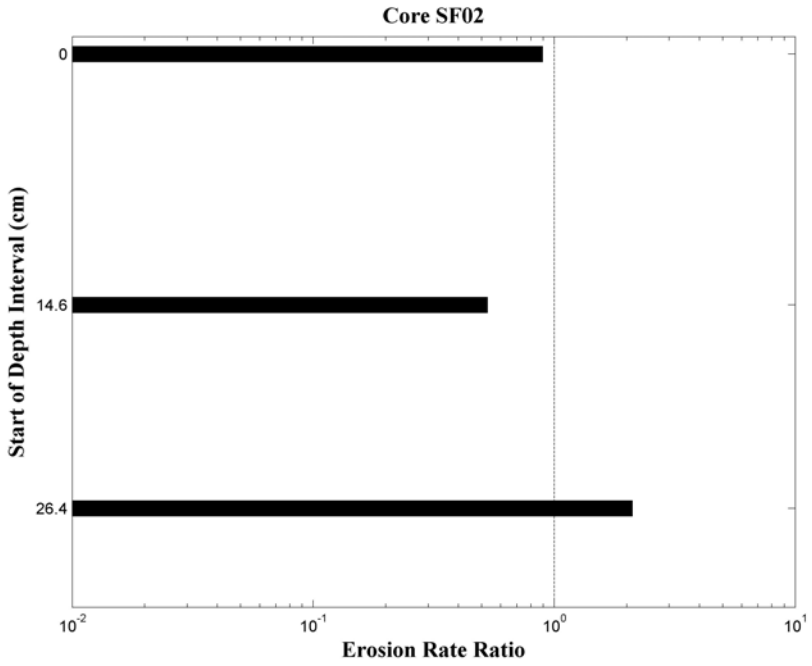


**Figure 9**. **Intra-core erosion rate ratios for core SF02. The dashed line indicates conditions for the core's average erosion rate (i.e., erosion rate ratio equals 1).**

**Table 5. Power law best-fit variables for specified depth intervals in core SF02.**

| Interval | Depth Start (cm) | Depth Finish (cm) | A | n | $r^2$ |
|---|---|---|---|---|---|
| 1 | 0.00 | 4.60 | 0.02688 | 2.60 | 0.94 |
| 2 | 6.90 | 12.8 | NA | NA | 0.53 |
| 3 | 14.6 | 20.5 | 0.00238 | 4.90 | 1.00 |
| 4 | 24.4 | 25.4 | NA | NA | 0.50 |
| 5 | 26.4 | 31.2 | 0.03342 | 3.40 | 1.00 |

**Table 6. Median particle size, bulk density, loss on ignition, and critical shear stress with depth for core SF02.**

| Depth (cm) | $d_{50}$ (µm) | $\rho_b$(g/cm$^3$) | *LOI* | Power Law $\tau_{cr}$ (Pa) | $\tau_{no}$ (Pa) | $\tau_{first}$ (Pa) | $\tau_{crit}$ (Pa) |
|---|---|---|---|---|---|---|---|
| 0.00 | 18.1 | 1.22 | 0.15 | 0.11 | NA | 0.01 | 0.10 |
| 6.90 | 53.9 | 1.20 | 0.18 | NA | 0.20 | 0.40 | 0.20 |
| 14.6 | 11.7 | 1.32 | 0.12 | 0.52 | 0.80 | 1.60 | 0.80 |
| 24.4 | 10.1 | 1.29 | 0.15 | NA | 0.40 | 0.80 | 0.40 |
| 26.4 | 11.3 | 1.32 | 0.1 | 0.18 | 0.40 | 0.80 | 0.40 |
| **Mean** | **21.0** | **1.27** | **0.13** | **0.27** | **0.45** | **0.74** | **0.38** |

## 2.3 SF03

Core SF03 was collected in 7.62 m of water. The top 5 cm of the core was mottled with gray and tan colored sediment containing bioturbation tunnels. Several faunal and algal growths were found at the surface, including 10 to 15 vertical stalks that were 1 to 2 cm in height. Detritus and black clumpy sediment extended from the surface to a depth of 1 cm. At 2 cm was black and gray mottled sediment with evidence of bioturbation, including detritus and small aggregations undulating from the horizon to the base. The remainder of the core was dark gray with several black striations.

A photograph of core SF03 aligned vertically with the corresponding erosion rate data is presented in Figure 10. Shear stresses ranging between 0.1 Pa and 10.0 Pa were applied to the core. Erosion rates fluctuated with depth; no apparent depth trends can be deduced from the erosion rate data (Figure 12). Sediment frequently mobilized in chunks while processing core SF03. The core's average critical shear stress was 0.57 Pa.

The median grain size generally consisted of fine silt, averaging to 6.56 µm. Bulk densities increased from 1.29 g/cm$^3$ at the surface to 1.53 g/cm$^3$ at a depth of 14.0 cm, and then decreased to 1.34 g/cm$^3$ at a depth of 28.5 cm (Figure 11 and Table 8). The average bulk density was 1.39 g/cm$^3$. The average Loss on Ignition (*LOI)* was 0.1.

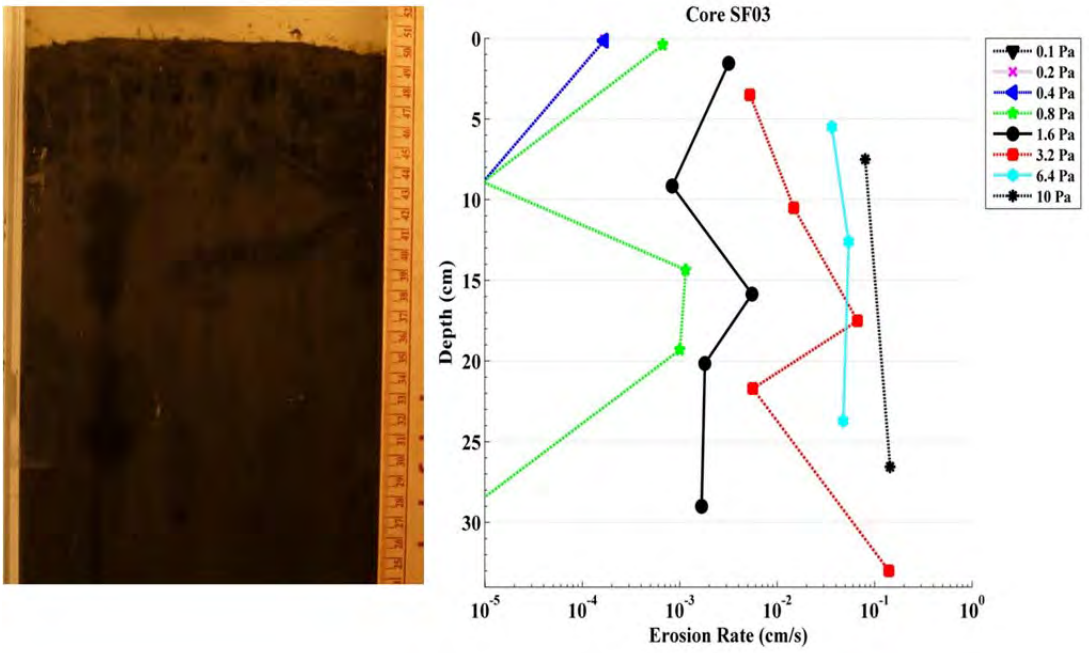


**Figure 10. Photo of core SF03 aligned vertically with the corresponding erosion rates.**

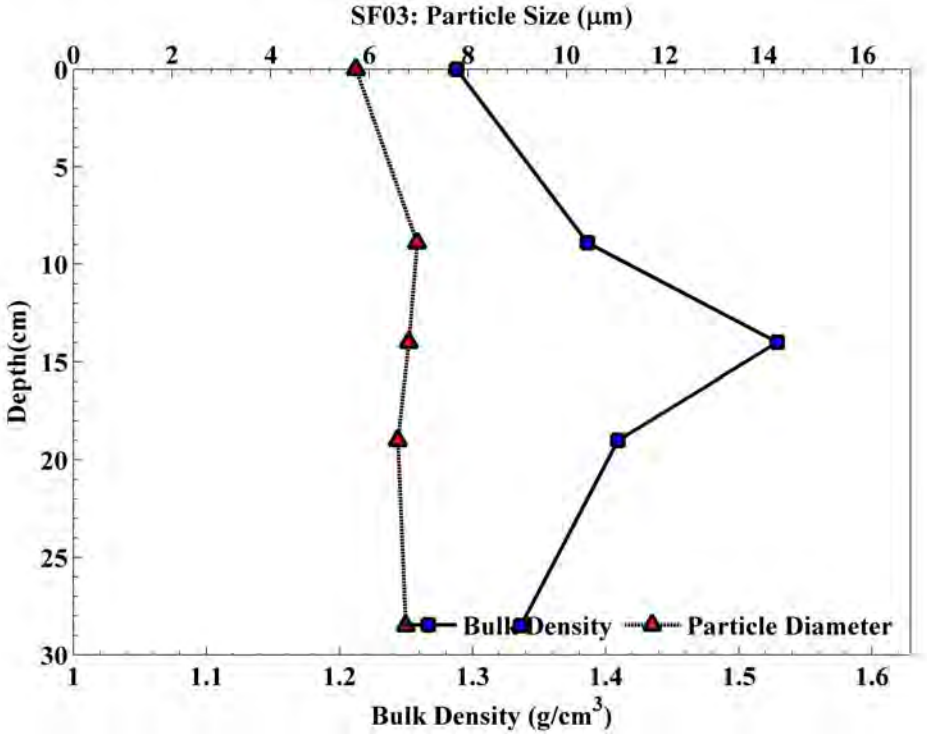


**Figure 11. Bulk density and median particle size ($d_{50}$) with depth for core SF03.**

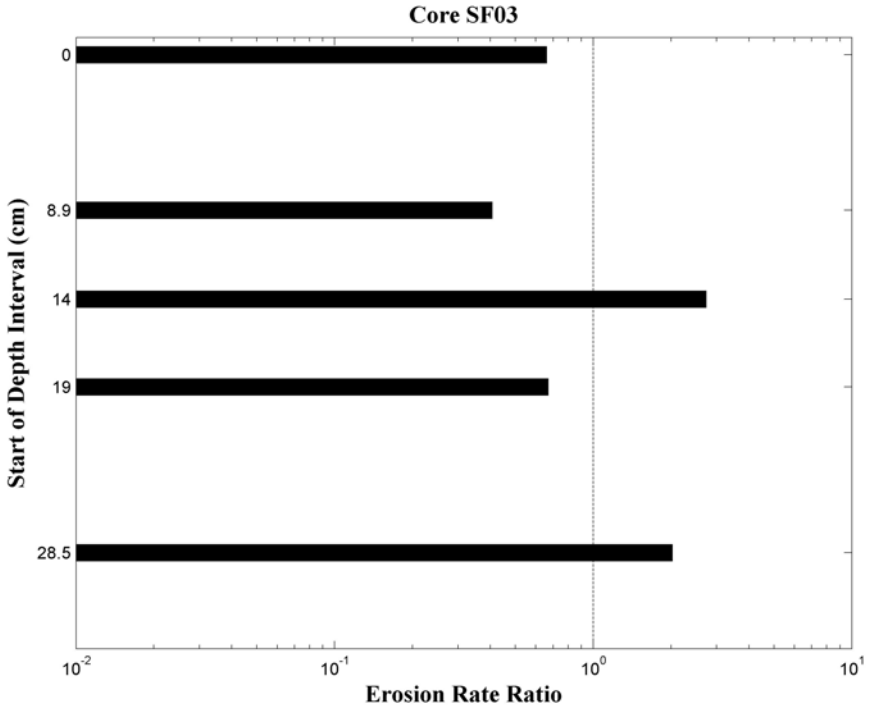


**Figure 12. Intra-core erosion rate ratios for core SF03. The dashed line indicates conditions for the core's average erosion rate (i.e., erosion rate ratio equals 1).**

**Table 7. Power law best-fit variables for specified depth intervals in core SF03.**

| Interval | Depth Start (cm) | Depth Finish (cm) | A | n | $r^2$ |
|---|---|---|---|---|---|
| 1 | 0.00 | 7.50 | 0.00127 | 1.7 | 0.97 |
| 2 | 8.90 | 12.6 | 0.00026 | 3.0 | 0.95 |
| 3 | 14.0 | 17.5 | 0.00189 | 2.9 | 0.98 |
| 4 | 19.0 | 26.6 | 0.00096 | 2.0 | 0.95 |
| 5 | 28.5 | 33.0 | 0.00008 | 6.4 | 1.00 |

**Table 8. Median particle size, bulk density, loss on ignition, and critical shear stress with depth for core SF03.**

| Depth (cm) | $d_{50}$ (µm) | $\rho_b$(g/cm$^3$) | *LOI* | Power Law $\tau_{cr}$ (Pa) | $\tau_{no}$ (Pa) | $\tau_{first}$ (Pa) | $\tau_{crit}$ (Pa) |
|---|---|---|---|---|---|---|---|
| 0.00 | 5.73 | 1.29 | 0.24 | 0.22 | 0.10 | 0.20 | 0.20 |
| 8.9 | 6.97 | 1.39 | 0.07 | 0.72 | 0.80 | 1.60 | 0.80 |
| 14.0 | 6.80 | 1.53 | 0.05 | 0.37 | 0.40 | 0.80 | 0.40 |
| 19.0 | 6.58 | 1.41 | 0.07 | 0.33 | 0.40 | 0.80 | 0.40 |
| 28.5 | 6.74 | 1.34 | 0.08 | 1.03 | 0.80 | 1.60 | 1.03 |
| **Mean** | **6.56** | **1.39** | **0.1** | **0.53** | **0.50** | **1.00** | **0.57** |

## 2.4 SF04

Core SF04 was collected in 6.1 m of water. The top 0.5 to 5 cm of the core was gray and tan in color. The top 1 cm of the core contained a light brown colored layer of very fine and somewhat clay-like material with vertically oriented detrital vegetation. The next 5 to 8 cm of the core was mottled gray and black sediment with a void at a depth of roughly 8 cm. Below this layer was a 5 to 10 cm horizon of thoroughly mixed gray and black sediment grains. The remanding 20 to 30 cm of the core was dark gray and uniform in color. At depths between 10 to 25 cm, pebbles and mussels were found mixed with core sediment. A six interval was run in Core SF04 to determine where the shells stopped; no shells were present below roughly 28 cm.

A photograph of core SF04 aligned vertically with the corresponding erosion rate data is presented in Figure 13. Shear stresses ranging between 0.1 Pa and 6.4 Pa were applied to the core. Erosion was dominated by the mobilization of large clumps of sediment. When shells and pebbles were present, they held sediment in place until the applied shear stress exceeded roughly 1 Pa. At this point, the pebbles and shells would mobilize and take sediment along with them. The core's average critical shear stress was 0.82 Pa. The power law regression analysis lead to $r^2$ values less than 0.8 for the last intervals, therefore no erosion rate ratios are presented for them (Figure 15).

Median particle sizes consisted of fine to medium silt, with a core average of 8.44 μm. Bulk densities increased from 1.24 g/cm$^3$ at the surface to 1.55 g/cm$^3$ at a depth of 10.8 cm, and then decreased to 1.43 g/cm$^3$ at a depth of 28.0 cm (Figure 14and Table 10). The average bulk density was 1.40 g/cm$^3$, and the core average *LOI* was 0.07.

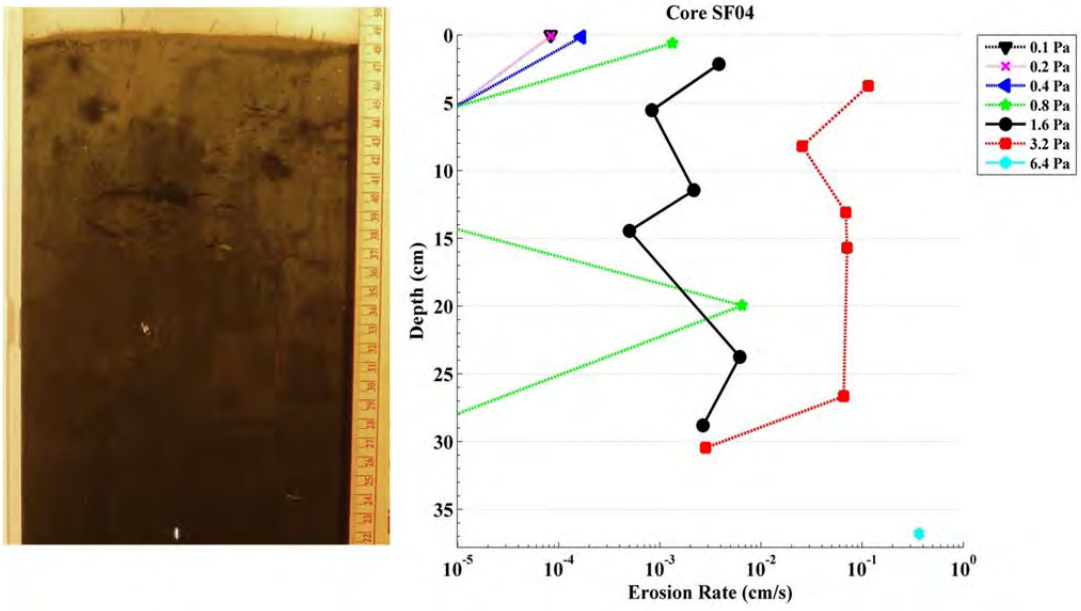


**Figure 13. Photo of core SF04 aligned vertically with the corresponding erosion rates.**

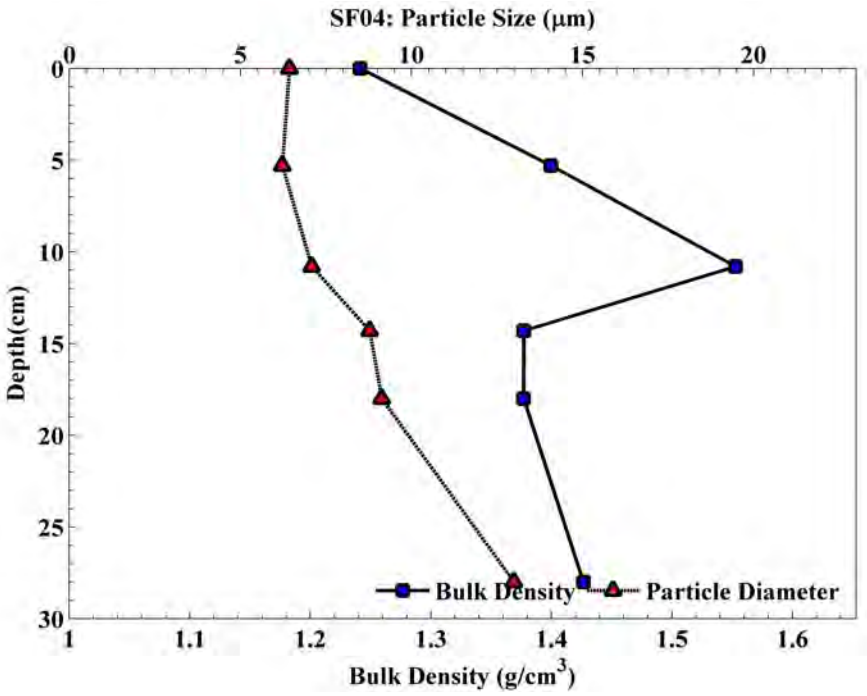


**Figure 14**. **Bulk density and median particle size ($d_{50}$) with depth for core SF04.**

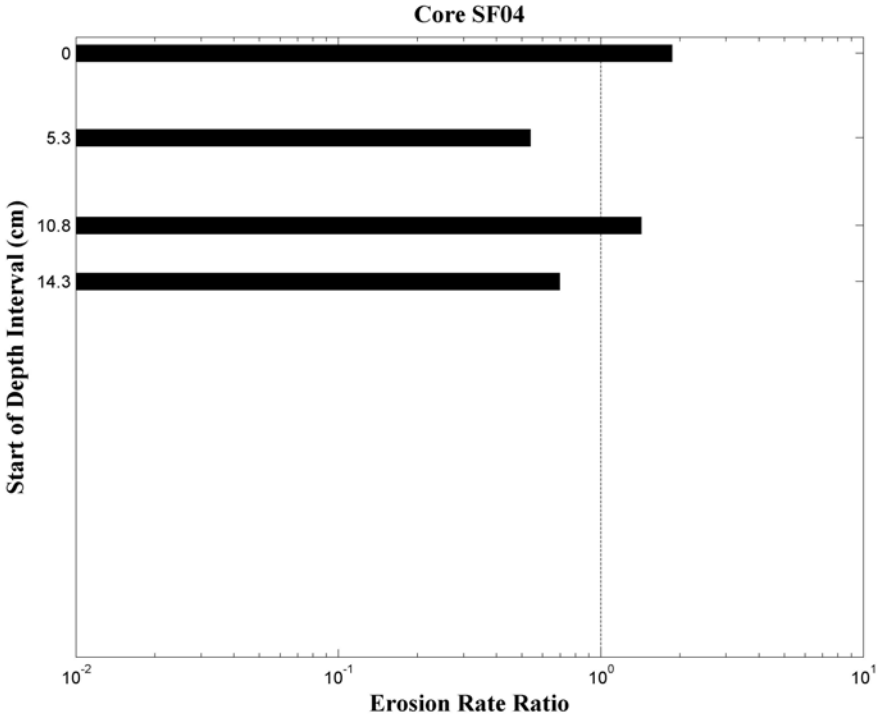


**Figure 15**. **Intra-core erosion rate ratios for core SF04. The dashed line indicates conditions for the core's average erosion rate (i.e., erosion rate ratio equals 1).**

**Table 9. Power law best-fit variables for specified depth intervals in core SF04.**

| Interval | Depth Start (cm) | Depth Finish (cm) | A | n | $r^2$ |
|---|---|---|---|---|---|
| 1 | 0.00 | 3.80 | 0.00301 | 2.00 | 0.88 |
| 2 | 5.30 | 8.20 | 0.00008 | 4.90 | 1.00 |
| 3 | 10.8 | 13.1 | 0.00021 | 5.00 | 1.00 |
| 4 | 14.3 | 15.7 | 0.00002 | 7.10 | 1.00 |
| 5 | 18.0 | 26.7 | NA | NA | 0.73 |
| 6 | 28.0 | 36.8 | NA | NA | 0.76 |

**Table 10. Median particle size, bulk density, loss on ignition, and critical shear stress with depth for core SF04.**

| Depth (cm) | $d_{50}$ (µm) | $\rho_b$(g/cm$^3$) | *LOI* | Power Law $\tau_{cr}$ (Pa) | $\tau_{no}$ (Pa) | $\tau_{first}$ (Pa) | $\tau_{crit}$ (Pa) |
|---|---|---|---|---|---|---|---|
| 0.00 | 6.43 | 1.24 | 0.08 | 0.19 | NA | 0.10 | 0.10 |
| 5.30 | 6.23 | 1.40 | 0.06 | 1.04 | 0.80 | 1.60 | 1.04 |
| 10.8 | 7.09 | 1.55 | 0.04 | 0.86 | 0.80 | 1.60 | 0.86 |
| 14.3 | 8.78 | 1.38 | 0.06 | 1.28 | 0.80 | 1.60 | 1.28 |
| 18.0 | 9.13 | 1.38 | 0.1 | NA | 0.40 | 0.80 | 0.40 |
| 28.0 | 13.0 | 1.43 | 0.6 | NA | 0.80 | 1.60 | 0.80 |
| **Mean** | **8.44** | **1.40** | **0.07** | **0.84** | **0.72** | **1.22** | **0.74** |

## 2.5 SF05

Core SF05 was collected in 7.32 m of water. The surface of the core was gray, tan, and buff mottled with black patches. Worm tubes were observed protruding from the core's surface, and a barnacle was encountered at a depth of 2 cm. The next 1 to 4 cm of the core was comprised of gray stiff sediment undulated unevenly with black spots. The remainder of the core was streaky black and gray with large 1 to 3 cm black spots. A 4x8 cm piece of steel was removed from interval two, and a large rock (4x6x8 cm) was also removed. Intervals 3 and 4 (depths between 15 and 25 cm) were found to contain rocks, gravel, and concrete.

A photograph of core SF05 is presented in Figure 16 along with its corresponding erosion rate data. Shear stresses ranging from 0.1 Pa to 6.4 Pa were applied to the core. Erosion rates generally increased with depth into the core (Figure 18 and Table 11). When applying shear stress above 0.8 Pa, sediment mobilized in large chunks. The core's average critical shear stress was 0.37 Pa.

Median particle sizes ranged from fine to nearly medium silt, with a core average of 9.58 µm. Bulk densities increased from 1.30 g/cm$^3$ at the surface to 1.88 g/cm$^3$ at a depth of 27.2 cm (Figure 17 and Table 12). The average bulk density was 1.63 g/cm$^3$. Core SF05 also had a core average *LOI* of 0.05.

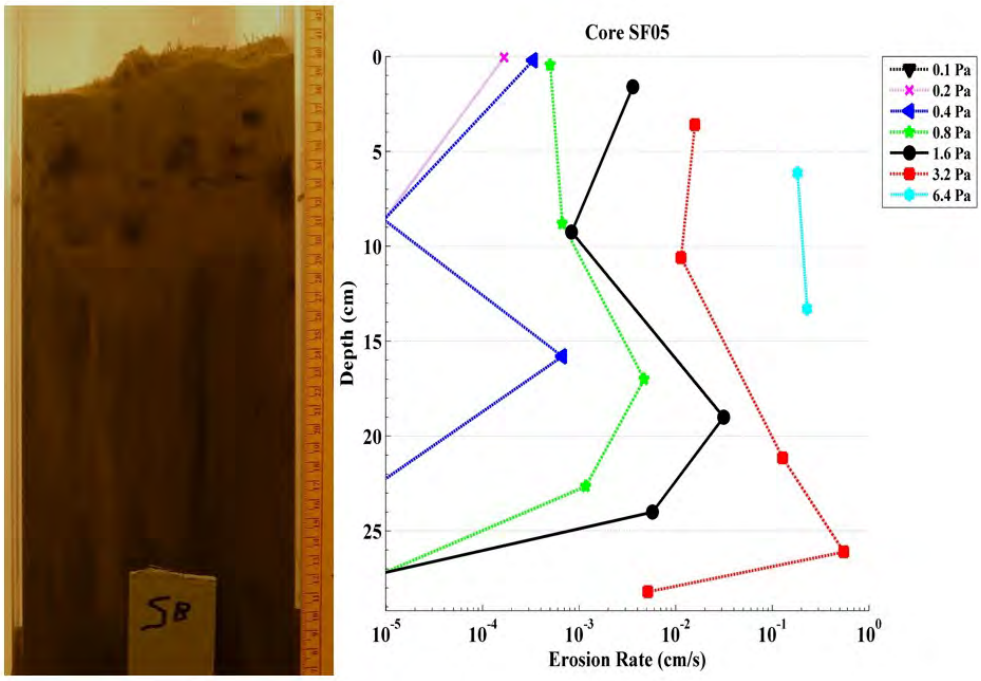

**Figure 16 Photo of core SF05 aligned vertically with the corresponding erosion rates.**

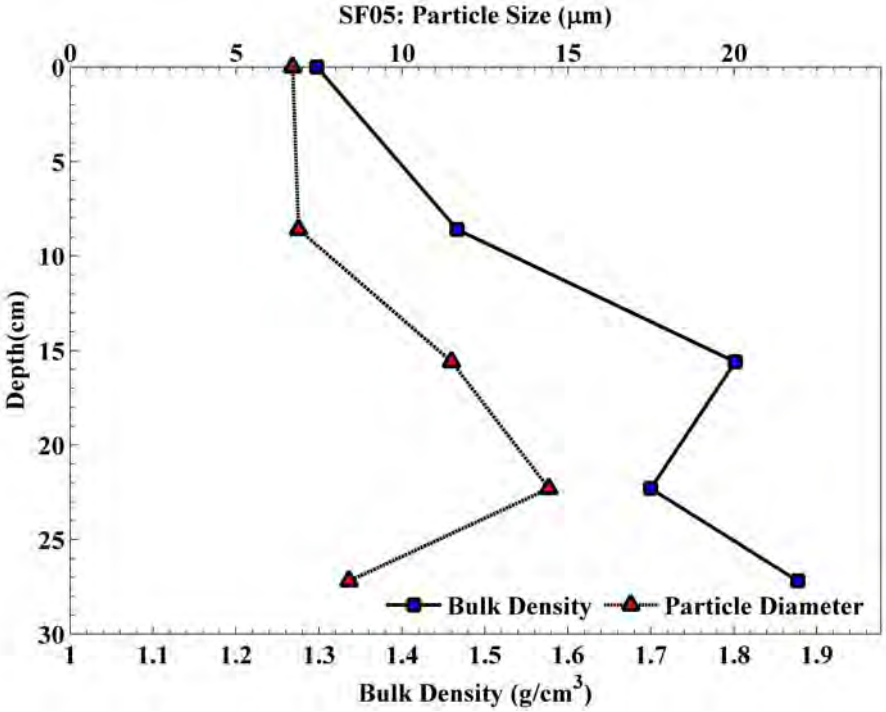


**Figure 17. Bulk density and median particle size ($d_{50}$) with depth for core SF05.**

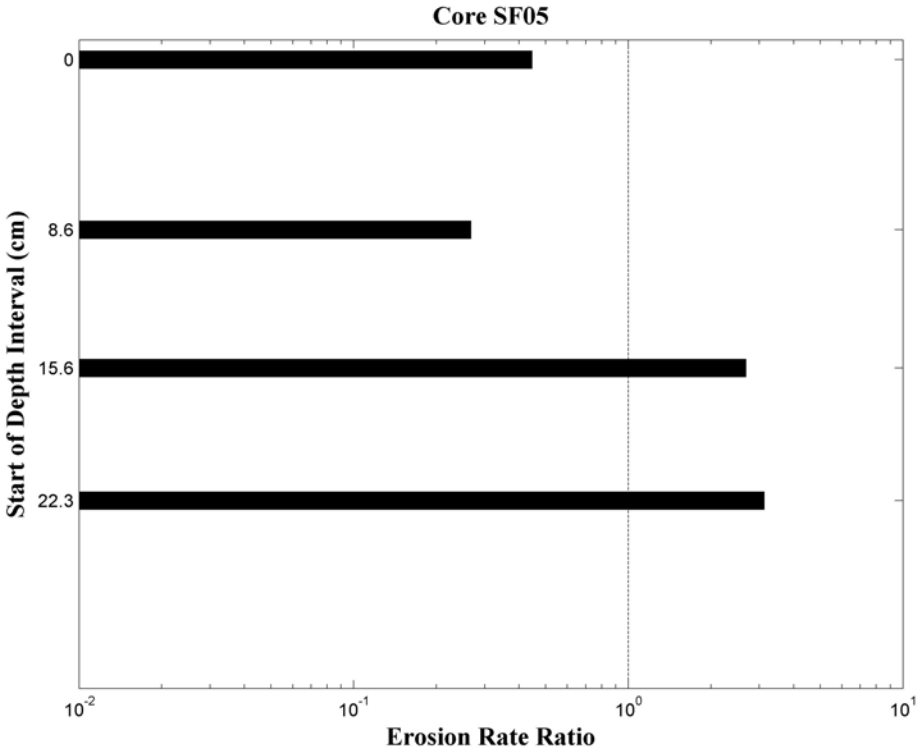

**Figure 18. Intra-core erosion rate ratios for core SF05. The dashed line indicates conditions for the core's average erosion rate (i.e., erosion rate ratio equals 1).**

**Table 11. Power law best-fit variables for specified depth intervals in core SF05.**

| Interval | Depth Start (cm) | Depth Finish (cm) | A | n | $r^2$ |
|---|---|---|---|---|---|
| 1 | 0.00 | 6.10 | 0.00201 | 2.0 | 0.94 |
| 2 | 8.60 | 13.3 | 0.00058 | 2.9 | 0.90 |
| 3 | 15.6 | 21.2 | 0.00772 | 2.5 | 0.99 |
| 4 | 22.3 | 26.1 | 0.00191 | 4.4 | 0.93 |
| 5 | 27.2 | 30.8 | NA | NA | 0.00 |

**Table 12. Median particle size, bulk density, loss on ignition, and critical shear stress with depth for core SF05.**

| Depth (cm) | $d_{50}$ (µm) | $\rho_b$(g/cm$^3$) | *LOI* | Power Law $\tau_{cr}$ (Pa) | $\tau_{no}$ (Pa) | $\tau_{first}$ (Pa) | $\tau_{crit}$ (Pa) |
|---|---|---|---|---|---|---|---|
| 0.00 | 6.70 | 1.30 | 0.07 | 0.22 | 0.10 | 0.20 | 0.20 |
| 8.60 | 6.88 | 1.47 | 0.05 | 0.55 | 0.40 | 0.80 | 0.55 |
| 15.6 | 11.5 | 1.80 | 0.02 | 0.18 | 0.20 | 0.40 | 0.20 |
| 22.3 | 14.4 | 1.70 | 0.04 | 0.51 | 0.40 | 0.80 | 0.51 |
| 27.2 | 8.40 | 1.88 | 0.04 | NA | 1.60 | 3.20 | NA |
| **Mean** | **9.58** | **1.63** | **.05** | **0.37** | **0.54** | **1.08** | **0.37** |

## 2.6 SF06

Core SF06 was collected in 7.32 m of water. The cores surface was convexed, with the sides roughly 1 cm below the center section. The core had a 3 cm surface layer that consisted of light gray, tan, and buff fine particles and sparse vertical sticks 0.5 cm to 1.5 cm in diameter. The remainder of the core was black and dark gray mottled sediment that appeared homogeneous and uniform. When begging to process the 5$^{th}$ interval, core sediment sucked into the flume. The analysis was stopped.

A photograph of core SF06 is presented in Figure 19 along with its corresponding erosion rate data. Shear stresses ranging from 0.1 Pa to 6.4 Pa were applied to the core. Though erosion rates fluctuated with depth, the sediment generally stiffened down core. This is apparent by the increase in critical shear stress with depth (Table 14). The core's average critical shear stress was 0.51 Pa. The power law regression analysis lead toan $r^2$ value less than 0.8 for the 4$^{th}$ and 5$^{th}$ interval. As a result, the erosion rate ratios for the last two intervals are not plotted in Figure 21.

Median particle sizes were generally fine silt, with a core average of 6.138 μm. Bulk densities increased from 1.19 g/cm$^3$ at the surface to 1.32 g/cm$^3$ at a depth of 21.2 cm (Figure 20 and Table 14). The average bulk density was 1.27 g/cm$^3$, and the core average *LOI* was 0.09.

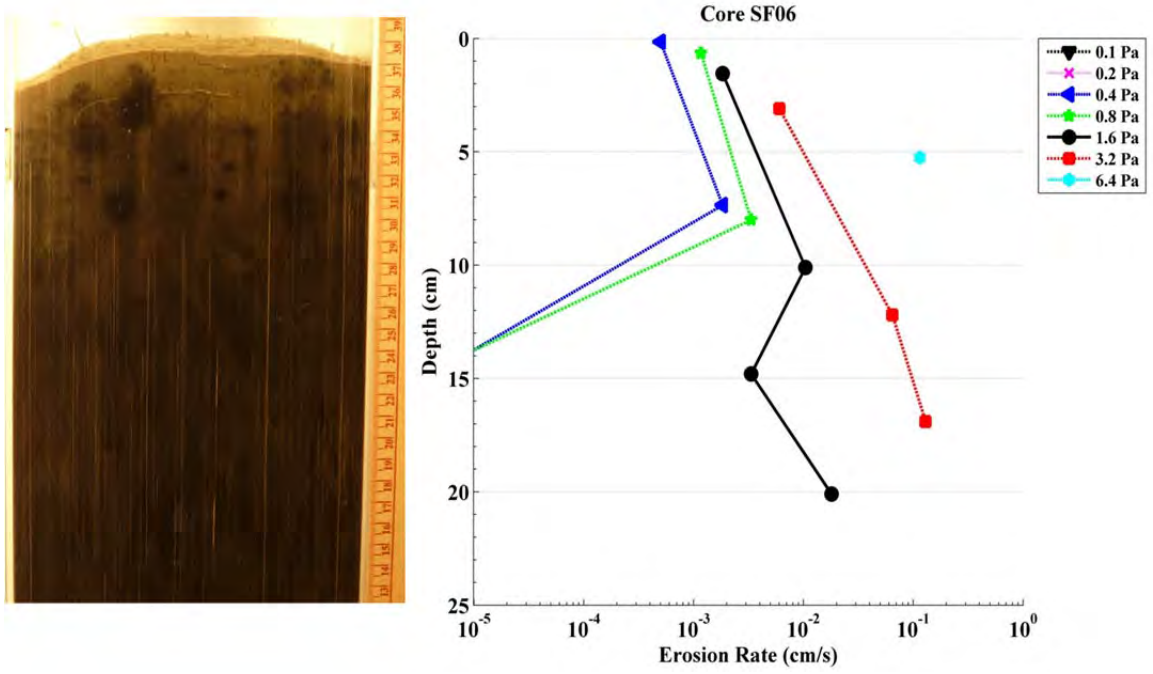


**Figure 19. Photo of core SF06 aligned vertically with the corresponding erosion rates.**

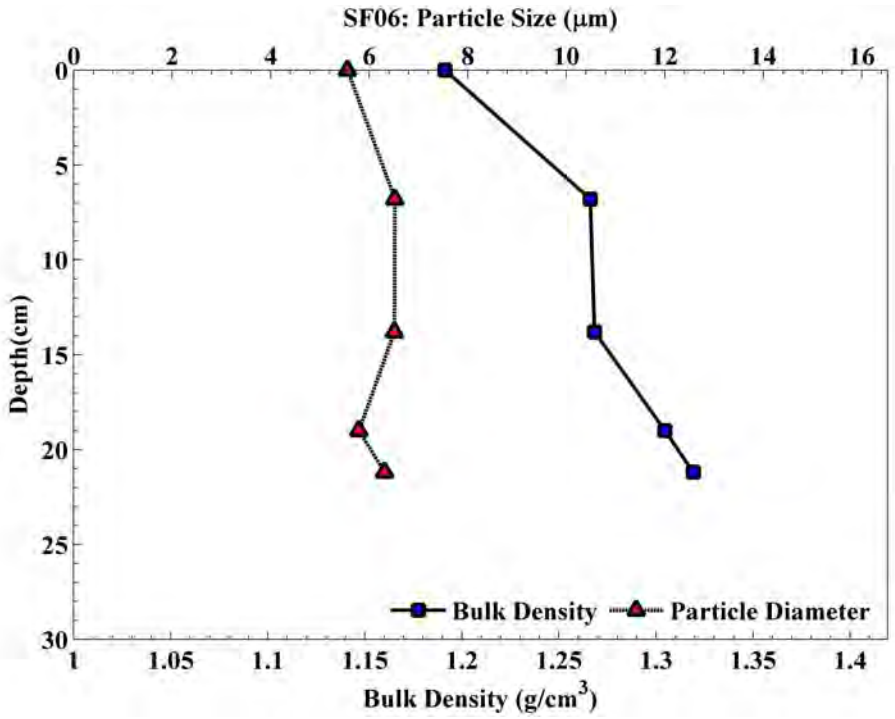


**Figure 20. Bulk density and median particle size ($d_{50}$) with depth for core SF06.**

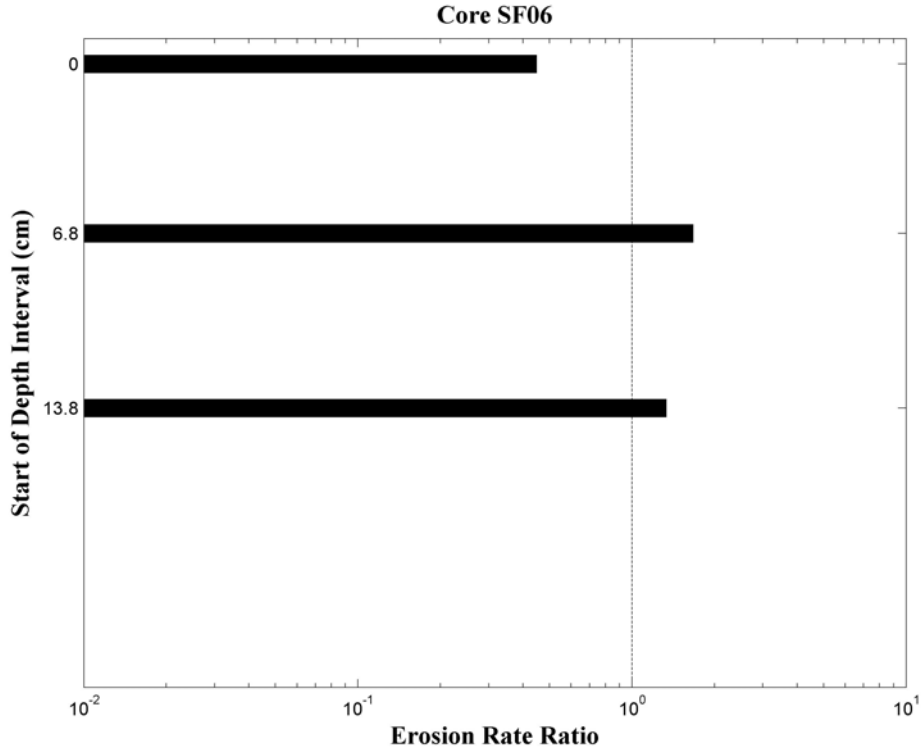


**Figure 21. Intra-core erosion rate ratios for core SF06. The dashed line indicates conditions for the core's average erosion rate (i.e., erosion rate ratio equals 1).**

**Table 13. Power law best-fit variables for specified depth intervals in core SF06.**

| Interval | Depth Start (cm) | Depth Finish (cm) | A | n | $r^2$ |
|---|---|---|---|---|---|
| 1 | 0.00 | 5.30 | 0.00161 | 1.80 | 0.88 |
| 2 | 6.80 | 12.2 | 0.00649 | 1.70 | 0.95 |
| 3 | 13.8 | 16.9 | 0.00028 | 5.30 | 1.00 |
| 4 | 19.0 | 20.1 | NA | NA | 0.50 |

**Table 14. Median particle size, bulk density, loss on ignition, and critical shear stress with depth for coreSF06.**

| Depth (cm) | $d_{50}$ (µm) | $\rho_b$(g/cm$^3$) | *LOI* | Power Law $\tau_{cr}$ (Pa) | $\tau_{no}$ (Pa) | $\tau_{first}$ (Pa) | $\tau_{crit}$ (Pa) |
|---|---|---|---|---|---|---|---|
| 0.00 | 5.56 | 1.19 | NA | 0.22 | 0.20 | 0.4 | 0.22 |
| 6.80 | 6.52 | 1.27 | 0.08 | 0.09 | 0.20 | 0.4 | 0.20 |
| 13.8 | 6.51 | 1.27 | 0.1 | 0.82 | 0.80 | 1.6 | 0.82 |
| 19.0 | 5.79 | 1.30 | 0.1 | NA | 0.80 | 1.6 | 0.80 |
| 21.2 | 6.31 | 1.32 | 0.1 | NA | NA | NA | NA |
| **Mean** | **6.138** | **1.27** | **0.09** | **0.38** | **0.50** | **1.0** | **0.51** |

## 2.7 SF07

Core SF07 was collected in 7.3 m of water. The top 2 to 4 cm of the core was a mix of black and gray sediment interspersed with organic detritus. Beneath the surface layer was a mottled layer of undulating black sediment that extended to a depth of 5 cm. The reminder of the core was gray to medium gray with black spots decreasing in frequency to the base of the core. Possible worm tubes were observed over the first 10 cm of the core (holes in sediment roughly 2 mm in diameter).

A photograph of core SF07 is presented in Figure 22 along with its corresponding erosion rate data. Shear stresses ranging from 0.1 Pa to 6.4 Pa were applied to the core. Generally, erosion rates remained constant until a depth of 10 cm, and then fluctuated with depth. Erosion was dominated by the mobilization of large chunks of sediment when applying shear stresses greater than 1.6 Pa. At the end of the fourth interval, air began to percolate though the bottom of the core. A Fifth interval was attempted, but the core sucked into the flume.The core's average critical shear stress was 0.23 Pa.

Median particle sizes ranged from fine to almost medium silt, with a core average of 6.83 µm. Bulk densities generally increased with depth, averaging to 1.29 g/cm$^3$ (Figure 23 and Table 16). Core SF07 had a core average *LOI* of 0.09.

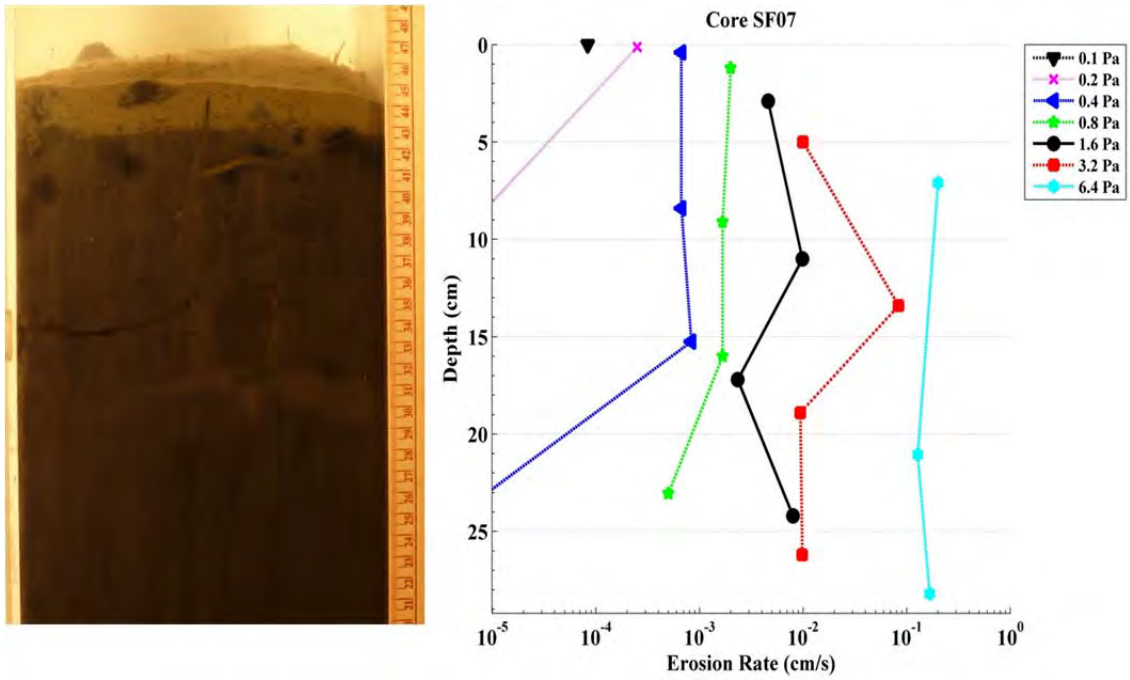


**Figure 22. Photo of core SF07 aligned vertically with the corresponding erosion rates.**

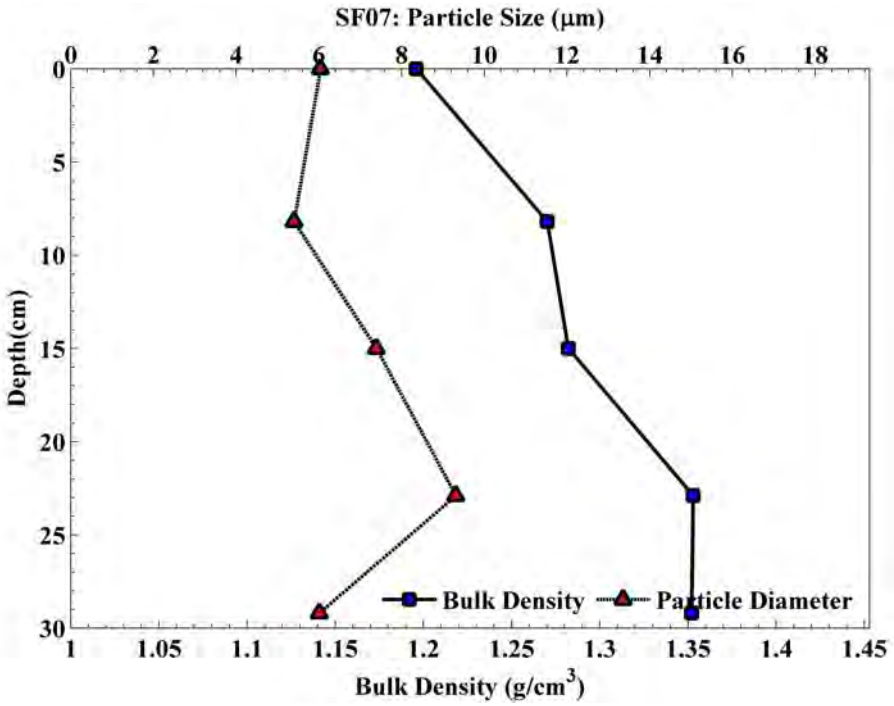


**Figure 23. Bulk density and median particle size ($d_{50}$) with depth for core SF07.**

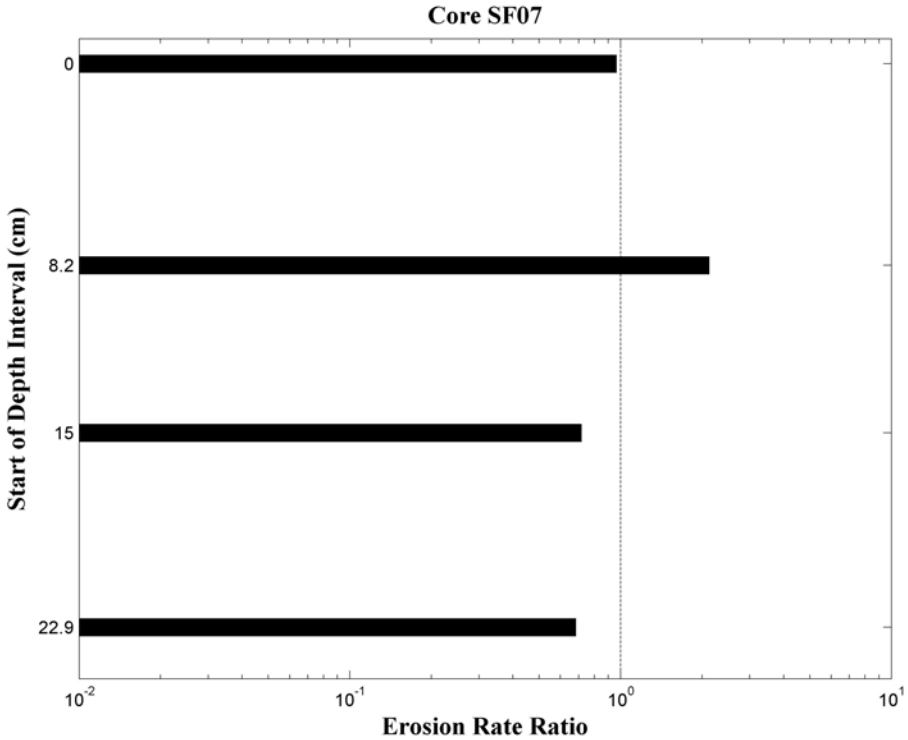


**Figure 24. Intra-core erosion rate ratios for core SF07. The dashed line indicates conditions for the core's average erosion rate (i.e., erosion rate ratio equals 1).**

**Table 15. Power law best-fit variables for specified depth intervals in coreSF07.**

| Interval | Depth Start (cm) | Depth Finish (cm) | A | n | $r^2$ |
|---|---|---|---|---|---|
| 1 | 0.00 | 7.10 | 0.00321 | 1.70 | 0.95 |
| 2 | 8.20 | 13.4 | 0.00411 | 2.30 | 0.97 |
| 3 | 15.0 | 21.1 | 0.00235 | 1.70 | 0.88 |
| 4 | 22.9 | 28.2 | 0.00112 | 2.50 | 0.92 |

**Table 16. Median particle size, bulk density, loss on ignition, and critical shear stress with depth for core SF07.**

| Depth (cm) | $d_{50}$ (µm) | $\rho_b$(g/cm$^3$) | *LOI* | Power Law $\tau_{cr}$ (Pa) | $\tau_{no}$ (Pa) | $\tau_{first}$ (Pa) | $\tau_{crit}$ (Pa) |
|---|---|---|---|---|---|---|---|
| 0.00 | 6.04 | 1.20 | 0.1 | 0.13 | NA | 0.10 | 0.10 |
| 8.20 | 5.40 | 1.27 | 0.09 | 0.21 | 0.20 | 0.40 | 0.21 |
| 15.0 | 7.39 | 1.28 | 0.08 | 0.16 | 0.20 | 0.40 | 0.20 |
| 22.9 | 9.31 | 1.35 | 0.08 | 0.39 | 0.40 | 0.80 | 0.40 |
| 29.2 | 6.01 | 1.35 | 0.08 | NA | NA | NA | NA |
| **Mean** | **6.83** | **1.29** | **0.09** | **0.22** | **0.27** | **0.43** | **0.23** |

## 2.8 SF08

Core SF08 was collected in 6.4 m of water. The core had roughly a 5 cm surface layer of light gray and tan sediment, undulating with scattered organic detritus. Sticks 1 cm in length protruded vertically from the cores surface. The top layer streaked vertically into darker sediment. Below roughly 12 cm the core sediment was black and dark gray with several void spaces seen on the cores edge, which may have been gas pockets. Large chuck erosion was prominent in later runs for each interval. A large (8x2 cm) rock was found at a depth of 8 cm. The rock was removed before processing proceeded. Because of the small size of the core, only three intervals were processed in Core SF08; water started to leak from the bottom of the core at the end of interval 3.

A photograph of core SF08 is presented in Figure 25 along with its corresponding erosion rate data. Shear stresses ranging from 0.1 Pa to 10.0 Pa were applied to the core. Erosion rates generally decreased with depth into the core. The core's average critical shear stress was 0.52 Pa.

Median particle remained in the fine silt range, with a core average of 6.92 μm. Bulk densities increased with depth from 1.28 g/cm$^3$ at the surface to 1.55 g/cm$^3$ at a depth of 12.9 cm (Figure 26 and Table 18). The average bulk density was 1.44 g/cm$^3$. Core SF08 had a core average *LOI* of 0.04.

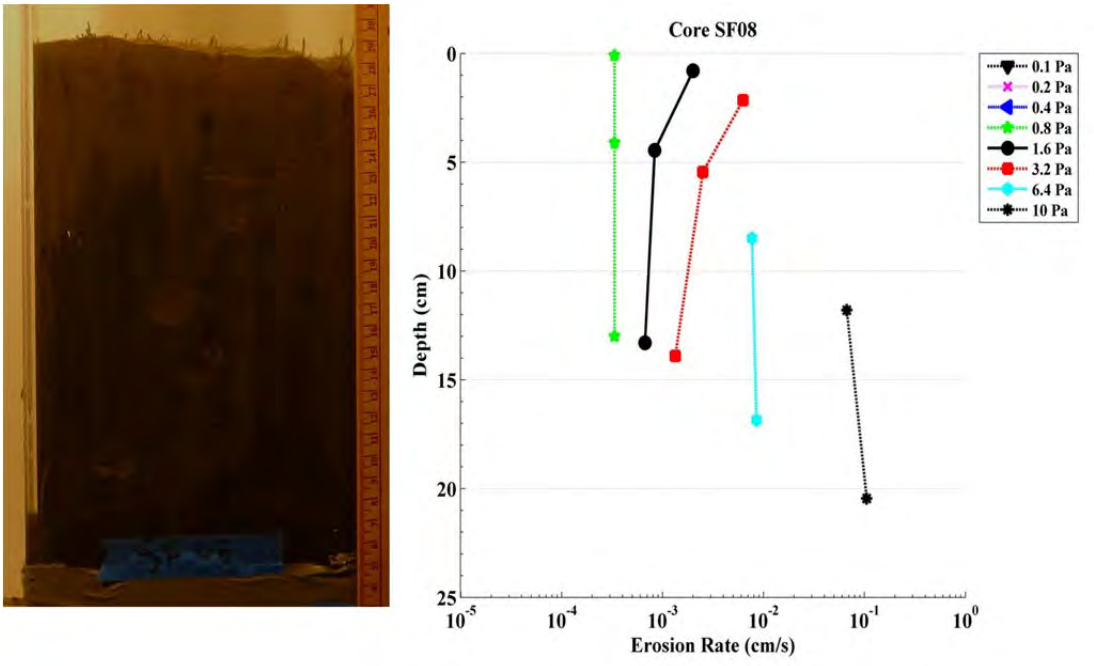


**Figure 25. Photo of core SF08 aligned vertically with the corresponding erosion rates.**

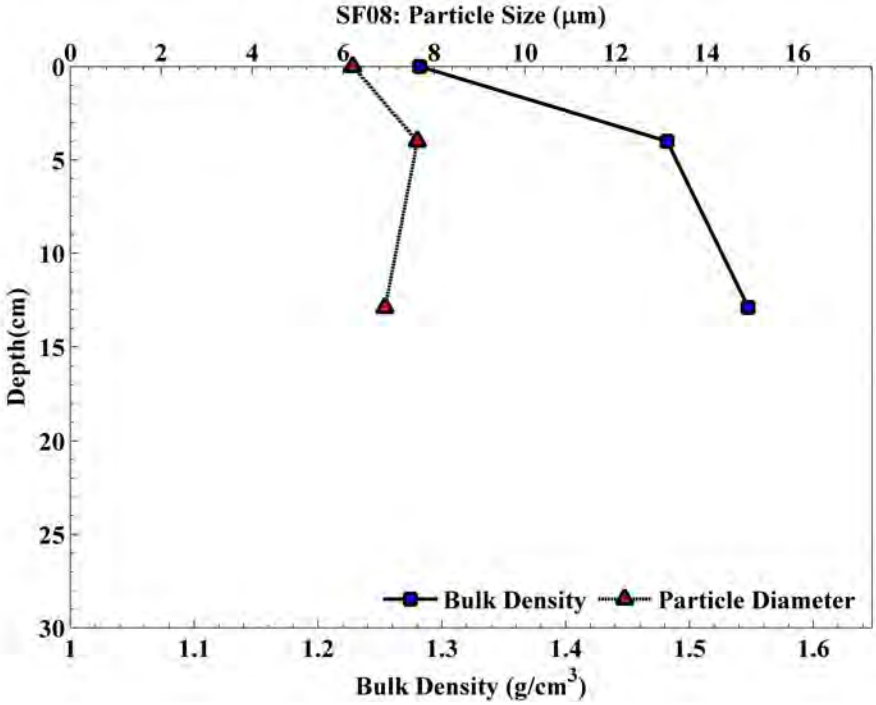


**Figure 26**. **Bulk density and median particle size ($d_{50}$) with depth for core SF08.**

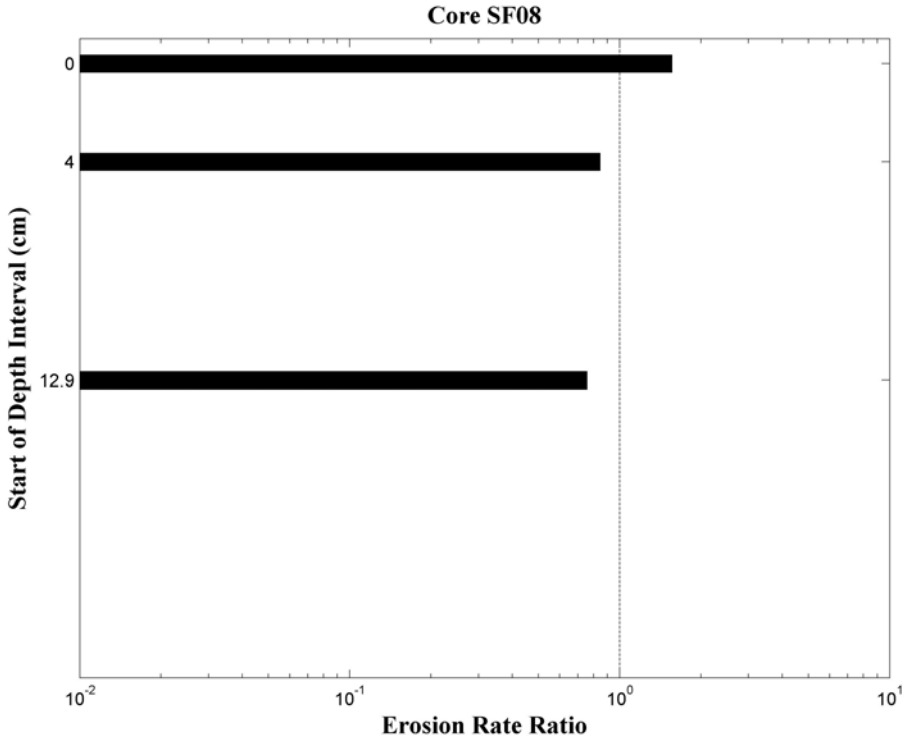


**Figure 27**. **Intra-core erosion rate ratios for core SF08. The dashed line indicates conditions for the core's average erosion rate (i.e., erosion rate ratio equals 1).**

**Table 17. Power law best-fit variables for specified depth intervals in core SF08.**

| Interval | Depth Start (cm) | Depth Finish (cm) | A | n | $r^2$ |
|---|---|---|---|---|---|
| 1 | 0.00 | 2.10 | 0.00060 | 2.1 | 0.98 |
| 2 | 4.00 | 11.8 | 0.00037 | 2.0 | 0.94 |
| 3 | 12.9 | 20.5 | 0.00029 | 2.1 | 0.88 |

**Table 18. Median particle size, bulk density, loss on ignition, and critical shear stress with depth for coreSF08.**

| Depth (cm) | $d_{50}$ (µm) | $\rho_b$(g/cm$^3$) | *LOI* | Power Law $\tau_{cr}$ (Pa) | $\tau_{no}$ (Pa) | $\tau_{first}$ (Pa) | $\tau_{crit}$ (Pa) |
|---|---|---|---|---|---|---|---|
| 0.00 | 6.21 | 1.28 | 0.07 | 0.43 | 0.40 | 0.80 | 0.43 |
| 4.00 | 7.63 | 1.48 | 0.05 | 0.51 | 0.40 | 0.80 | 0.51 |
| 12.9 | 6.92 | 1.55 | 0.05 | 0.61 | 0.40 | 0.80 | 0.61 |
| **Mean** | **6.92** | **1.44** | **0.04** | **0.52** | **0.40** | **0.80** | **0.52** |

## 2.9 SF09

Core SF09 was collected in 7.3 m of water. Six coring attempts were made at the site before extracting any sediment. The bottom was extremely hard-packed and could not be penetrated even with the additional force of a fence post hammer. Once a core was obtained, it was kept even though it had a slanted surface (makes processing difficult) and was short in length. The core's surface was sparsely populated by plant stalks and small bivalve shells. Uniform tan sediment extended from the surface to a depth of 4 cm. A medium to light gray sediment extended from 4 to 12 cm from the surface. Small black patches were interspersed throughout this section, reducing in frequency further from the surface. The remaining sediment was a heterogeneous mixture of brown sand in a clay matrix with black patches. The sandy clay mixture was extremely firm. Due to the small size of the core, only two intervals were run.

A photograph of core SF09 is presented in Figure 28 along with the corresponding erosion rate data. Shear stresses ranging from 0.1 Pa to 1.6 Pa were applied to the core. Erosion rates, for the portion of the core analyzed, decreased with depth as shown Figure 30. An average critical shear stress of 0.16 Pa was determined for the top 6 cm of the core, but the sandy clay layer likely had a much higher critical shear stress; the layer was hard packed. When processing the core, water started to leak from its bottom, so the clay layer was not tested.

The median grain size was in the very fine to fine silt range, having an average median particle size of 8.58 µm. Bulk densities increased from 1.3 g/cm$^3$ at the surface to 2.65 g/cm$^3$ at a depth of 3.9 cm (Figure 29 and Table 20). The average bulk density was 1.98 g/cm$^3$. The average Loss on Ignition (*LOI)* was 0.3.

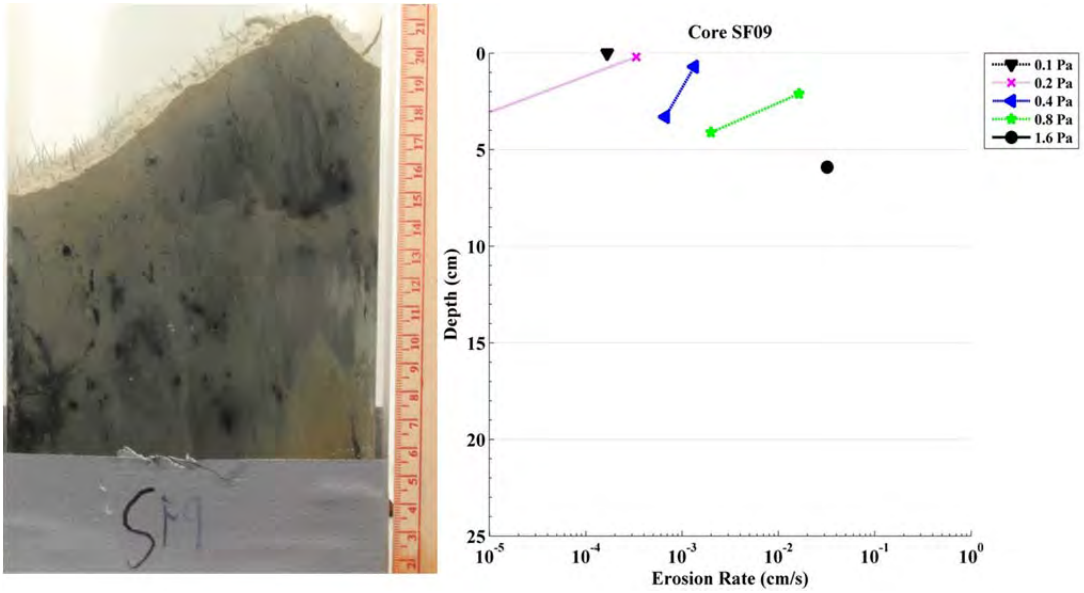


**Figure 28. Photo of core SF09 aligned vertically with the corresponding erosion rates.**

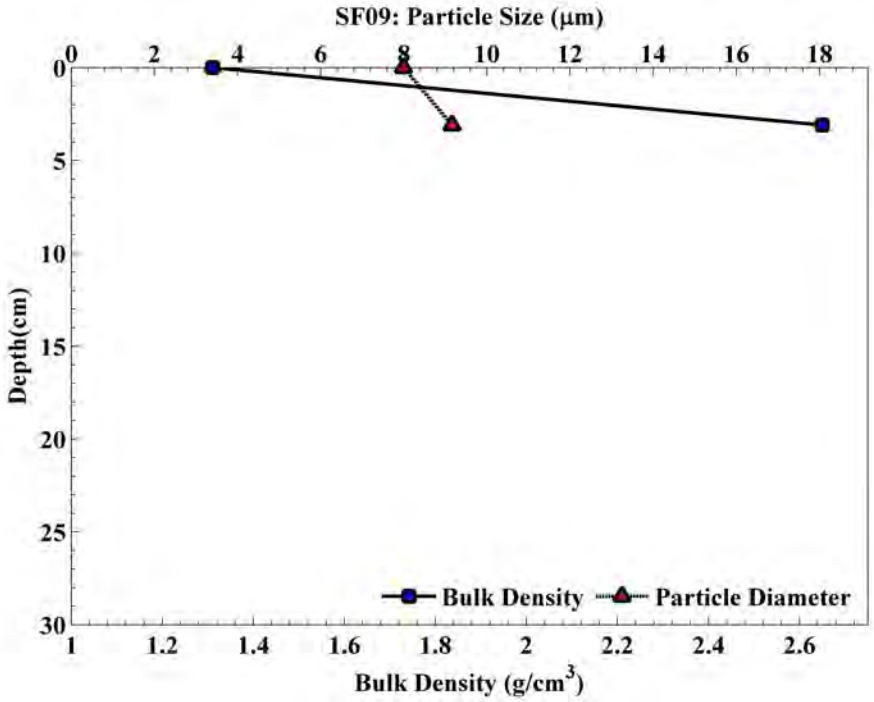


**Figure 29**. **Bulk density and median particle size ($d_{50}$) with depth for core SF09.**

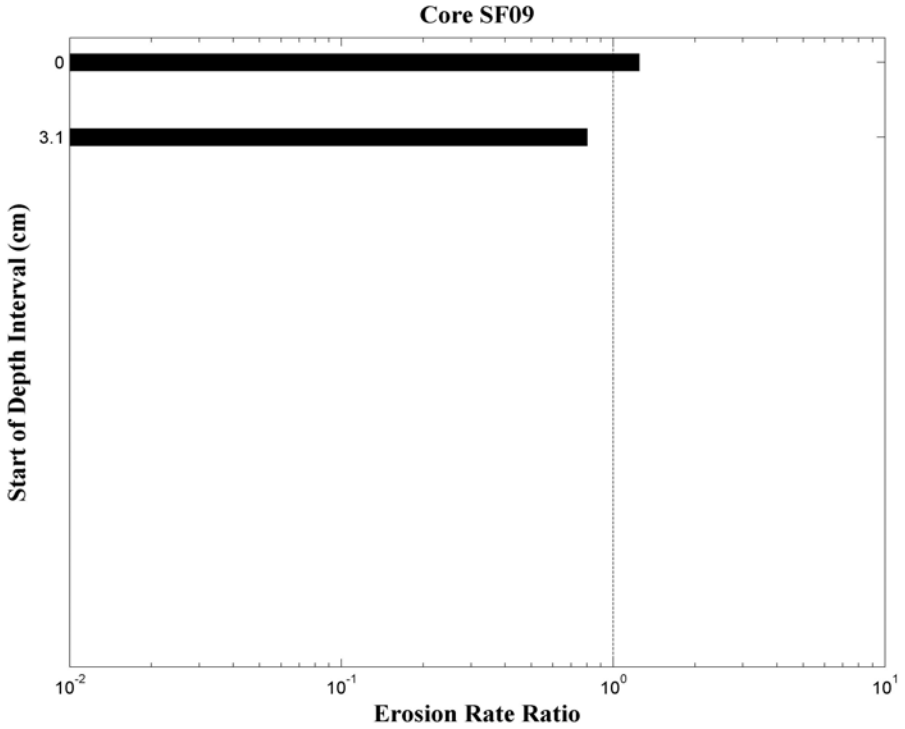


**Figure 30**. **Intra-core erosion rate ratios for core SF09. The dashed line indicates conditions for the core's average erosion rate (i.e., erosion rate ratio equals 1).**

**Table 19. Power law best-fit variables for specified depth intervals in core SF09.**

| Interval | Depth Start (cm) | Depth Finish (cm) | A | n | $r^2$ |
|---|---|---|---|---|---|
| 1 | 0 | 2.1 | 0.01660 | 2.2 | 0.93 |
| 2 | 3.1 | 5.9 | 0.00652 | 2.8 | 0.94 |

**Table 20. Median particle size, bulk density, loss on ignition, and critical shear stress with depth for core SF09.**

| Depth (cm) | $d_{50}$ (µm) | $\rho_b$(g/cm$^3$) | *LOI* | Power Law $\tau_{cr}$ (Pa) | $\tau_{no}$ (Pa) | $\tau_{first}$ (Pa) | $\tau_{crit}$ (Pa) |
|---|---|---|---|---|---|---|---|
| 0.00 | 7.99 | 1.31 | 0.06 | 0.10 | NA | 0.10 | 0.10 |
| 3.10 | 9.16 | 2.65 | 0.55 | 0.22 | 0.20 | 0.40 | 0.22 |
| **Mean** | **8.58** | **1.98** | **0.3** | **0.16** | **0.20** | **0.25** | **0.16** |

## 2.10 SF10

Core SF10 was collected in 6.1 m of water. The core had a 1 to 2 mm low density, flocculation layer. Below the surface layer was medium to dark gray fine sediment that extended roughly 1 cm into the core. Intermittent organic material and small bioturbation tracks were found in the top layer. The following 2 to 4 cm of the core was vertically streaked with medium to dark gray fine material. Black sediment patches 1 to 2 cm in diameter were interspersed within this layer. Dark gray fine material with sporadic vertical streaks of lighter gray material was found from 4 to 12 cm in depth. The remainder of the core was uniform and black in color.

A photograph of core SF10 is presented in Figure 31 along with the corresponding erosion rate data. Shear Stresses from 0.1 Pa to 6.4 Pa were applied to the core. Erosion rates were fairly constant at each applied stress greater than 0.2 Pa and less than 6.4 Pa. When applying a shear stress of 6.4 Pa, erosion rates fluctuated with depth. An average critical shear stress of 0.47 Pa was determined for the entire core.

The median particle size was in the fine silt range, with an average median particle size of 8.32 µm. Bulk densities generally increased with depth from 1.28 g/cm$^3$ at the surface to 1.39 g/cm$^3$ at a depth of 30.6 cm (Figure 32 and Table 22). The average bulk density was 1.31 g/cm$^3$. Core SF10 had an average *LOI* of 0.08.

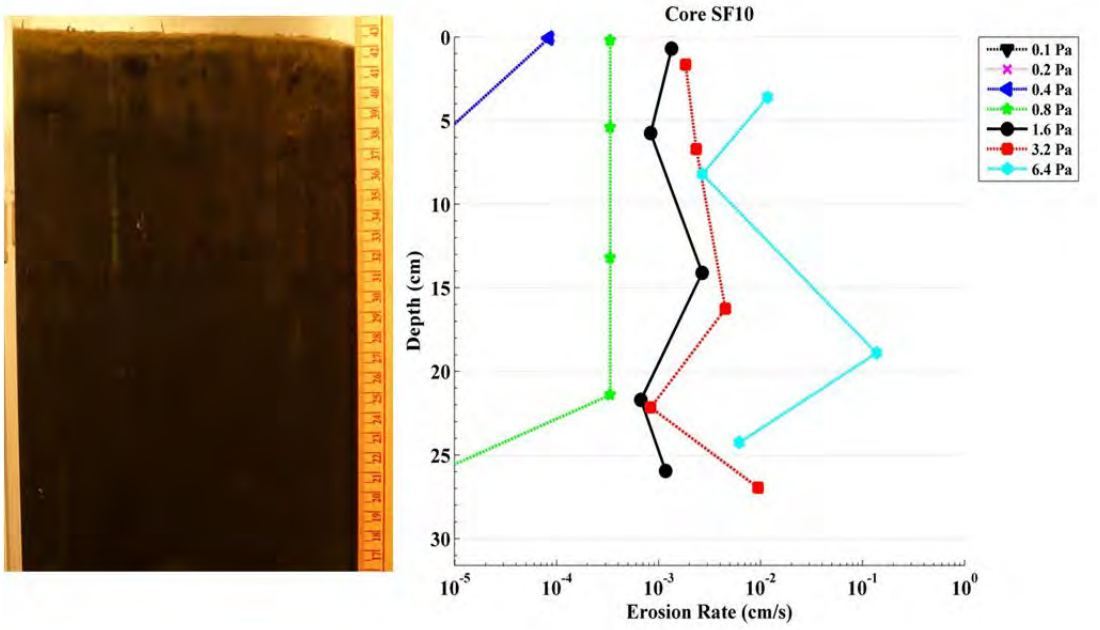


**Figure 31. Photo of core SF10 aligned vertically with the corresponding erosion rates.**

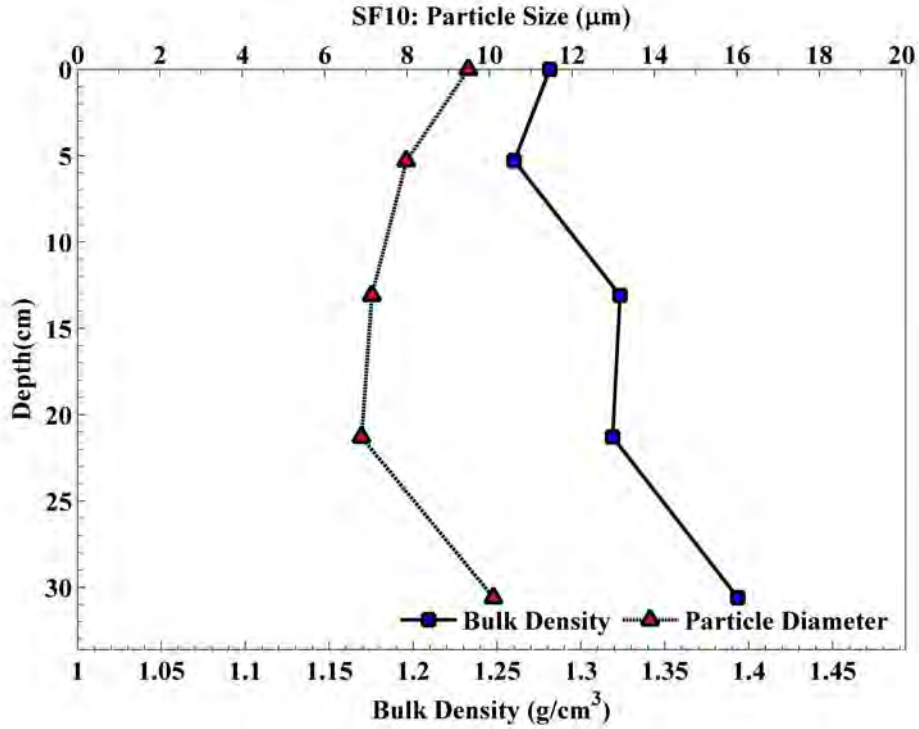


**Figure 32. Bulk density and median particle size ($d_{50}$) with depth for core SF10.**

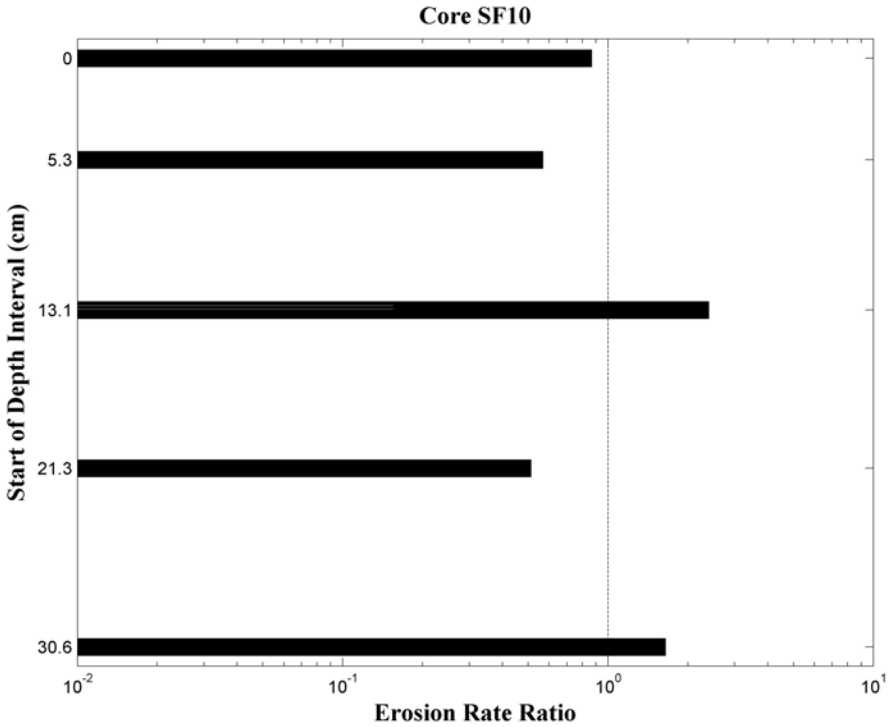


**Figure 33. Intra-core erosion rate ratios for core SF10. The dashed line indicates conditions for the core's average erosion rate (i.e., erosion rate ratio equals 1).**

**Table 21. Power law best-fit variables for specified depth intervals in core SF10.**

| Interval | Depth Start (cm) | Depth Finish (cm) | A | n | $r^2$ |
|---|---|---|---|---|---|
| 1 | 0.00 | 3.60 | 0.00054 | 1.4 | 0.95 |
| 2 | 5.30 | 8.20 | 0.00049 | 1.0 | 0.93 |
| 3 | 13.1 | 18.9 | 0.00054 | 2.7 | 0.92 |
| 4 | 21.3 | 24.3 | 0.00036 | 1.3 | 0.86 |
| 5 | 30.6 | 27.0 | 0.00028 | 3.0 | 1.00 |

**Table 22. Median particle size, bulk density, loss on ignition, and critical shear stress with depth for core SF10.**

| Depth (cm) | $d_{50}$ (µm) | $\rho_b$(g/cm$^3$) | *LOI* | Power Law $\tau_{cr}$ (Pa) | $\tau_{no}$ (Pa) | $\tau_{first}$ (Pa) | $\tau_{crit}$ (Pa) |
|---|---|---|---|---|---|---|---|
| 0.00 | 9.48 | 1.28 | 0.08 | 0.31 | 0.10 | 0.20 | 0.20 |
| 5.30 | 7.98 | 1.26 | 0.09 | 0.22 | 0.40 | 0.80 | 0.40 |
| 13.1 | 7.14 | 1.32 | 0.09 | 0.53 | 0.40 | 0.80 | 0.53 |
| 21.3 | 6.89 | 1.32 | 0.08 | 0.37 | 0.40 | 0.80 | 0.40 |
| 30.6 | 10.1 | 1.39 | 0.07 | 0.71 | 0.80 | 1.60 | 0.80 |
| **Mean** | **8.32** | **1.31** | **0.08** | **0.43** | **0.42** | **0.84** | **0.47** |

# Section 3
# Summary

Sea Engineering, Inc. (SEI) conducted a Sediment Erosion at Depth Flume (Sedflume) analysis on 10 sediment cores obtained from Richmond Harbor, CA in the Lauritzen Channel. The Lauritzen channel is part of the United Heckathorn Superfund Site. The cores were collected in water depths ranging between 5.8 m to 7.9 m. The primary goal of this work was to characterize the erosion rates and physical properties of the sediments within the Lauritzen channel. The cores were eroded to determine erosion rates as a function of shear stress and depth into core. In addition, cores were sub-sampled during the analysis to determine sediment bulk density, loss on ignition fraction and particle size distributions at specific depths within the core. Critical shear stresses were calculated from the erosion rate data for five intervals in each core, ranging from 0.1 Pa to 1.28 Pa.

The presence of detritus, pebbles and shells had a noticeable effect on erosion. The Sedflume analysis provided a quantification of the overall effect of each of these constituents on sediment erosion characteristics. When high concentrations of organic material were present in a core, erosion was often dominated by the mobilization of large chunks of material as organic pieces lifted from the test section taking sediment along with them. Pebbles and shells often acted to armor the bed until the applied shear stress was large enough to mobilize them.

Although erosion rates fluctuated between intervals, core sediments generally stiffened with depth. This trend is common for sites with cohesive sediments. Cohesive sediments will often self-compact due to the weight of the overlying material. Compaction reduces the potential for sediment mobility. However, Sedflume results must be analyzed in conjunction with other system characteristics, such as hydrodynamic forcing, to assess overall site stability and sediment transport trends.

To better visualize the relative erodibility of the sediment at the locations where cores were recovered, the ratio of the mean erosion rate of each core (core vertically averaged erosion rate) to the average mean erosion rate of all cores at the site was calculated and plotted (Figure 34). The dashed line in Figure 34 denotes a site-wide average erosion rate ratio of 1.0. A ratio above this line generally means the core is more susceptible to erosion than those below. It is important to note that this analysis does not take into account the hydrodynamic forces or sediment coarsening processes that are responsible for net in-situ transport. The cores where plotted in Figure 34 such that the cores closest to the mouth of the Lauritzen Channel are plotted on the left-hand side of the figure. Generally, sediment near the mouth of the channel was stiffer than sediment at the end of the channel.

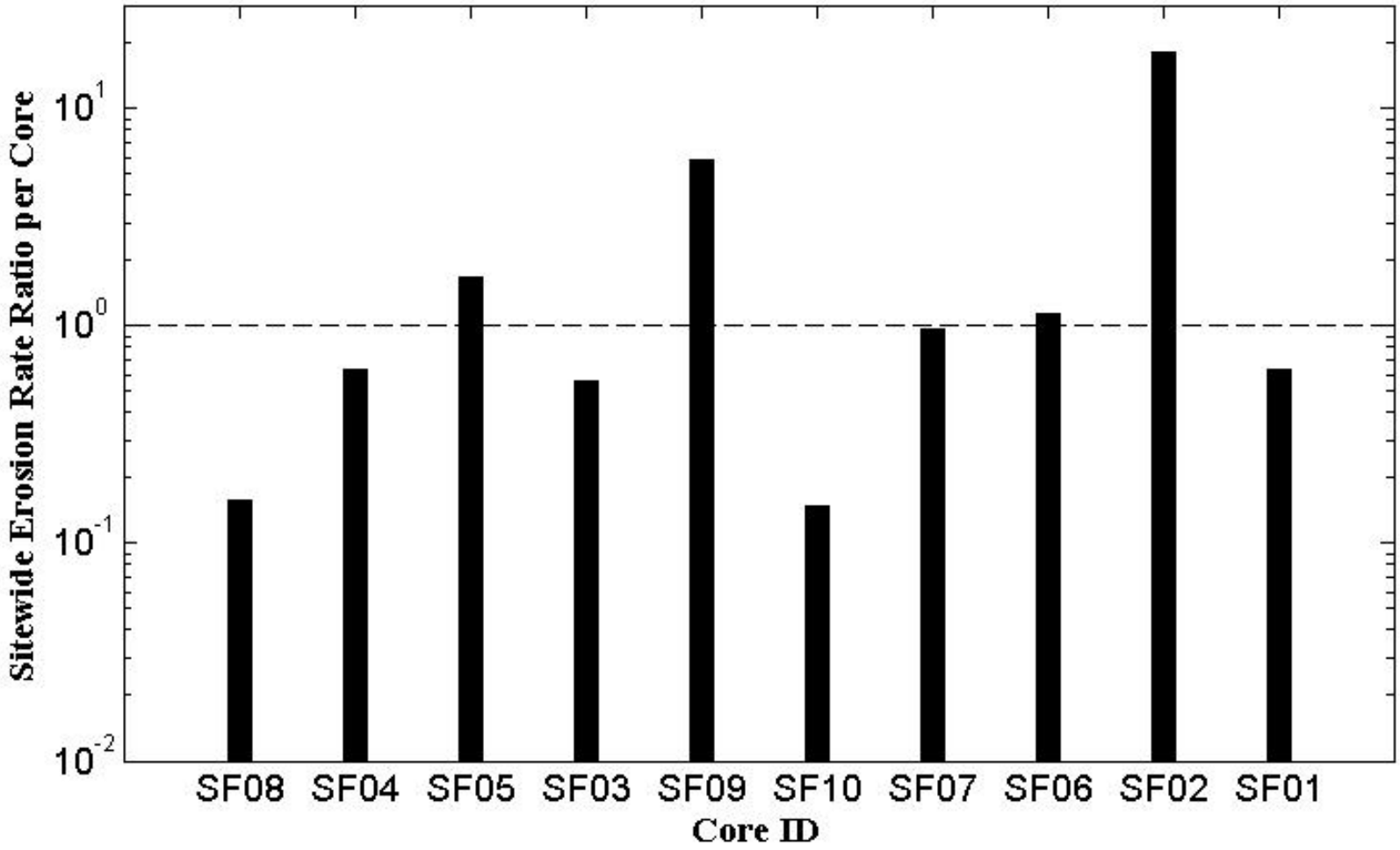


**Figure 34. Inter-core erosion rate ratios. Depth-averaged core erosion rates compared to the site-wide average erosion rates.**

# Section 4
# References

ASTM Standard, 2007, Annual Book of ASTM Standards. ASTM International, West Conshohocken, Pennsylvania, USA. Vol. 04.08 Soil and Rock (I): D 420 - D5611: 314-315.

Hakanson, L., and M. Jansson, 2002, Principles of Lake Sedimentology. Blackburn Press, Caldwell, New Jersey, USA.

Jepsen, R., J. Roberts, and W. Lick, 1997, Effects of bulk density on sediment erosion rates, Water, Air and Soil Pollution, 99:21-31.

McNeil, J., C. Taylor, and W. Lick, 1996, Measurements of erosion of undisturbed bottom sediments with depth, J. Hydr. Engr., 122(6):316-324.

Roberts, J., R. Jepsen, D. Gotthard, and W. Lick, 1998, Effects of particle size and bulk density on erosion of quartz particles, J. Hydr. Engr., 124(12):1261 1267.

# Appendix – Particle Size Distributions

# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\1-1__195.$av |
| | 1-1__195.$av |
| File ID: | 1-1 |
| Operator: | Szesciorka |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

Average of 3 files:
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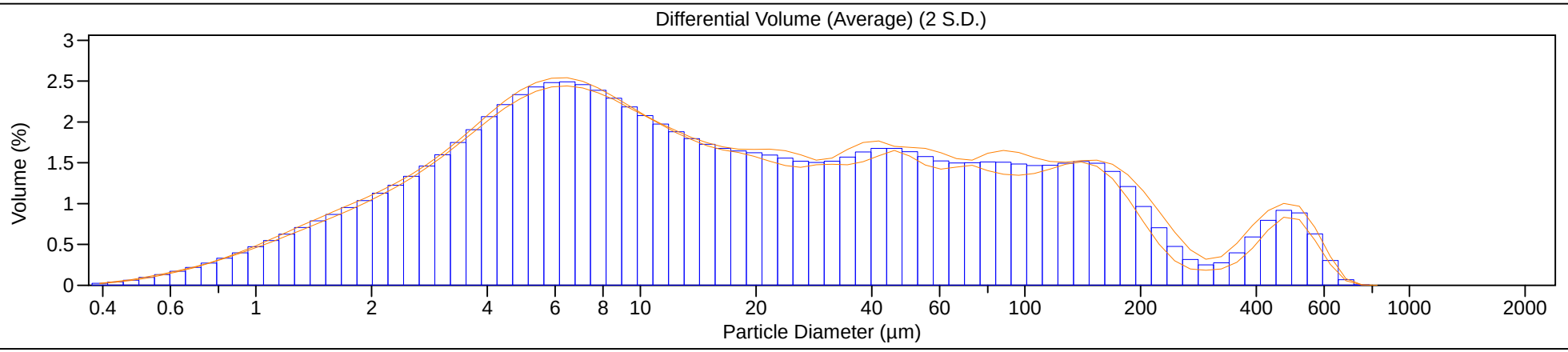
C:\LS13320\Projects\Heckathorne\1-1__194.$ls
C:\LS13320\Projects\Heckathorne\1-1__195.$ls

Volume Statistics (Arithmetic) 1-1__195.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 60.74 µm | S.D.: | 108.9 µm |
| Median: | 14.90 µm | Variance: | 11869 µm$^2$ |
| Mean/Median ratio: | 4.076 | C.V.: | 179% |
| Mode: | 6.453 µm | Skewness: | 3.034 Right skewed |
| | | Kurtosis: | 9.688 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 2.406 µm | 5.160 µm | 14.90 µm | 64.01 µm | 163.4 µm |



# Beckman Coulter LS Particle Size Analyzer

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## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\1-2__252.$av |
| | 1-2__252.$av |
| File ID: | 1-2 |
| Operator: | Reyes |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Pump speed: | 66 |
| Fluid: | water |

Average of 3 files:
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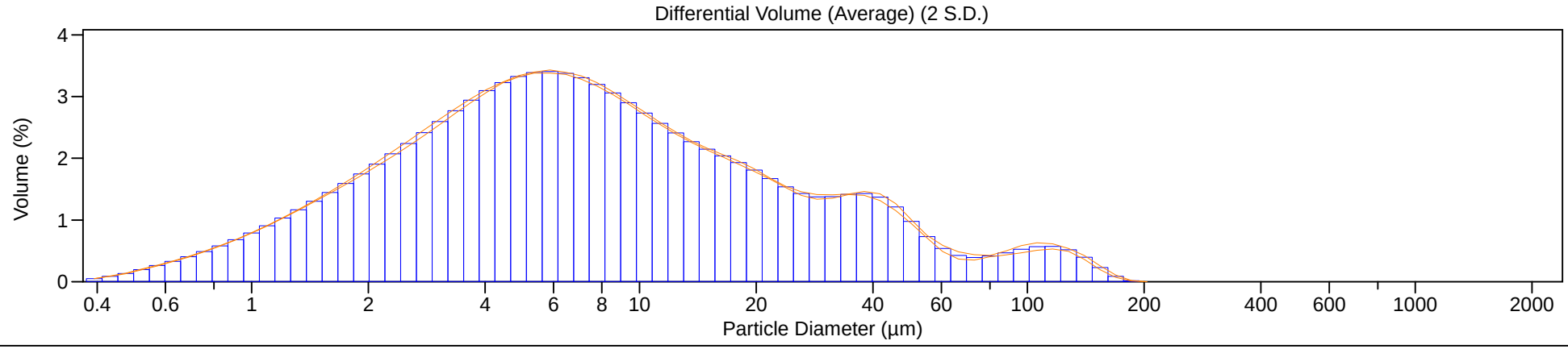
C:\LS13320\Projects\Heckathorne\1-2__252.$ls

Volume Statistics (Arithmetic) 1-2__252.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 15.40 µm | S.D.: | 23.70 µm |
| Median: | 6.771 µm | Variance: | 561.7 µm$^2$ |
| Mean/Median ratio: | 2.275 | C.V.: | 154% |
| Mode: | 5.878 µm | Skewness: | 3.285 Right skewed |
| | | Kurtosis: | 12.35 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.683 µm | 3.271 µm | 6.771 µm | 16.00 µm | 38.41 µm |



# Beckman Coulter LS Particle Size Analyzer

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## Heckathorn

| | | | |
|---|---|---|---|
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| | 1-3__204.$av | | |
| File ID: | 1-3 | | |
| Operator: | Szesciorka | | |
| Comment 1: | Heckathorne | | |
| Comment 2: | mixed, blended | | |
| Optical model: | garnet.rf780z | | |
| LS 13 320 SW | Aqueous Liquid Module | | |
| | | Run length: | 60 seconds |
| Pump speed: | 66 | | |
| Fluid: | water | | |

Average of 3 files:
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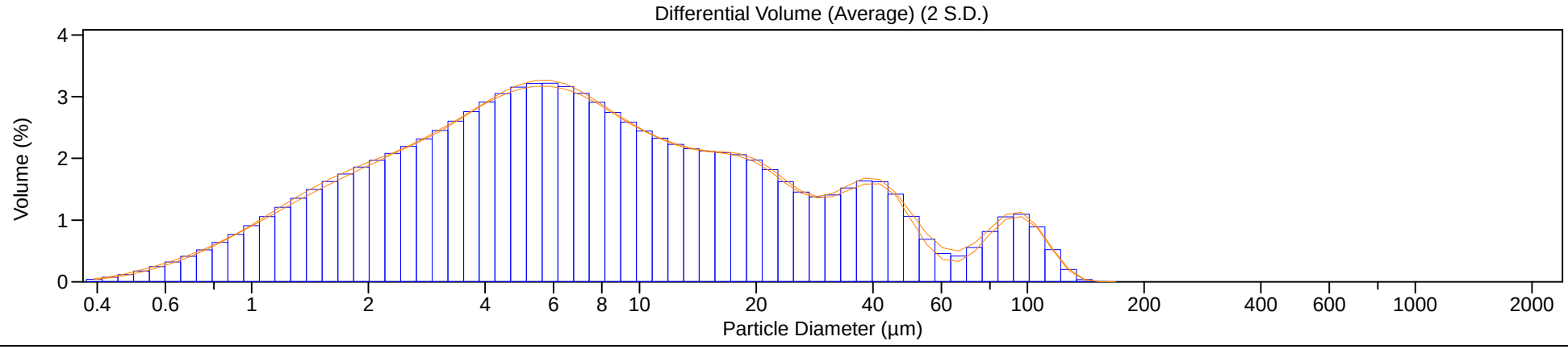
Volume Statistics (Arithmetic) 1-3__204.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 15.90 µm | S.D.: | 22.61 µm |
| Median: | 6.838 µm | Variance: | 511.2 µm$^2$ |
| Mean/Median ratio: | 2.325 | C.V.: | 142% |
| Mode: | 5.878 µm | Skewness: | 2.591 Right skewed |
| | | Kurtosis: | 6.902 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.580 µm | 3.138 µm | 6.838 µm | 17.75 µm | 41.79 µm |



# Beckman Coulter LS Particle Size Analyzer

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## Heckathorn

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|---|---|
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| | 1-4__207.$av |
| File ID: | 1-4 |
| Operator: | Szesciorka |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

Average of 3 files:
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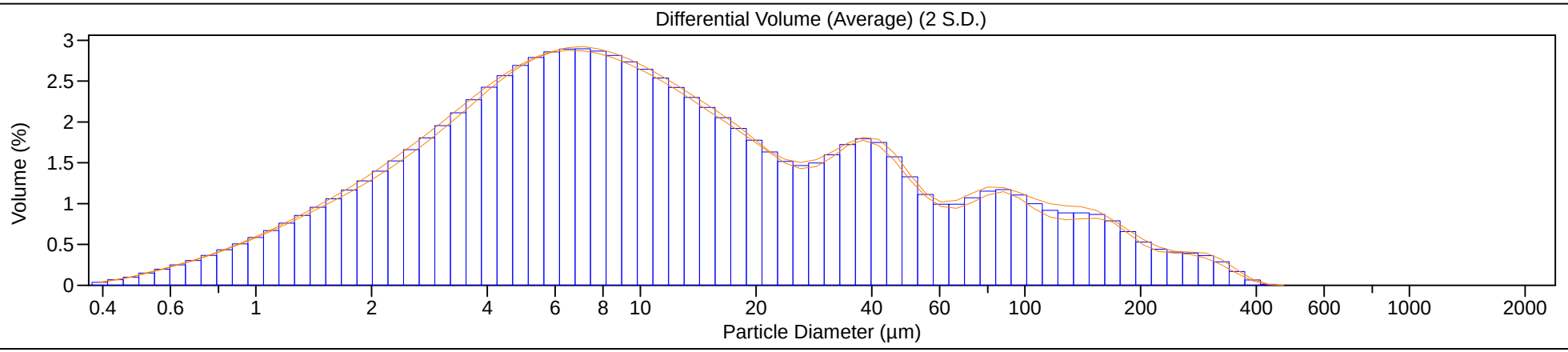
Volume Statistics (Arithmetic) 1-4__207.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 31.34 µm | S.D.: | 53.35 µm |
| Median: | 9.816 µm | Variance: | 2847 µm$^2$ |
| Mean/Median ratio: | 3.193 | C.V.: | 170% |
| Mode: | 7.084 µm | Skewness: | 3.127 Right skewed |
| | | Kurtosis: | 11.33 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 2.046 µm | 4.257 µm | 9.816 µm | 31.99 µm | 90.57 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

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1-5__222.$av
File ID: 1-5
Operator: Reyes
Comment 1: Heckathorne
Comment 2: mixed, blended
Optical model: garnet.rf780z
LS 13 320 SW Aqueous Liquid Module
Run length: 60 seconds
Pump speed: 66
Fluid: water
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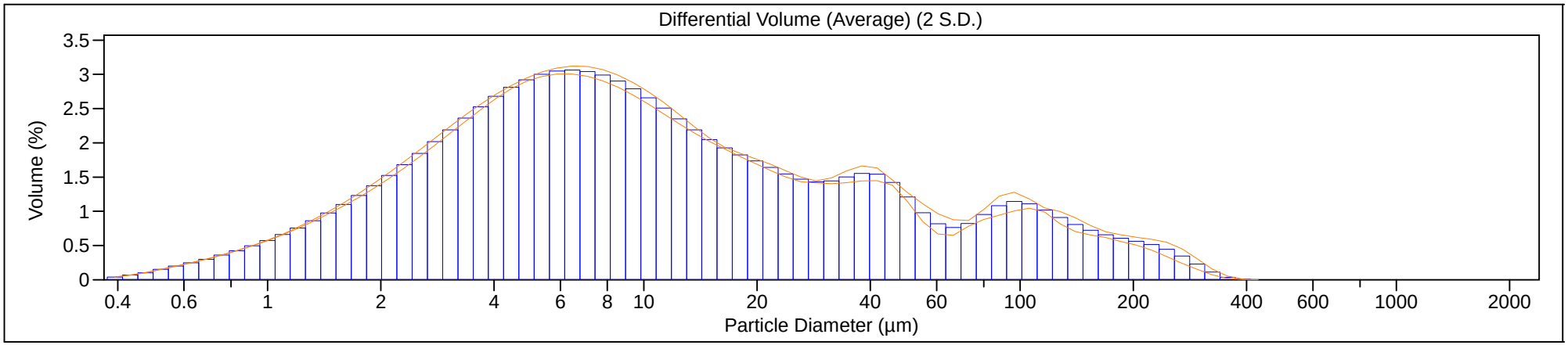
C:\LS13320\Projects\Heckathorne\1-5__222.$ls

Volume Statistics (Arithmetic) 1-5__222.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 28.34 µm | S.D.: | 48.39 µm |
| Median: | 8.794 µm | Variance: | 2342 µm$^2$ |
| Mean/Median ratio: | 3.223 | C.V.: | 171% |
| Mode: | 6.453 µm | Skewness: | 3.018 Right skewed |
| | | Kurtosis: | 10.18 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 2.019 µm | 3.992 µm | 8.794 µm | 27.01 µm | 86.35 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

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|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\2-1__180.$av |
| | 2-1__180.$av |
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| Operator: | Szesciorka |
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| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

Average of 3 files:
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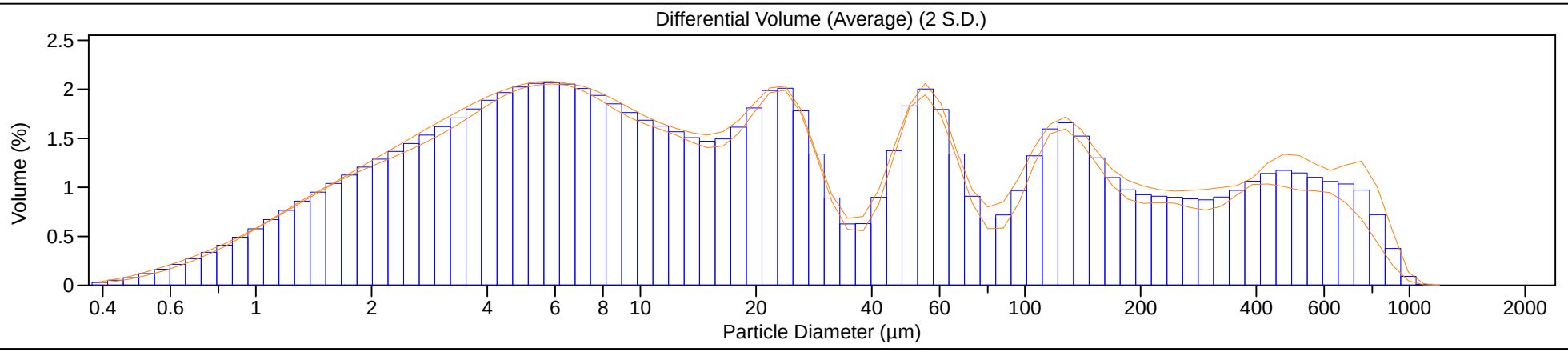
C:\LS13320\Projects\Heckathorne\2-1__179.$ls
C:\LS13320\Projects\Heckathorne\2-1__180.$ls

Volume Statistics (Arithmetic) 2-1__180.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 102.5 µm | S.D.: | 182.6 µm |
| Median: | 18.14 µm | Variance: | 33332 µm$^2$ |
| Mean/Median ratio: | 5.651 | C.V.: | 178% |
| Mode: | 5.878 µm | Skewness: | 2.407 Right skewed |
| | | Kurtosis: | 5.348 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 2.109 µm | 4.887 µm | 18.14 µm | 106.5 µm | 369.3 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
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| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

Average of 3 files:
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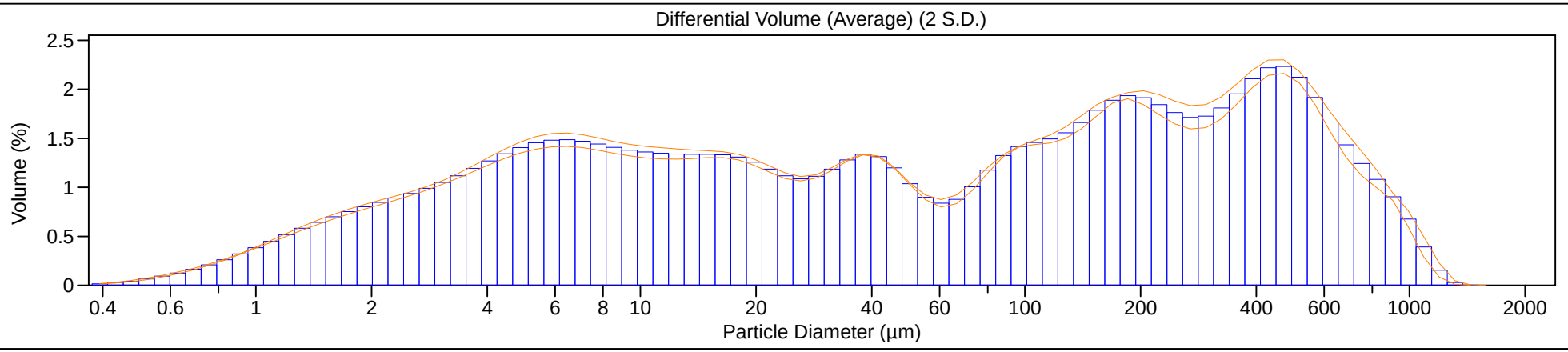
C:\LS13320\Projects\Heckathorne\2-2__288.$ls

Volume Statistics (Arithmetic) 2-2__288.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 174.7 µm | S.D.: | 236.3 µm |
| Median: | 53.89 µm | Variance: | 55822 µm$^2$ |
| Mean/Median ratio: | 3.241 | C.V.: | 135% |
| Mode: | 471.1 µm | Skewness: | 1.695 Right skewed |
| | | Kurtosis: | 2.464 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 2.970 µm | 8.417 µm | 53.89 µm | 262.6 µm | 530.6 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

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2-3__192.$av
File ID: 2-3
Operator: Szesciorka
Comment 1: Heckathorne
Comment 2: mixed, blended
Optical model: garnet.rf780z
LS 13 320 SW Aqueous Liquid Module
Run length: 60 seconds
Pump speed: 66
Fluid: water
Average of 3 files:
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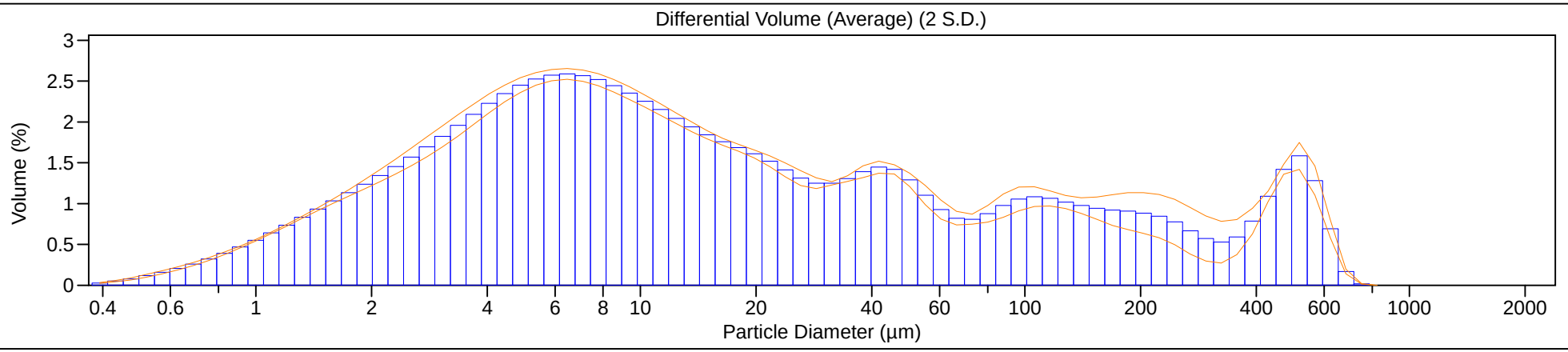
C:\LS13320\Projects\Heckathorne\2-3__191.$ls
C:\LS13320\Projects\Heckathorne\2-3__192.$ls

Volume Statistics (Arithmetic) 2-3__192.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 71.92 µm | S.D.: | 136.7 µm |
| Median: | 11.77 µm | Variance: | 18698 µm$^2$ |
| Mean/Median ratio: | 6.110 | C.V.: | 190% |
| Mode: | 6.453 µm | Skewness: | 2.543 Right skewed |
| | | Kurtosis: | 5.713 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 2.130 µm | 4.532 µm | 11.77 µm | 54.50 µm | 239.3 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

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| | 2-4__234.$av |
| File ID: | 2-4 |
| Operator: | Reyes |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| | Run length: 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

Average of 3 files:
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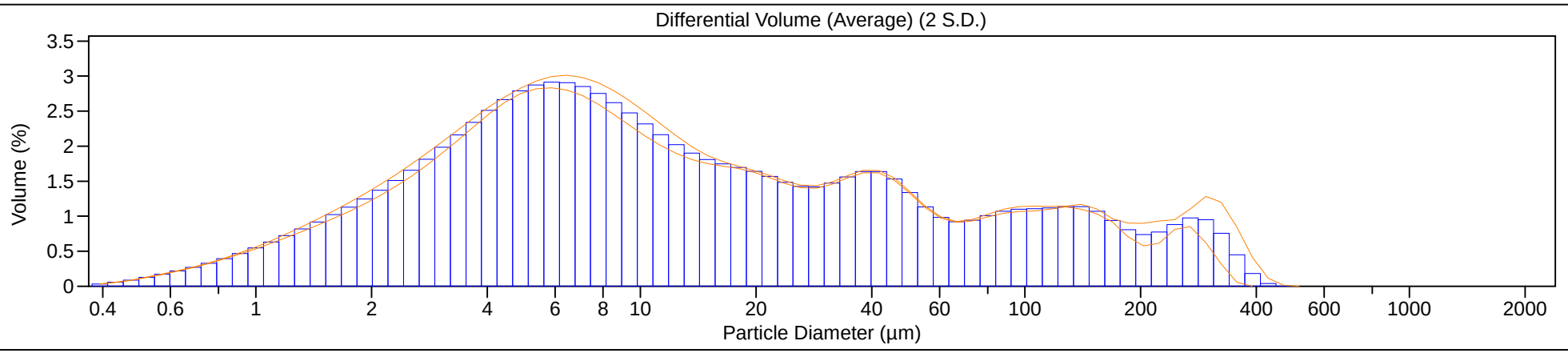
C:\LS13320\Projects\Heckathorne\2-4__233.$ls
C:\LS13320\Projects\Heckathorne\2-4__234.$ls

Volume Statistics (Arithmetic) 2-4__234.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 40.97 µm | S.D.: | 70.34 µm |
| Median: | 10.07 µm | Variance: | 4948 µm$^2$ |
| Mean/Median ratio: | 4.067 | C.V.: | 172% |
| Mode: | 5.878 µm | Skewness: | 2.614 Right skewed |
| | | Kurtosis: | 6.752 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 2.126 µm | 4.312 µm | 10.07 µm | 39.23 µm | 130.7 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
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| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\2-5__237.$av |
| | 2-5__237.$av |
| File ID: | 2-5 |
| Operator: | Reyes |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

Average of 3 files:
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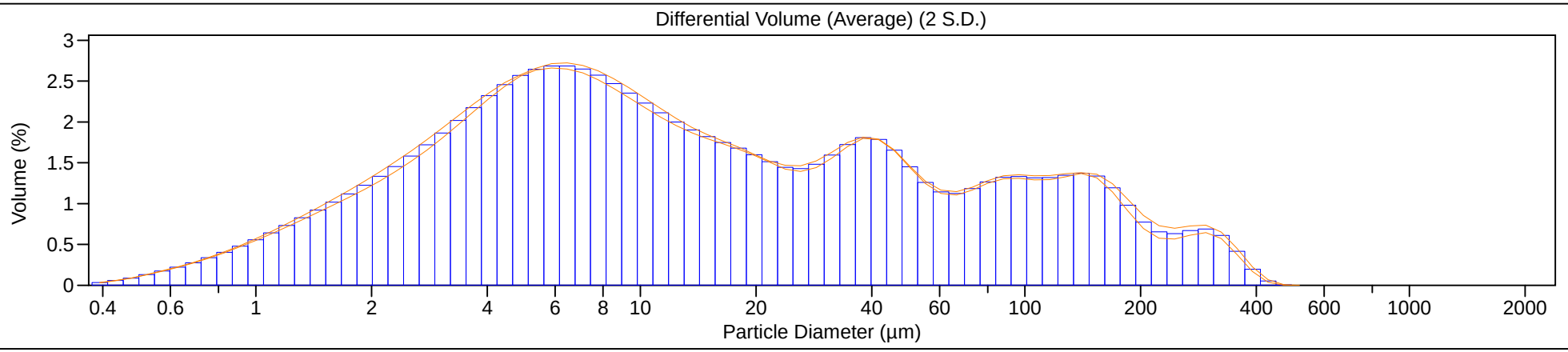
C:\LS13320\Projects\Heckathorne\2-5__236.$ls
C:\LS13320\Projects\Heckathorne\2-5__237.$ls

Volume Statistics (Arithmetic) 2-5__237.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 41.60 µm | S.D.: | 67.31 µm |
| Median: | 11.26 µm | Variance: | 4531 µm$^2$ |
| Mean/Median ratio: | 3.696 | C.V.: | 162% |
| Mode: | 5.878 µm | Skewness: | 2.581 Right skewed |
| | | Kurtosis: | 7.093 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 2.121 µm | 4.456 µm | 11.26 µm | 44.49 µm | 130.2 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | | | |
|---|---|---|---|
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| | 3-1__276.$av | | |
| File ID: | 3-1 | | |
| Operator: | Reyes | | |
| Comment 1: | Heckathorne | | |
| Comment 2: | mixed, blended | | |
| Optical model: | garnet.rf780z | | |
| LS 13 320 SW | Aqueous Liquid Module | | |
| | | Run length: | 60 seconds |
| Pump speed: | 66 | | |
| Fluid: | water | | |

Average of 3 files:
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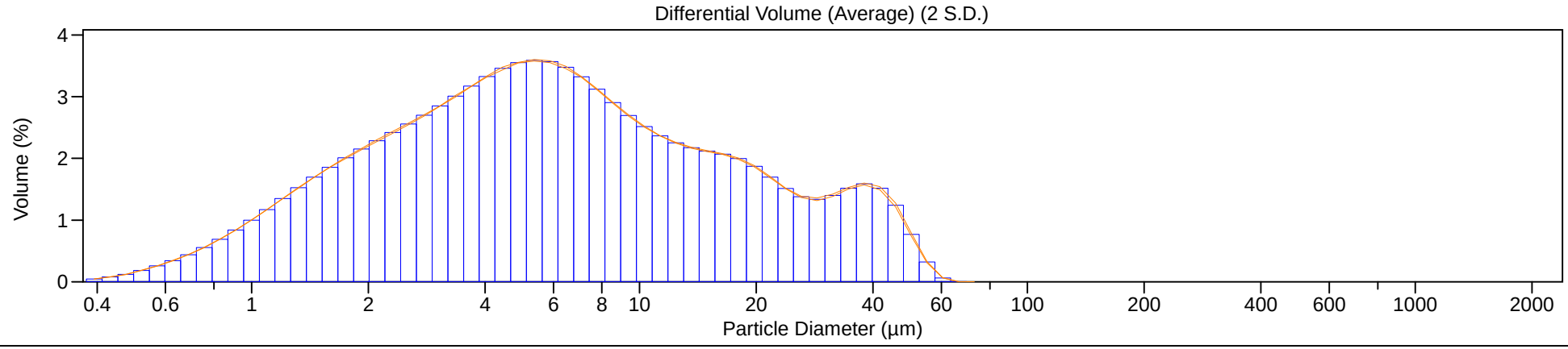
C:\LS13320\Projects\Heckathorne\3-1__275.$ls
C:\LS13320\Projects\Heckathorne\3-1__276.$ls

Volume Statistics (Arithmetic) 3-1__276.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 10.16 µm | S.D.: | 11.21 µm |
| Median: | 5.731 µm | Variance: | 125.7 µm$^2$ |
| Mean/Median ratio: | 1.773 | C.V.: | 110% |
| Mode: | 5.355 µm | Skewness: | 1.869 Right skewed |
| | | Kurtosis: | 3.047 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.497 µm | 2.798 µm | 5.731 µm | 12.77 µm | 26.97 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | | | |
|---|---|---|---|
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| | 3-2__264.$av | | |
| File ID: | 3-2 | | |
| Operator: | Reyes | | |
| Comment 1: | Heckathorne | | |
| Comment 2: | mixed, blended | | |
| Optical model: | garnet.rf780z | | |
| LS 13 320 SW | Aqueous Liquid Module | | |
| | | Run length: | 60 seconds |
| Pump speed: | 66 | | |
| Fluid: | water | | |

Average of 3 files:
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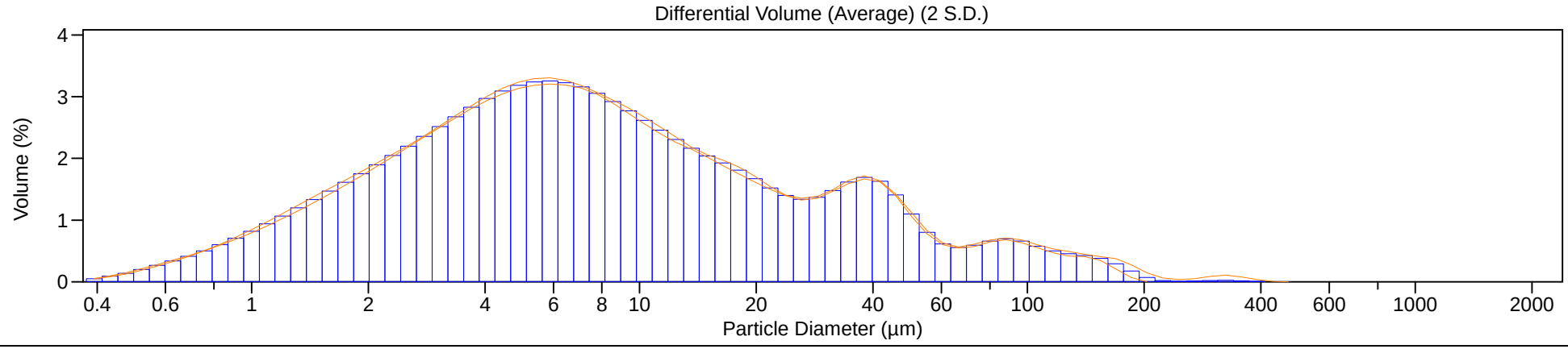
C:\LS13320\Projects\Heckathorne\3-2__263.$ls
C:\LS13320\Projects\Heckathorne\3-2__264.$ls

Volume Statistics (Arithmetic) 3-2__264.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 17.62 µm | S.D.: | 28.98 µm |
| Median: | 6.974 µm | Variance: | 839.8 µm$^2$ |
| Mean/Median ratio: | 2.527 | C.V.: | 164% |
| Mode: | 5.878 µm | Skewness: | 3.835 Right skewed |
| | | Kurtosis: | 21.37 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.655 µm | 3.263 µm | 6.974 µm | 17.75 µm | 43.93 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | | | |
|---|---|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\3-3__270.$av | | |
| | 3-3__270.$av | | |
| File ID: | 3-3 | | |
| Operator: | Reyes | | |
| Comment 1: | Heckathorne | | |
| Comment 2: | mixed, blended | | |
| Optical model: | garnet.rf780z | | |
| LS 13 320 SW | Aqueous Liquid Module | | |
| | | Run length: | 60 seconds |
| Pump speed: | 66 | | |
| Fluid: | water | | |

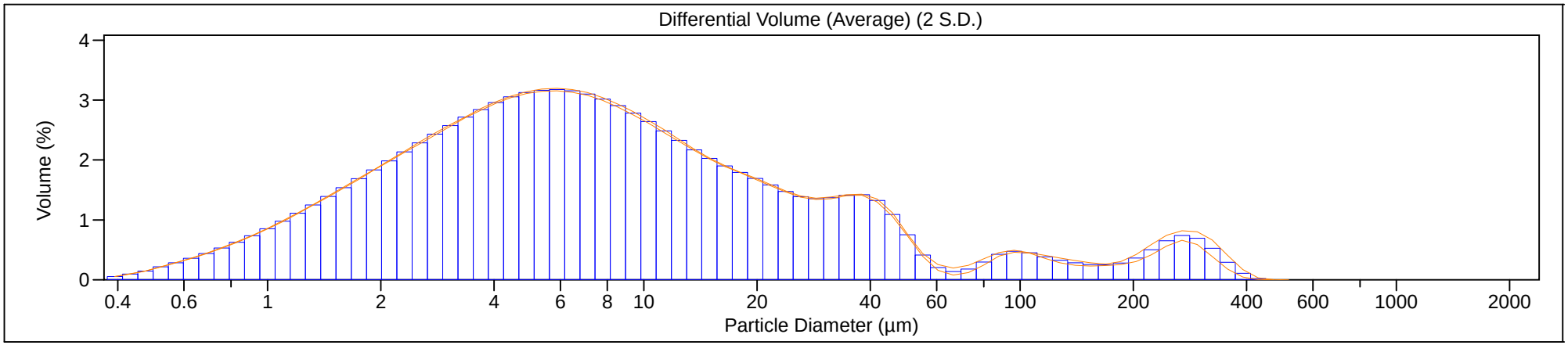
Average of 3 files:
C:\LS13320\Projects\Heckathorne\3-3__268.$ls
C:\LS13320\Projects\Heckathorne\3-3__269.$ls
C:\LS13320\Projects\Heckathorne\3-3__270.$ls

Volume Statistics (Arithmetic) 3-3__270.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 24.85 µm | S.D.: | 56.81 µm |
| Median: | 6.820 µm | Variance: | 3228 $\mu m^2$ |
| Mean/Median ratio: | 3.644 | C.V.: | 229% |
| Mode: | 5.878 µm | Skewness: | 3.972 Right skewed |
| | | Kurtosis: | 16.13 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.610 µm | 3.146 µm | 6.820 µm | 17.12 µm | 44.12 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

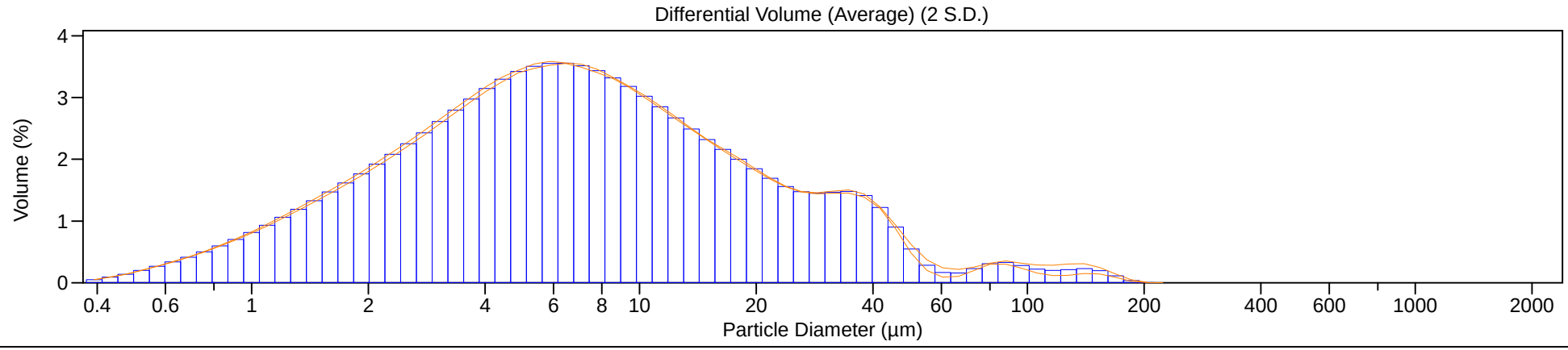
File name: C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\3-4__291.$av
3-4__291.$av
File ID: 3-4
Operator: Reyes
Comment 1: Heckathorne
Comment 2: mixed, blended
Optical model: garnet.rf780z
LS 13 320 SW Aqueous Liquid Module
Run length: 60 seconds
Pump speed: 66
Fluid: water
Average of 3 files:
C:\LS13320\Projects\Heckathorne\3-4__289.$ls
C:\LS13320\Projects\Heckathorne\3-4__290.$ls
C:\LS13320\Projects\Heckathorne\3-4__291.$ls

Volume Statistics (Arithmetic) 3-4__291.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 12.79 µm | S.D.: | 19.23 µm |
| Median: | 6.588 µm | Variance: | 369.9 µm$^2$ |
| Mean/Median ratio: | 1.941 | C.V.: | 150% |
| Mode: | 6.453 µm | Skewness: | 4.262 Right skewed |
| | | Kurtosis: | 23.67 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.658 µm | 3.231 µm | 6.588 µm | 14.01 µm | 30.08 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\3-5__294.$av |
| | 3-5__294.$av |
| File ID: | 3-5 |
| Operator: | Reyes |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

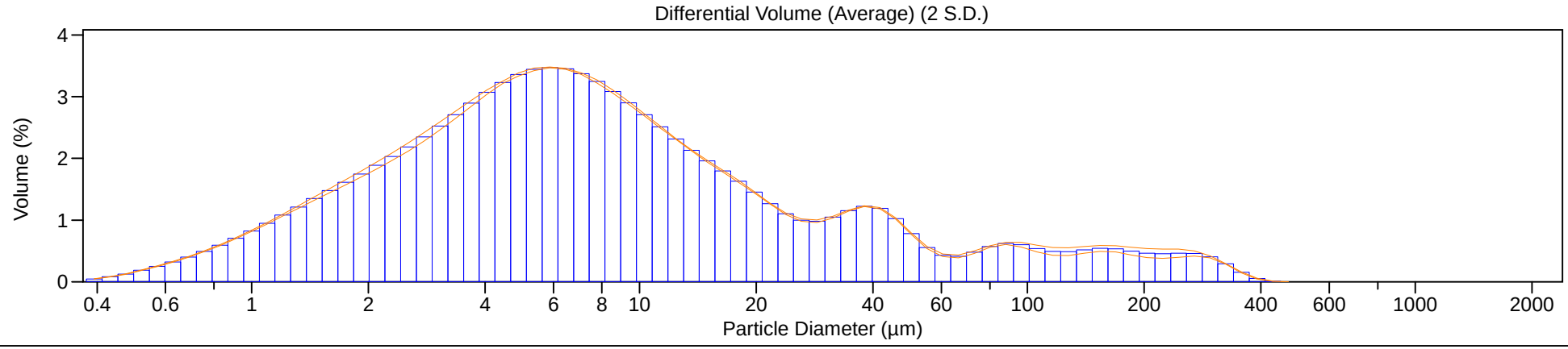
Average of 3 files:
C:\LS13320\Projects\Heckathorne\3-5__292.$ls
C:\LS13320\Projects\Heckathorne\3-5__293.$ls
C:\LS13320\Projects\Heckathorne\3-5__294.$ls

Volume Statistics (Arithmetic) 3-5__294.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 23.88 µm | S.D.: | 50.75 µm |
| Median: | 6.748 µm | Variance: | 2576 µm$^2$ |
| Mean/Median ratio: | 3.539 | C.V.: | 213% |
| Mode: | 5.878 µm | Skewness: | 3.843 Right skewed |
| | | Kurtosis: | 16.11 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.658 µm | 3.270 µm | 6.748 µm | 16.25 µm | 53.07 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | | | |
|---|---|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\4B-1__255.$av | | |
| | 4B-1__255.$av | | |
| File ID: | 4B-1 | | |
| Operator: | Reyes | | |
| Comment 1: | Heckathorne | | |
| Comment 2: | mixed, blended | | |
| Optical model: | garnet.rf780z | | |
| LS 13 320 SW | Aqueous Liquid Module | | |
| | | Run length: | 60 seconds |
| Pump speed: | 66 | | |
| Fluid: | water | | |

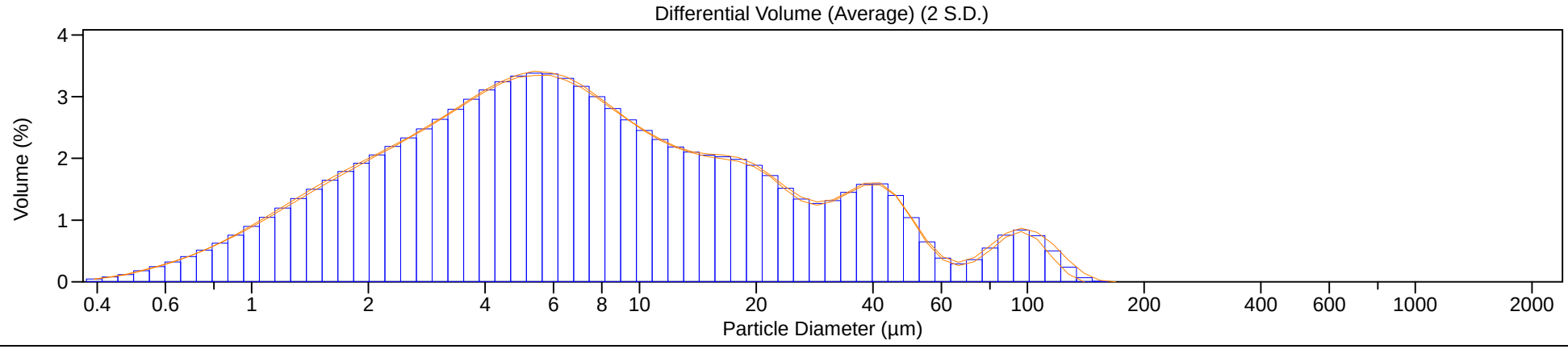
Average of 3 files:
C:\LS13320\Projects\Heckathorne\4B-1__253.$ls
C:\LS13320\Projects\Heckathorne\4B-1__254.$ls
C:\LS13320\Projects\Heckathorne\4B-1__255.$ls

Volume Statistics (Arithmetic) 4B-1__255.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 14.64 µm | S.D.: | 21.30 µm |
| Median: | 6.431 µm | Variance: | 453.5 µm$^2$ |
| Mean/Median ratio: | 2.276 | C.V.: | 145% |
| Mode: | 5.355 µm | Skewness: | 2.885 Right skewed |
| | | Kurtosis: | 9.149 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.585 µm | 3.061 µm | 6.431 µm | 16.03 µm | 38.48 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | | | |
|---|---|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\4B-2__216.$av | | |
| | 4B-2__216.$av | | |
| File ID: | 4B-2 | | |
| Operator: | Szesciorka | | |
| Comment 1: | Heckathorne | | |
| Comment 2: | mixed, blended | | |
| Optical model: | garnet.rf780z | | |
| LS 13 320 SW | Aqueous Liquid Module | | |
| | | Run length: | 60 seconds |
| Pump speed: | 66 | | |
| Fluid: | water | | |

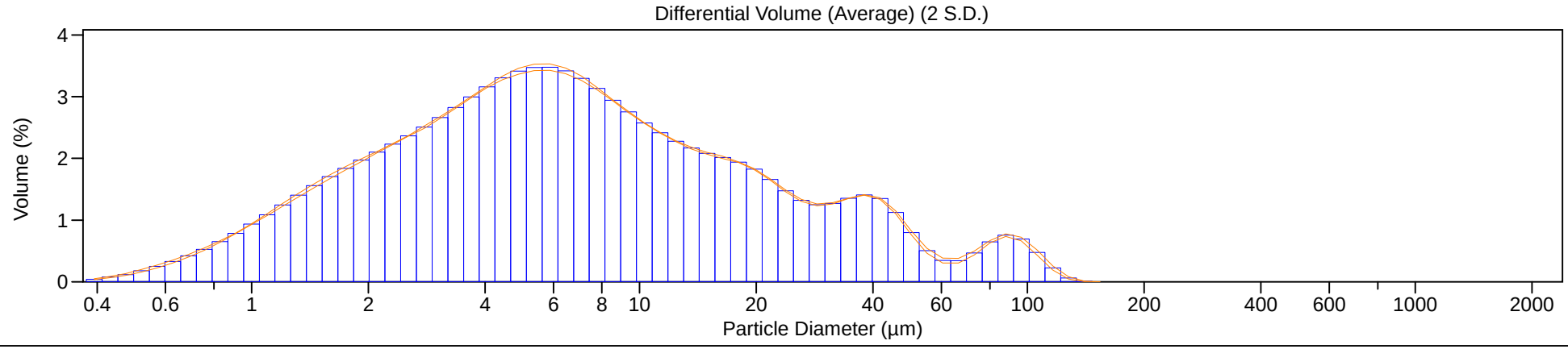
Average of 3 files:
C:\LS13320\Projects\Heckathorne\4B-2__214.$ls
C:\LS13320\Projects\Heckathorne\4B-2__215.$ls
C:\LS13320\Projects\Heckathorne\4B-2__216.$ls

Volume Statistics (Arithmetic) 4B-2__216.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 13.28 µm | S.D.: | 18.87 µm |
| Median: | 6.225 µm | Variance: | 356.2 µm$^2$ |
| Mean/Median ratio: | 2.133 | C.V.: | 142% |
| Mode: | 5.878 µm | Skewness: | 2.935 Right skewed |
| | | Kurtosis: | 9.652 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.554 µm | 2.993 µm | 6.225 µm | 14.53 µm | 34.35 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

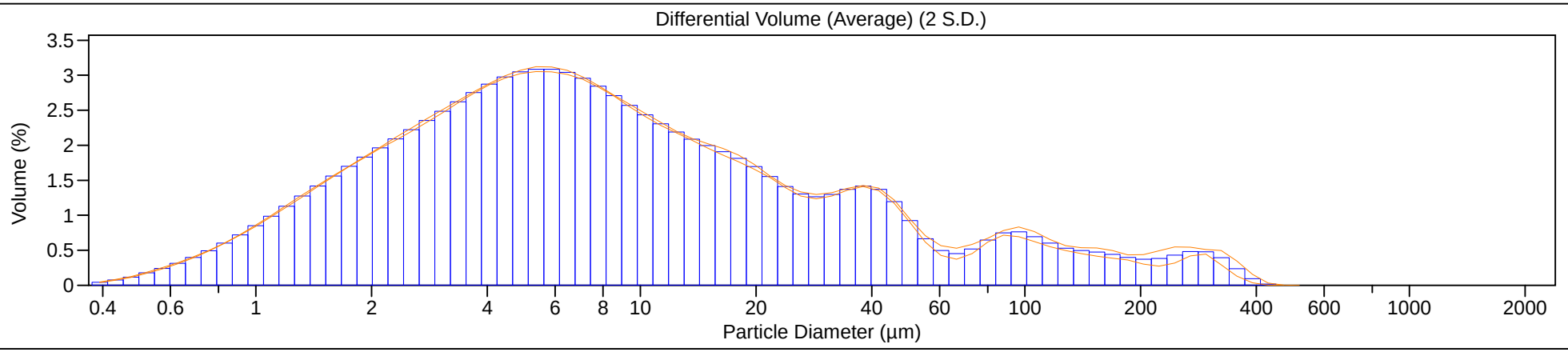
File name: C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\4B-3__219.$av
4B-3__219.$av
File ID: 4B-3
Operator: Reyes
Comment 1: Heckathorne
Comment 2: mixed, blended
Optical model: garnet.rf780z
LS 13 320 SW Aqueous Liquid Module
Run length: 60 seconds
Pump speed: 66
Fluid: water
Average of 3 files:
C:\LS13320\Projects\Heckathorne\4B-3__217.$ls
C:\LS13320\Projects\Heckathorne\4B-3__218.$ls
C:\LS13320\Projects\Heckathorne\4B-3__219.$ls

Volume Statistics (Arithmetic) 4B-3__219.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 25.50 µm | S.D.: | 53.01 µm |
| Median: | 7.088 µm | Variance: | 2810 µm$^2$ |
| Mean/Median ratio: | 3.598 | C.V.: | 208% |
| Mode: | 5.355 µm | Skewness: | 3.863 Right skewed |
| | | Kurtosis: | 16.46 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.629 µm | 3.199 µm | 7.088 µm | 19.57 µm | 59.70 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\4B-4__231.$av |
| | 4B-4__231.$av |
| File ID: | 4B-4 |
| Operator: | Reyes |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

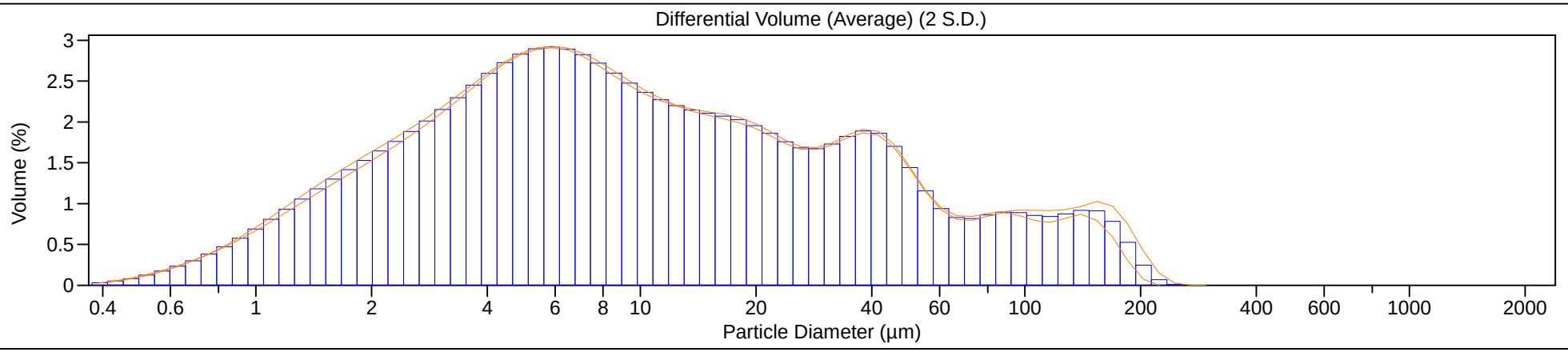
Average of 3 files:
C:\LS13320\Projects\Heckathorne\4B-4__229.$ls
C:\LS13320\Projects\Heckathorne\4B-4__230.$ls
C:\LS13320\Projects\Heckathorne\4B-4__231.$ls

Volume Statistics (Arithmetic) 4B-4__231.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 24.05 µm | S.D.: | 36.59 µm |
| Median: | 8.778 µm | Variance: | 1339 $\mu m^2$ |
| Mean/Median ratio: | 2.740 | C.V.: | 152% |
| Mode: | 5.878 µm | Skewness: | 2.608 Right skewed |
| | | Kurtosis: | 6.946 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.853 µm | 3.787 µm | 8.778 µm | 26.73 µm | 65.90 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\4B-5__258.$av |
| | 4B-5__258.$av |
| File ID: | 4B-5 |
| Operator: | Reyes |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

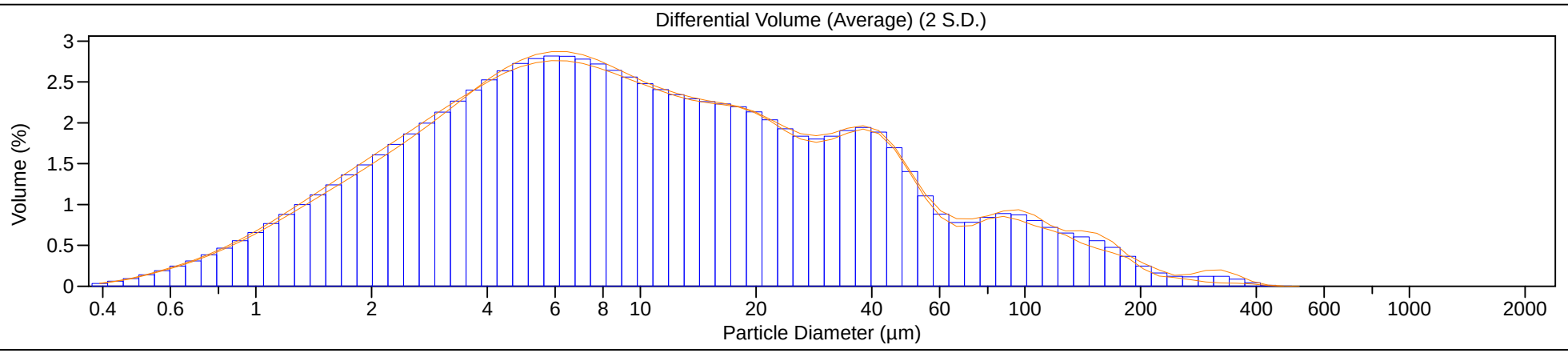
Average of 3 files:
C:\LS13320\Projects\Heckathorne\4B-5__256.$ls
C:\LS13320\Projects\Heckathorne\4B-5__257.$ls
C:\LS13320\Projects\Heckathorne\4B-5__258.$ls

Volume Statistics (Arithmetic) 4B-5__258.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 24.09 µm | S.D.: | 40.34 µm |
| Median: | 9.132 µm | Variance: | 1627 µm$^2$ |
| Mean/Median ratio: | 2.638 | C.V.: | 167% |
| Mode: | 5.878 µm | Skewness: | 3.856 Right skewed |
| | | Kurtosis: | 20.08 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.889 µm | 3.863 µm | 9.132 µm | 25.86 µm | 59.50 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

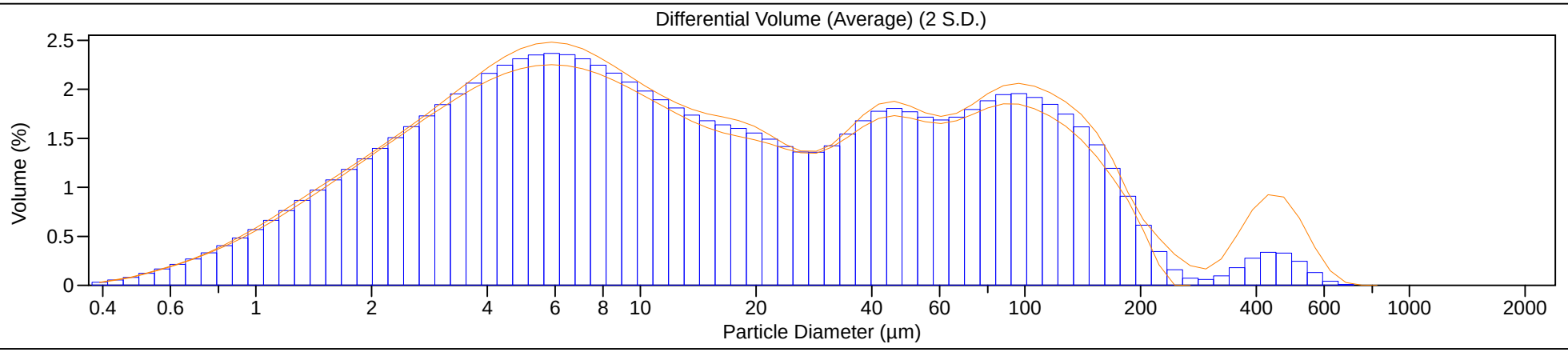
| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\4B-6__225.$av |
| | 4B-6__225.$av |
| File ID: | 4B-6 |
| Operator: | Reyes |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |
| Average of 3 files: | |
| C:\LS13320\Projects\Heckathorne\4B-6__223.$ls | |
| C:\LS13320\Projects\Heckathorne\4B-6__224.$ls | |
| C:\LS13320\Projects\Heckathorne\4B-6__225.$ls | |

Volume Statistics (Arithmetic) 4B-6__225.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 43.63 µm | S.D.: | 71.77 µm |
| Median: | 13.05 µm | Variance: | 5151 µm$^2$ |
| Mean/Median ratio: | 3.344 | C.V.: | 164% |
| Mode: | 5.878 µm | Skewness: | 3.654 Right skewed |
| | | Kurtosis: | 18.06 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 2.075 µm | 4.459 µm | 13.05 µm | 56.38 µm | 120.6 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

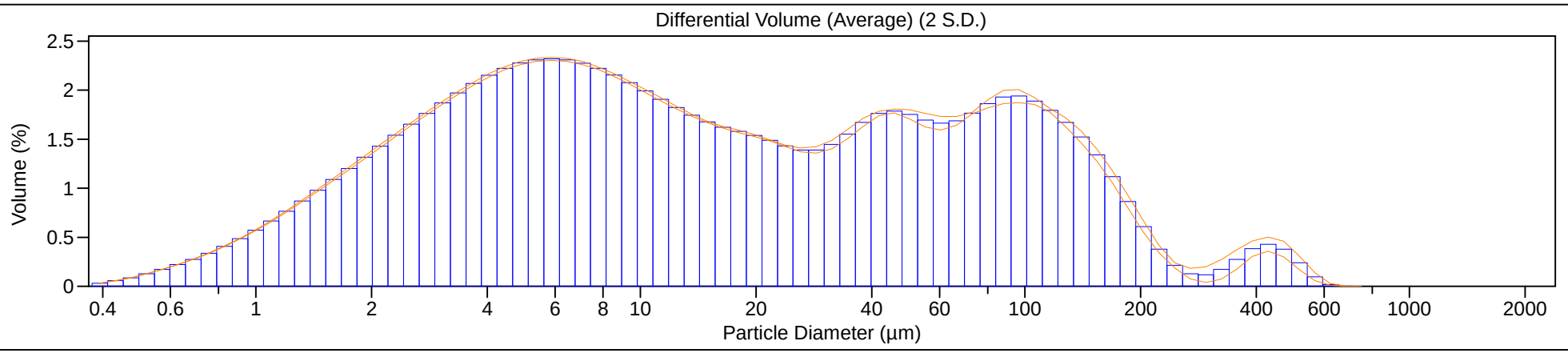
| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\4B-6__228.$av |
| | 4B-6__228.$av |
| File ID: | 4B-6 |
| Operator: | Reyes |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |
| Average of 3 files: | |
| C:\LS13320\Projects\Heckathorne\4B-6__226.$ls | |
| C:\LS13320\Projects\Heckathorne\4B-6__227.$ls | |
| C:\LS13320\Projects\Heckathorne\4B-6__228.$ls | |

Volume Statistics (Arithmetic) 4B-6__228.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 44.58 µm | S.D.: | 74.14 µm |
| Median: | 12.99 µm | Variance: | 5496 µm$^2$ |
| Mean/Median ratio: | 3.431 | C.V.: | 166% |
| Mode: | 5.878 µm | Skewness: | 3.477 Right skewed |
| | | Kurtosis: | 15.50 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 2.057 µm | 4.407 µm | 12.99 µm | 56.21 µm | 121.6 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\5B-14__334.$av |
| | 5B-14__334.$av |
| File ID: | 5B-14 |
| Operator: | Reyes/Szesciorka |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

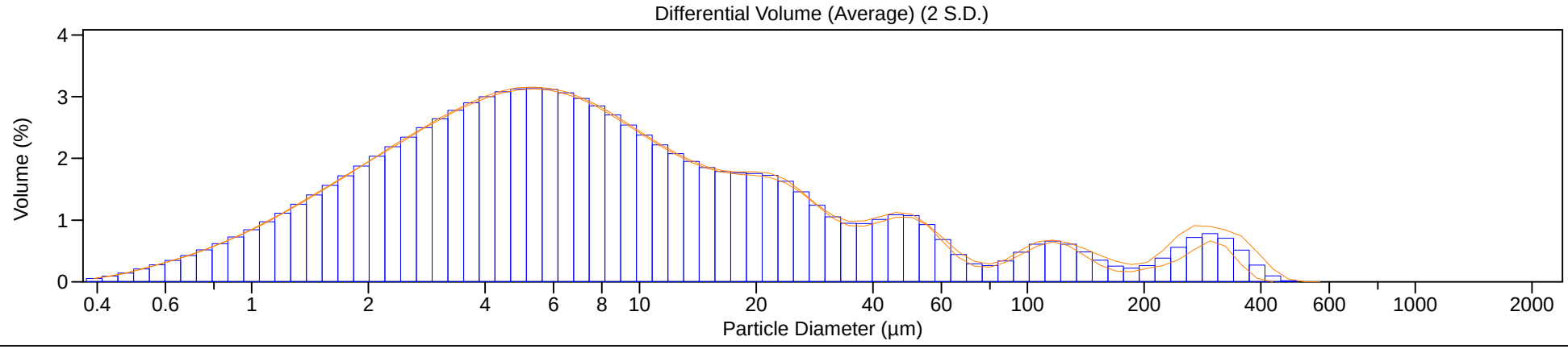
Average of 3 files:
C:\LS13320\Projects\Heckathorne\5B-14__332.$ls
C:\LS13320\Projects\Heckathorne\5B-14__333.$ls
C:\LS13320\Projects\Heckathorne\5B-14__334.$ls

Volume Statistics (Arithmetic) 5B-14__334.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 28.13 µm | S.D.: | 63.46 µm |
| Median: | 6.751 µm | Variance: | 4027 $\mu m^2$ |
| Mean/Median ratio: | 4.167 | C.V.: | 226% |
| Mode: | 5.355 µm | Skewness: | 3.762 Right skewed |
| | | Kurtosis: | 14.50 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.616 µm | 3.114 µm | 6.751 µm | 18.73 µm | 57.84 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\5B-2__349.$av |
| | 5B-2__349.$av |
| File ID: | 5B-2 |
| Operator: | Reyes/Szesciorka |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

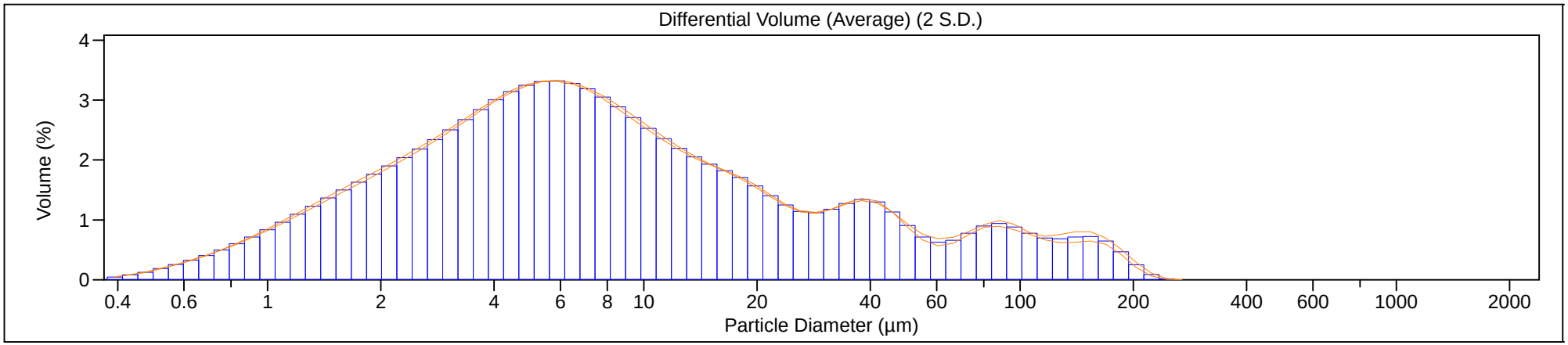
Average of 3 files:
C:\LS13320\Projects\Heckathorne\5B-2__347.$ls
C:\LS13320\Projects\Heckathorne\5B-2__348.$ls
C:\LS13320\Projects\Heckathorne\5B-2__349.$ls

Volume Statistics (Arithmetic) 5B-2__349.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 20.47 µm | S.D.: | 34.79 µm |
| Median: | 6.885 µm | Variance: | 1211 µm$^2$ |
| Mean/Median ratio: | 2.973 | C.V.: | 170% |
| Mode: | 5.878 µm | Skewness: | 2.954 Right skewed |
| | | Kurtosis: | 9.110 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.646 µm | 3.254 µm | 6.885 µm | 18.05 µm | 56.71 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

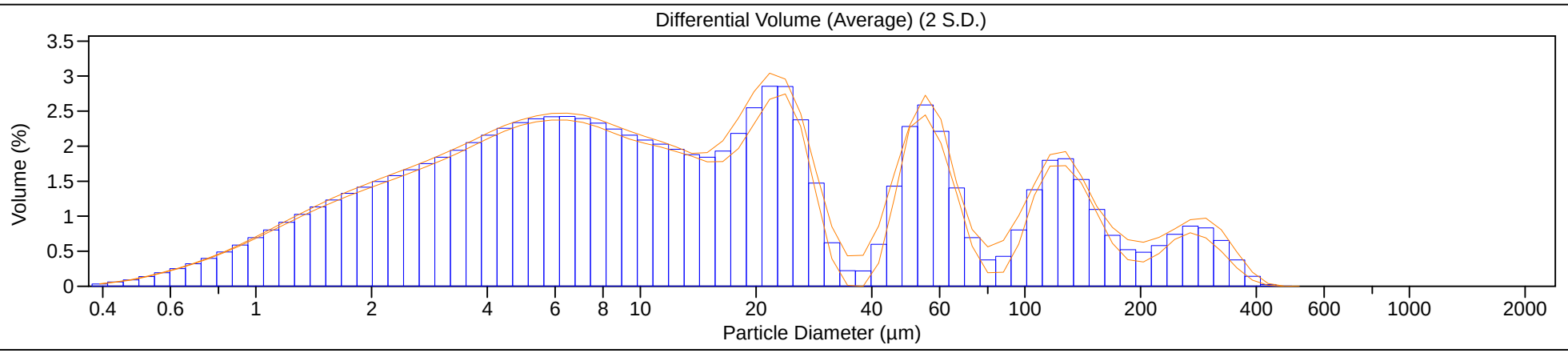
| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\5B-3__313.$av |
| | 5B-3__313.$av |
| File ID: | 5B-3 |
| Operator: | Reyes/Szesciorka |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| | Run length: 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |
| Average of 3 files: | |
| C:\LS13320\Projects\Heckathorne\5B-3__311.$ls | |
| C:\LS13320\Projects\Heckathorne\5B-3__312.$ls | |
| C:\LS13320\Projects\Heckathorne\5B-3__313.$ls | |

Volume Statistics (Arithmetic) 5B-3__313.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 39.74 µm | S.D.: | 66.31 µm |
| Median: | 11.49 µm | Variance: | 4396 µm$^2$ |
| Mean/Median ratio: | 3.458 | C.V.: | 167% |
| Mode: | 21.70 µm | Skewness: | 2.682 Right skewed |
| | | Kurtosis: | 7.506 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.870 µm | 4.137 µm | 11.49 µm | 46.03 µm | 124.4 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\5B-4__325.$av |
| | 5B-4__325.$av |
| File ID: | 5B-4 |
| Operator: | Reyes/Szesciorka |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

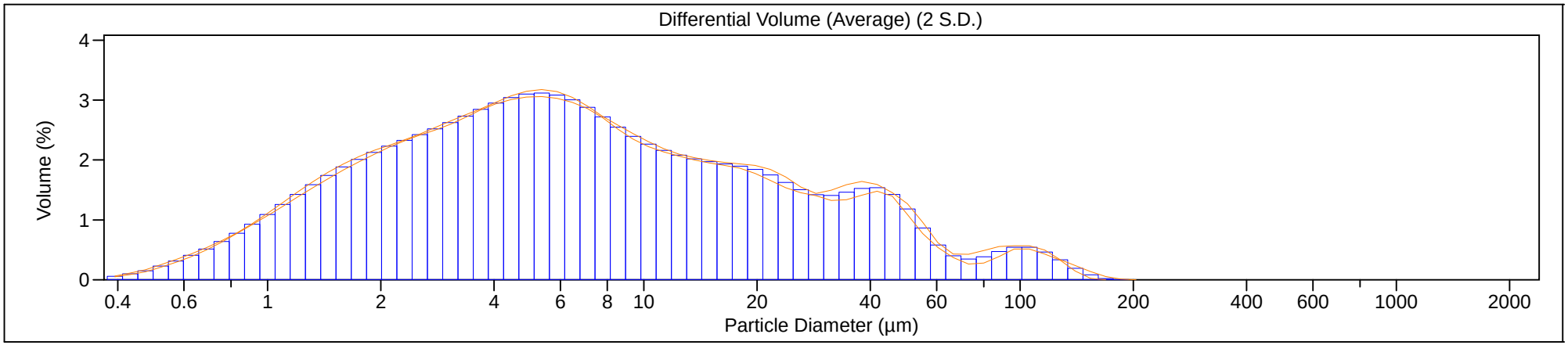
Average of 3 files:
C:\LS13320\Projects\Heckathorne\5B-4__323.$ls
C:\LS13320\Projects\Heckathorne\5B-4__324.$ls
C:\LS13320\Projects\Heckathorne\5B-4__325.$ls

Volume Statistics (Arithmetic) 5B-4__325.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 14.42 µm | S.D.: | 21.40 µm |
| Median: | 6.120 µm | Variance: | 458.0 µm$^2$ |
| Mean/Median ratio: | 2.356 | C.V.: | 148% |
| Mode: | 5.355 µm | Skewness: | 3.084 Right skewed |
| | | Kurtosis: | 11.35 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.426 µm | 2.741 µm | 6.120 µm | 16.24 µm | 38.31 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\5B-5__340.$av |
| | 5B-5__340.$av |
| File ID: | 5B-5 |
| Operator: | Reyes/Szesciorka |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

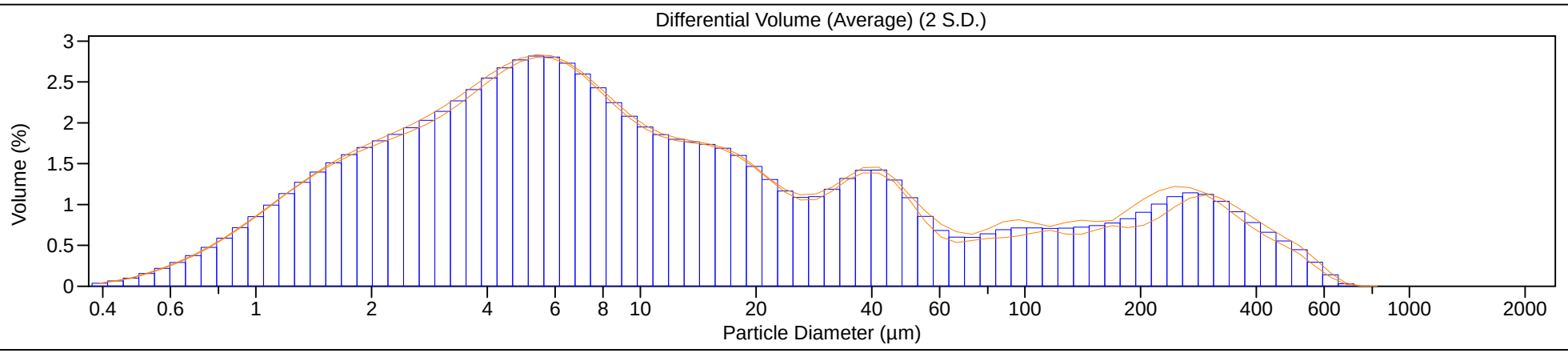
Average of 3 files:
C:\LS13320\Projects\Heckathorne\5B-5__338.$ls
C:\LS13320\Projects\Heckathorne\5B-5__339.$ls
C:\LS13320\Projects\Heckathorne\5B-5__340.$ls

Volume Statistics (Arithmetic) 5B-5__340.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 52.87 µm | S.D.: | 104.3 µm |
| Median: | 8.400 µm | Variance: | 10880 $\mu m^2$ |
| Mean/Median ratio: | 6.294 | C.V.: | 197% |
| Mode: | 5.355 µm | Skewness: | 2.762 Right skewed |
| | | Kurtosis: | 7.635 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.650 µm | 3.448 µm | 8.400 µm | 37.13 µm | 197.2 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | | | |
|---|---|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\6-1__279.$av | | |
| | 6-1__279.$av | | |
| File ID: | 6-1 | | |
| Operator: | Reyes | | |
| Comment 1: | Heckathorne | | |
| Comment 2: | mixed, blended | | |
| Optical model: | garnet.rf780z | | |
| LS 13 320 SW | Aqueous Liquid Module | | |
| | | Run length: | 60 seconds |
| Pump speed: | 66 | | |
| Fluid: | water | | |

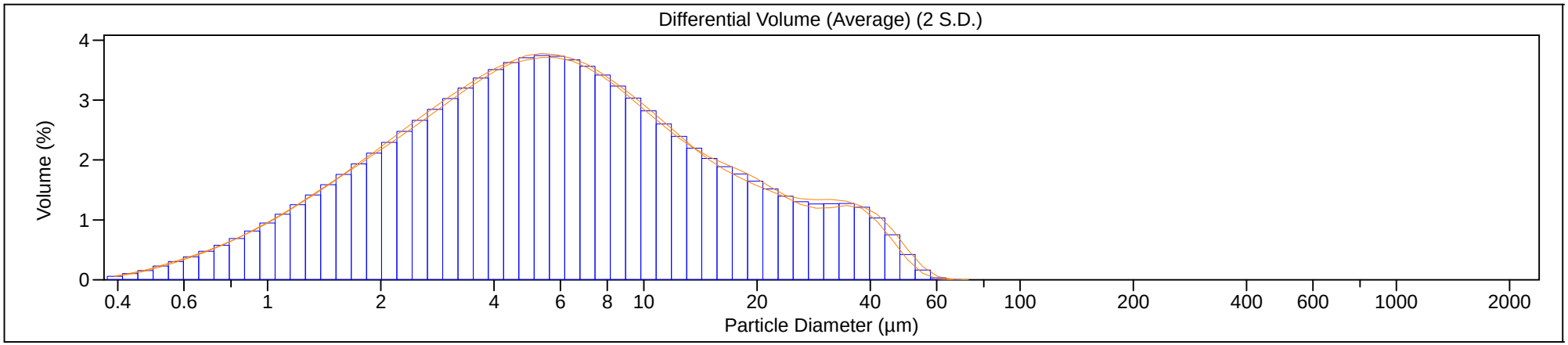
Average of 3 files:
C:\LS13320\Projects\Heckathorne\6-1__277.$ls
C:\LS13320\Projects\Heckathorne\6-1__278.$ls
C:\LS13320\Projects\Heckathorne\6-1__279.$ls

Volume Statistics (Arithmetic) 6-1__279.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 9.207 µm | S.D.: | 9.924 µm |
| Median: | 5.563 µm | Variance: | 98.48 µm$^2$ |
| Mean/Median ratio: | 1.655 | C.V.: | 108% |
| Mode: | 5.355 µm | Skewness: | 2.037 Right skewed |
| | | Kurtosis: | 4.109 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.512 µm | 2.813 µm | 5.563 µm | 11.25 µm | 22.94 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | | | |
|---|---|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\6-2__213.$av | | |
| | 6-2__213.$av | | |
| File ID: | 6-2 | | |
| Operator: | Szesciorka | | |
| Comment 1: | Heckathorne | | |
| Comment 2: | mixed, blended | | |
| Optical model: | garnet.rf780z | | |
| LS 13 320 SW | Aqueous Liquid Module | | |
| | | Run length: | 60 seconds |
| Pump speed: | 66 | | |
| Fluid: | water | | |

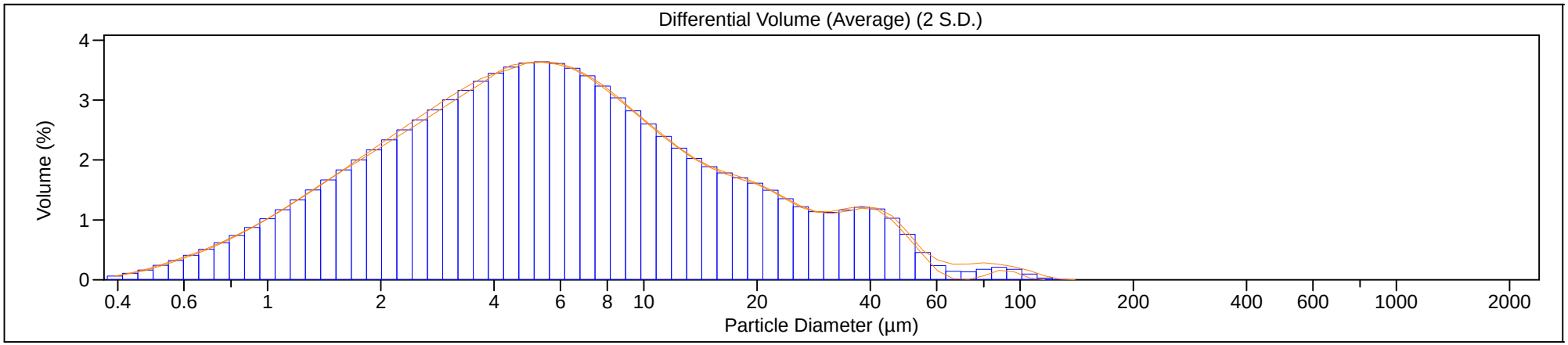
Average of 3 files:
C:\LS13320\Projects\Heckathorne\6-2__211.$ls
C:\LS13320\Projects\Heckathorne\6-2__212.$ls
C:\LS13320\Projects\Heckathorne\6-2__213.$ls

Volume Statistics (Arithmetic) 6-2__213.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 10.28 µm | S.D.: | 13.24 µm |
| Median: | 5.498 µm | Variance: | 175.4 µm$^2$ |
| Mean/Median ratio: | 1.869 | C.V.: | 129% |
| Mode: | 5.355 µm | Skewness: | 3.028 Right skewed |
| | | Kurtosis: | 12.32 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.461 µm | 2.729 µm | 5.498 µm | 11.63 µm | 25.92 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\6-3__240.$av |
| | 6-3__240.$av |
| File ID: | 6-3 |
| Operator: | Reyes |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

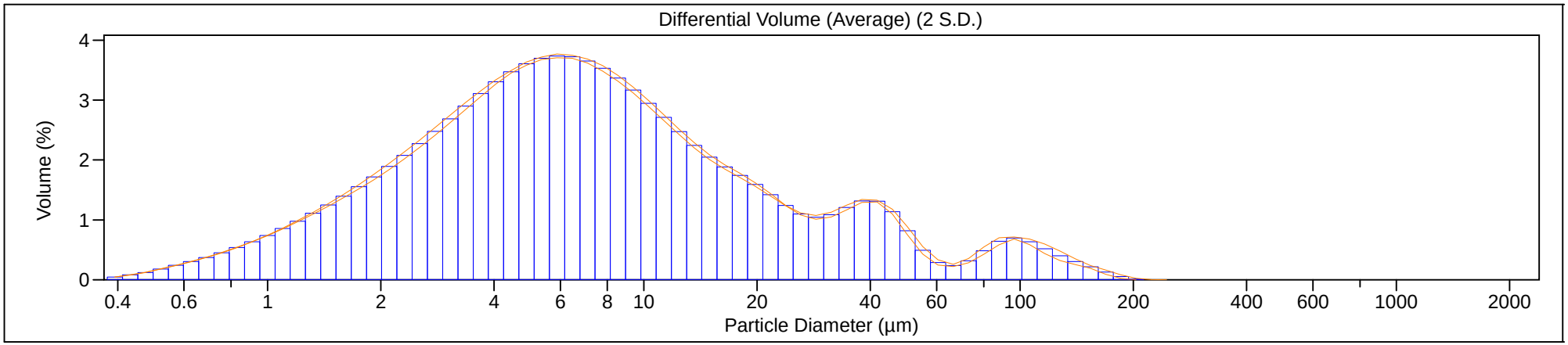
Average of 3 files:
C:\LS13320\Projects\Heckathorne\6-3__238.$ls
C:\LS13320\Projects\Heckathorne\6-3__239.$ls
C:\LS13320\Projects\Heckathorne\6-3__240.$ls

Volume Statistics (Arithmetic) 6-3__240.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 14.67 µm | S.D.: | 23.60 µm |
| Median: | 6.515 µm | Variance: | 556.9 µm$^2$ |
| Mean/Median ratio: | 2.251 | C.V.: | 161% |
| Mode: | 5.878 µm | Skewness: | 3.506 Right skewed |
| | | Kurtosis: | 14.08 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.742 µm | 3.317 µm | 6.515 µm | 13.91 µm | 36.30 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

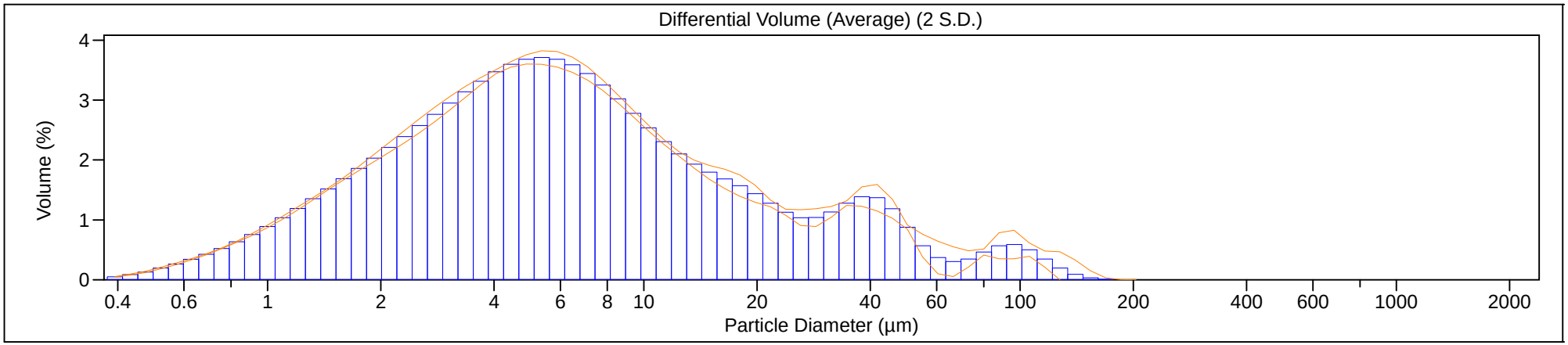
| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\6-4__243.$av |
| | 6-4__243.$av |
| File ID: | 6-4 |
| Operator: | Reyes |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| | Run length: 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |
| Average of 3 files: | |
| C:\LS13320\Projects\Heckathorne\6-4__241.$ls | |
| C:\LS13320\Projects\Heckathorne\6-4__242.$ls | |
| C:\LS13320\Projects\Heckathorne\6-4__243.$ls | |

Volume Statistics (Arithmetic) 6-4__243.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 12.87 µm | S.D.: | 19.57 µm |
| Median: | 5.795 µm | Variance: | 383.0 µm$^2$ |
| Mean/Median ratio: | 2.221 | C.V.: | 152% |
| Mode: | 5.355 µm | Skewness: | 3.272 Right skewed |
| | | Kurtosis: | 12.47 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.573 µm | 2.929 µm | 5.795 µm | 12.73 µm | 34.27 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

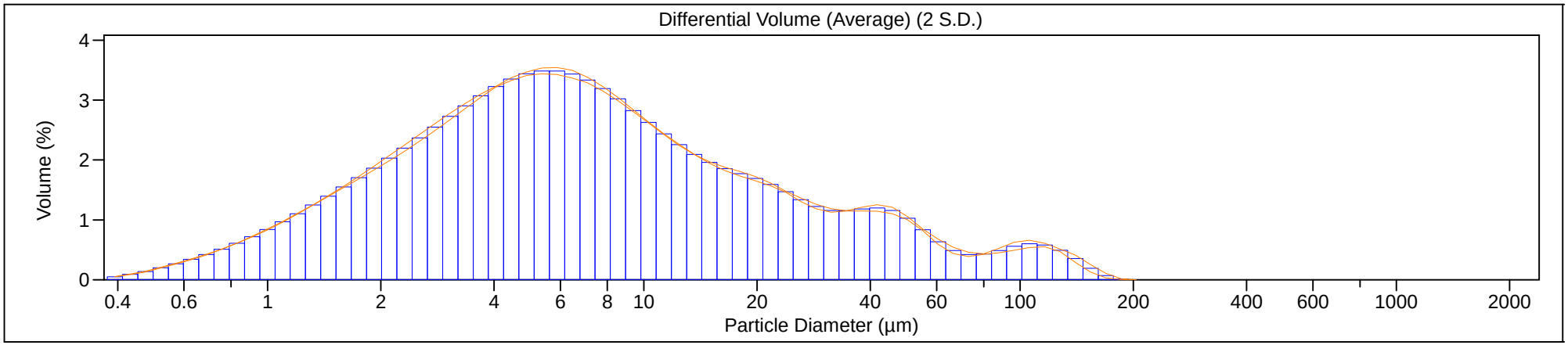
File name: C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\6-5__198.$av
6-5__198.$av
File ID: 6-5
Operator: Szesciorka
Comment 1: Heckathorne
Comment 2: mixed, blended
Optical model: garnet.rf780z
LS 13 320 SW Aqueous Liquid Module
Run length: 60 seconds
Pump speed: 66
Fluid: water
Average of 3 files:
C:\LS13320\Projects\Heckathorne\6-5__196.$ls
C:\LS13320\Projects\Heckathorne\6-5__197.$ls
C:\LS13320\Projects\Heckathorne\6-5__198.$ls

Volume Statistics (Arithmetic) 6-5__198.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 14.95 µm | S.D.: | 23.50 µm |
| Median: | 6.361 µm | Variance: | 552.0 µm$^2$ |
| Mean/Median ratio: | 2.351 | C.V.: | 157% |
| Mode: | 5.355 µm | Skewness: | 3.256 Right skewed |
| | | Kurtosis: | 11.99 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.625 µm | 3.112 µm | 6.361 µm | 14.93 µm | 38.44 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\7-1__316.$av |
| | 7-1__316.$av |
| File ID: | 7-1 |
| Operator: | Reyes/Szesciorka |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

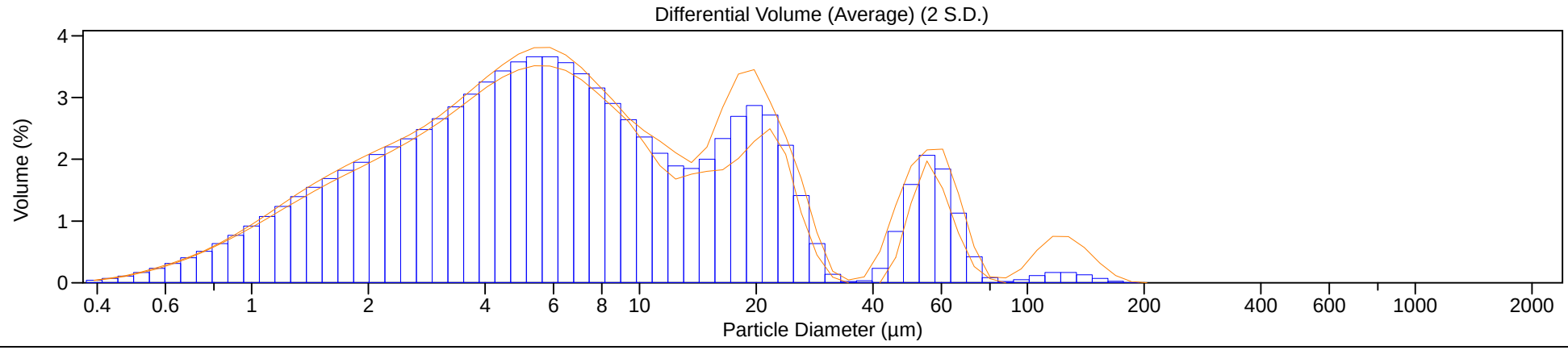
Average of 3 files:
C:\LS13320\Projects\Heckathorne\7-1__314.$ls
C:\LS13320\Projects\Heckathorne\7-1__315.$ls
C:\LS13320\Projects\Heckathorne\7-1__316.$ls

Volume Statistics (Arithmetic) 7-1__316.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 12.83 µm | S.D.: | 18.07 µm |
| Median: | 6.142 µm | Variance: | 326.5 µm$^2$ |
| Mean/Median ratio: | 2.088 | C.V.: | 141% |
| Mode: | 5.878 µm | Skewness: | 3.213 Right skewed |
| | | Kurtosis: | 13.93 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.570 µm | 3.030 µm | 6.142 µm | 14.98 µm | 27.02 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\7-2__310.$av |
| | 7-2__310.$av |
| File ID: | 7-2 |
| Operator: | Reyes/Szesciorka |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

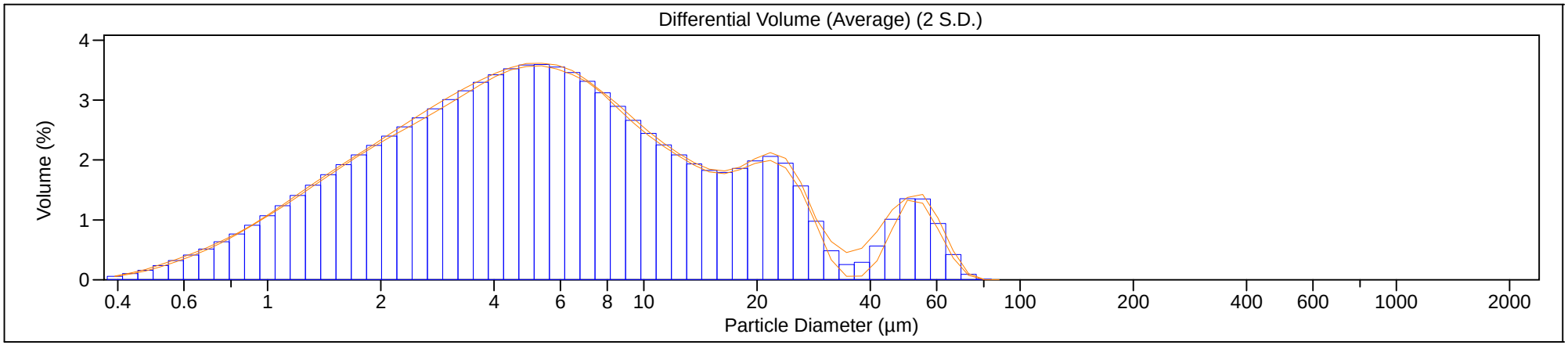
Average of 3 files:
C:\LS13320\Projects\Heckathorne\7-2__308.$ls
C:\LS13320\Projects\Heckathorne\7-2__309.$ls
C:\LS13320\Projects\Heckathorne\7-2__310.$ls

Volume Statistics (Arithmetic) 7-2__310.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 10.19 µm | S.D.: | 12.77 µm |
| Median: | 5.401 µm | Variance: | 163.1 µm$^2$ |
| Mean/Median ratio: | 1.887 | C.V.: | 125% |
| Mode: | 5.355 µm | Skewness: | 2.440 Right skewed |
| | | Kurtosis: | 5.992 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.431 µm | 2.654 µm | 5.401 µm | 11.74 µm | 24.18 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\7-3__337.$av |
| | 7-3__337.$av |
| File ID: | 7-3 |
| Operator: | Reyes/Szesciorka |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

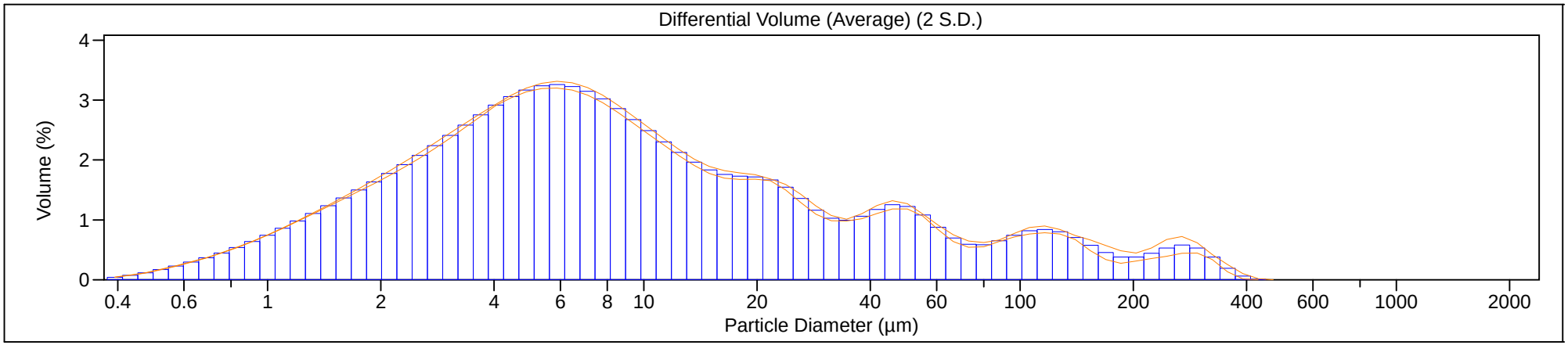
Average of 3 files:
C:\LS13320\Projects\Heckathorne\7-3__335.$ls
C:\LS13320\Projects\Heckathorne\7-3__336.$ls
C:\LS13320\Projects\Heckathorne\7-3__337.$ls

Volume Statistics (Arithmetic) 7-3__337.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 27.40 µm | S.D.: | 54.29 µm |
| Median: | 7.394 µm | Variance: | 2947 µm$^2$ |
| Mean/Median ratio: | 3.705 | C.V.: | 198% |
| Mode: | 5.878 µm | Skewness: | 3.530 Right skewed |
| | | Kurtosis: | 13.61 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.753 µm | 3.475 µm | 7.394 µm | 21.19 µm | 72.69 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

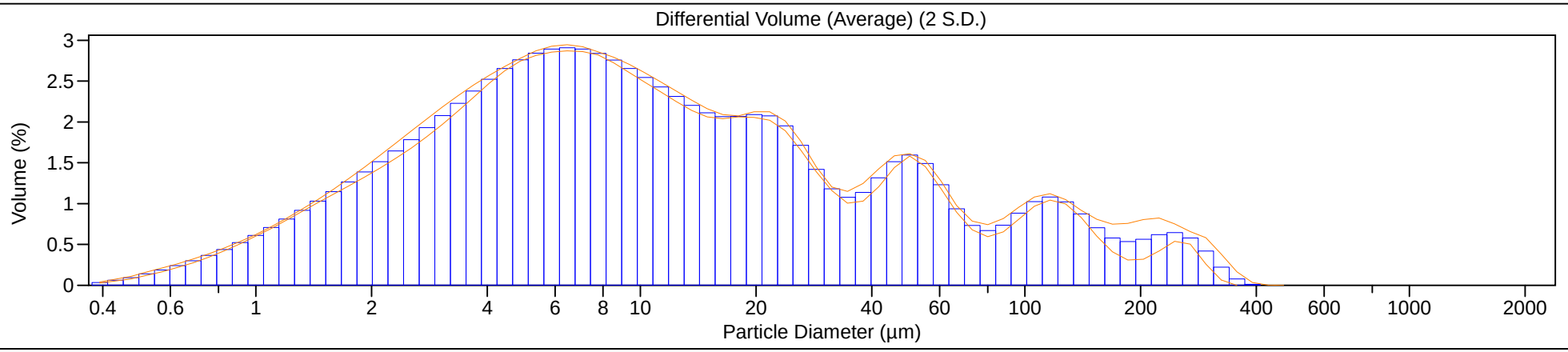
| | | | |
|---|---|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\7-4__03.$av | | |
| | 7-4__03.$av | | |
| File ID: | 7-4 | | |
| Operator: | Szesciorka | | |
| Comment 1: | Heckathorne | | |
| Comment 2: | mixed, sonicated | | |
| Optical model: | garnet.rf780z | | |
| LS 13 320 SW | Aqueous Liquid Module | | |
| | | Run length: | 60 seconds |
| Pump speed: | 66 | | |
| Fluid: | water | | |
| Average of 3 files: | | | |
| C:\LS13320\Projects\Heckathorne\7-4__01.$ls | | | |
| C:\LS13320\Projects\Heckathorne\7-4__02.$ls | | | |
| C:\LS13320\Projects\Heckathorne\7-4__03.$ls | | | |

Volume Statistics (Arithmetic) 7-4__03.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 30.53 µm | S.D.: | 53.33 µm |
| Median: | 9.310 µm | Variance: | 2844 µm$^2$ |
| Mean/Median ratio: | 3.279 | C.V.: | 175% |
| Mode: | 6.453 µm | Skewness: | 3.046 Right skewed |
| | | Kurtosis: | 10.02 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.976 µm | 4.039 µm | 9.310 µm | 27.24 µm | 90.46 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | | | |
|---|---|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\7-5__343.$av | | |
| | 7-5__343.$av | | |
| File ID: | 7-5 | | |
| Operator: | Reyes/Szesciorka | | |
| Comment 1: | Heckathorne | | |
| Comment 2: | mixed, blended | | |
| Optical model: | garnet.rf780z | | |
| LS 13 320 SW | Aqueous Liquid Module | | |
| | | Run length: | 60 seconds |
| Pump speed: | 66 | | |
| Fluid: | water | | |

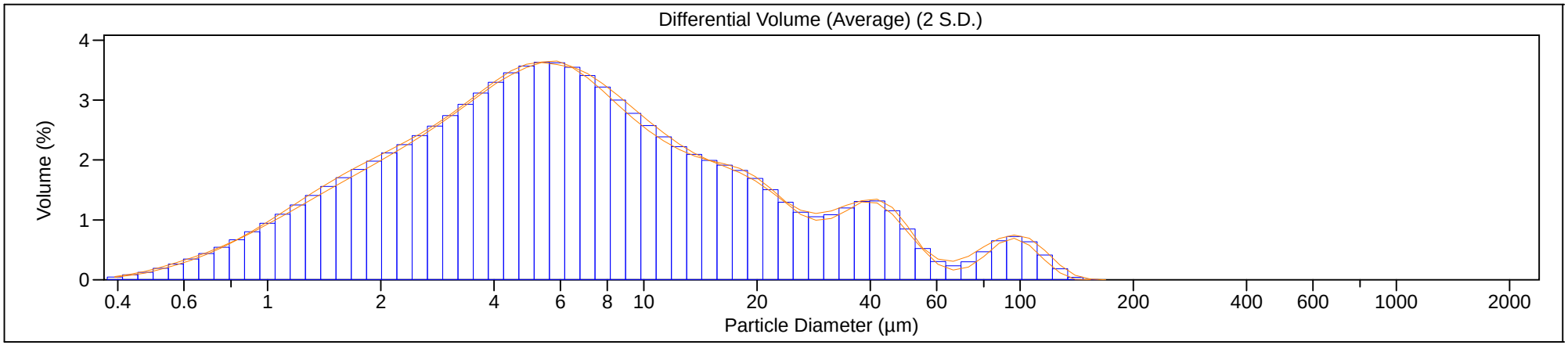
Average of 3 files:
C:\LS13320\Projects\Heckathorne\7-5__341.$ls
C:\LS13320\Projects\Heckathorne\7-5__342.$ls
C:\LS13320\Projects\Heckathorne\7-5__343.$ls

Volume Statistics (Arithmetic) 7-5__343.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 13.13 µm | S.D.: | 19.72 µm |
| Median: | 6.009 µm | Variance: | 389.0 µm$^2$ |
| Mean/Median ratio: | 2.185 | C.V.: | 150% |
| Mode: | 5.355 µm | Skewness: | 3.182 Right skewed |
| | | Kurtosis: | 11.34 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.541 µm | 2.958 µm | 6.009 µm | 13.52 µm | 33.82 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | | | |
|---|---|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\8-1__246.$av | | |
| | 8-1__246.$av | | |
| File ID: | 8-1 | | |
| Operator: | Reyes | | |
| Comment 1: | Heckathorne | | |
| Comment 2: | mixed, blended | | |
| Optical model: | garnet.rf780z | | |
| LS 13 320 SW | Aqueous Liquid Module | | |
| | | Run length: | 60 seconds |
| Pump speed: | 66 | | |
| Fluid: | water | | |

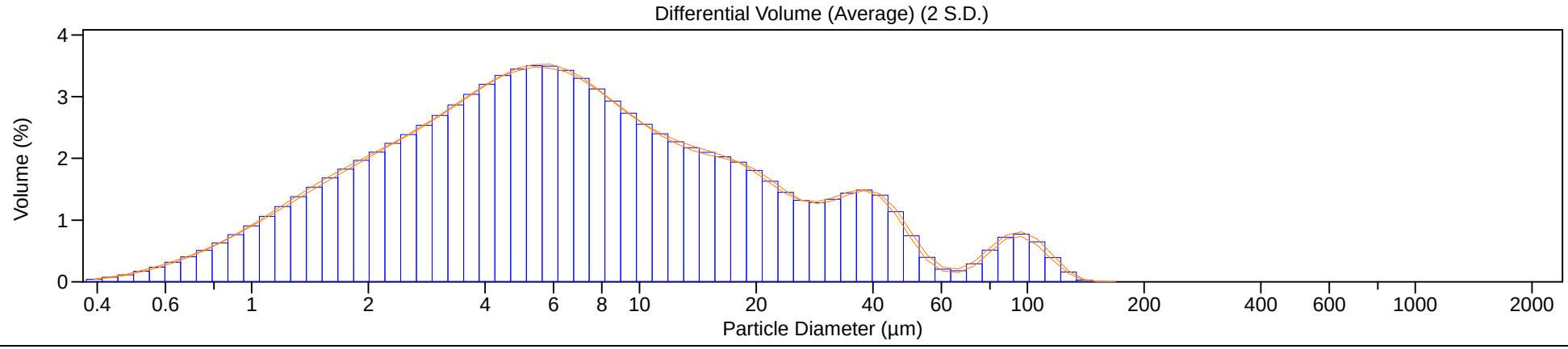
Average of 3 files:
C:\LS13320\Projects\Heckathorne\8-1__244.$ls
C:\LS13320\Projects\Heckathorne\8-1__245.$ls
C:\LS13320\Projects\Heckathorne\8-1__246.$ls

Volume Statistics (Arithmetic) 8-1__246.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 13.46 µm | S.D.: | 19.70 µm |
| Median: | 6.214 µm | Variance: | 387.9 µm$^2$ |
| Mean/Median ratio: | 2.166 | C.V.: | 146% |
| Mode: | 5.355 µm | Skewness: | 3.110 Right skewed |
| | | Kurtosis: | 10.88 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.576 µm | 3.015 µm | 6.214 µm | 14.54 µm | 34.20 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

File name: C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\8-2__249.$av
8-2__249.$av
File ID: 8-2
Operator: Reyes
Comment 1: Heckathorne
Comment 2: mixed, blended
Optical model: garnet.rf780z
LS 13 320 SW Aqueous Liquid Module
Run length: 60 seconds
Pump speed: 66
Fluid: water
Average of 3 files:
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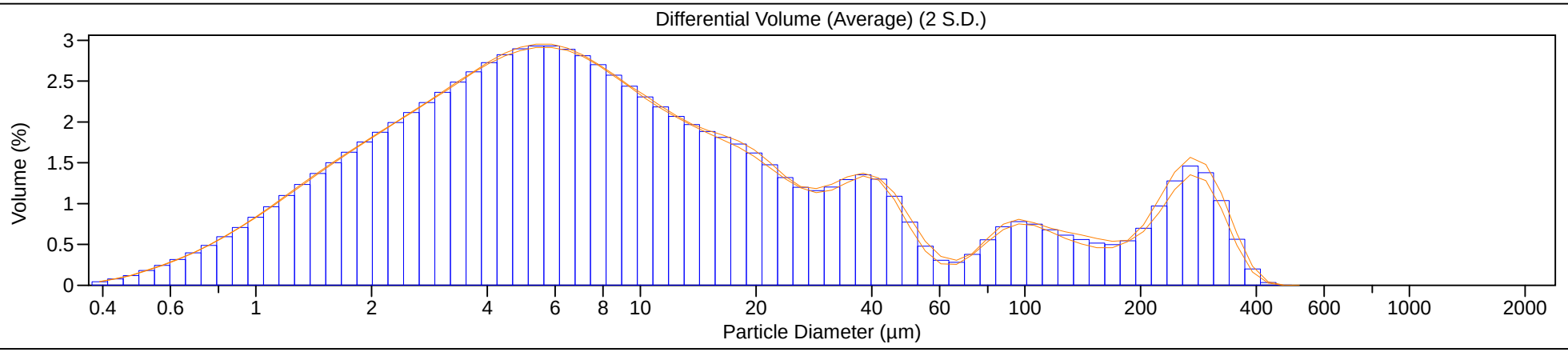
C:\LS13320\Projects\Heckathorne\8-2__248.$ls
C:\LS13320\Projects\Heckathorne\8-2__249.$ls

Volume Statistics (Arithmetic) 8-2__249.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 38.26 µm | S.D.: | 76.01 µm |
| Median: | 7.623 µm | Variance: | 5777 µm$^2$ |
| Mean/Median ratio: | 5.018 | C.V.: | 199% |
| Mode: | 5.355 µm | Skewness: | 2.702 Right skewed |
| | | Kurtosis: | 6.484 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.651 µm | 3.314 µm | 7.623 µm | 24.41 µm | 128.9 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

File name: C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\8-3__261.$av
8-3__261.$av
File ID: 8-3
Operator: Reyes
Comment 1: Heckathorne
Comment 2: mixed, blended
Optical model: garnet.rf780z
LS 13 320 SW Aqueous Liquid Module
Run length: 60 seconds
Pump speed: 66
Fluid: water
Average of 3 files:
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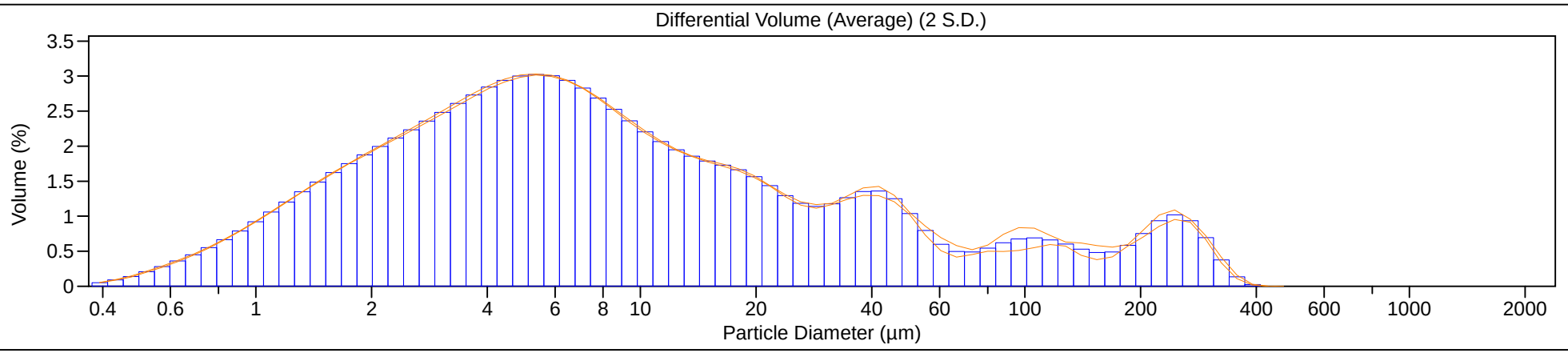
C:\LS13320\Projects\Heckathorne\8-3__260.$ls
C:\LS13320\Projects\Heckathorne\8-3__261.$ls

Volume Statistics (Arithmetic) 8-3__261.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 30.08 µm | S.D.: | 60.36 µm |
| Median: | 6.962 µm | Variance: | 3643 µm$^2$ |
| Mean/Median ratio: | 4.320 | C.V.: | 201% |
| Mode: | 5.355 µm | Skewness: | 3.090 Right skewed |
| | | Kurtosis: | 9.340 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.555 µm | 3.085 µm | 6.962 µm | 21.61 µm | 86.70 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\9-1__328.$av |
| | 9-1__328.$av |
| File ID: | 9-1 |
| Operator: | Reyes/Szesciorka |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

Average of 3 files:
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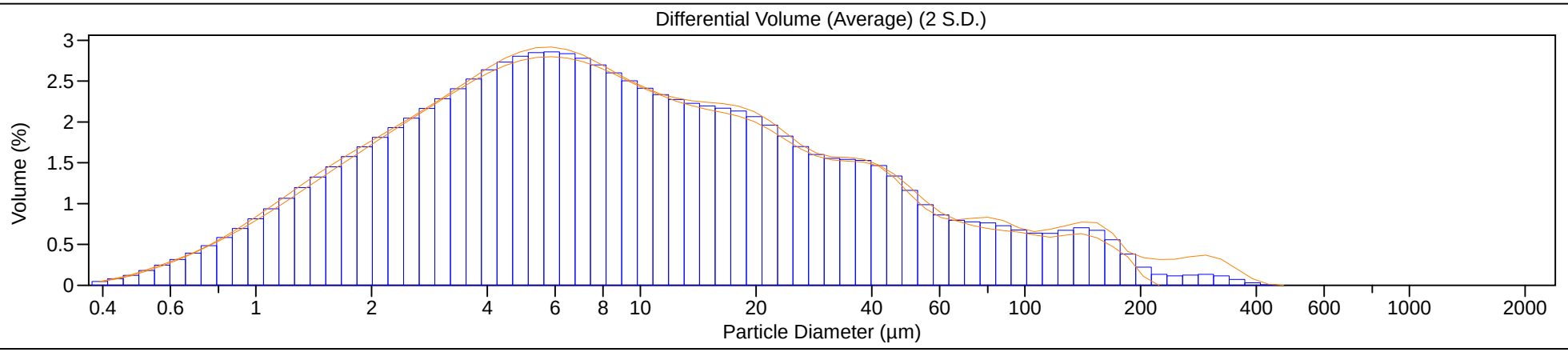
C:\LS13320\Projects\Heckathorne\9-1__327.$ls
C:\LS13320\Projects\Heckathorne\9-1__328.$ls

Volume Statistics (Arithmetic) 9-1__328.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 22.67 µm | S.D.: | 39.95 µm |
| Median: | 7.991 µm | Variance: | 1596 µm$^2$ |
| Mean/Median ratio: | 2.837 | C.V.: | 176% |
| Mode: | 5.878 µm | Skewness: | 3.835 Right skewed |
| | | Kurtosis: | 19.15 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.674 µm | 3.407 µm | 7.991 µm | 22.26 µm | 56.91 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\9-2__352.$av |
| | 9-2__352.$av |
| File ID: | 9-2 |
| Operator: | Reyes/Szesciorka |
| Comment 1: | Heckathorne |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

Average of 3 files:
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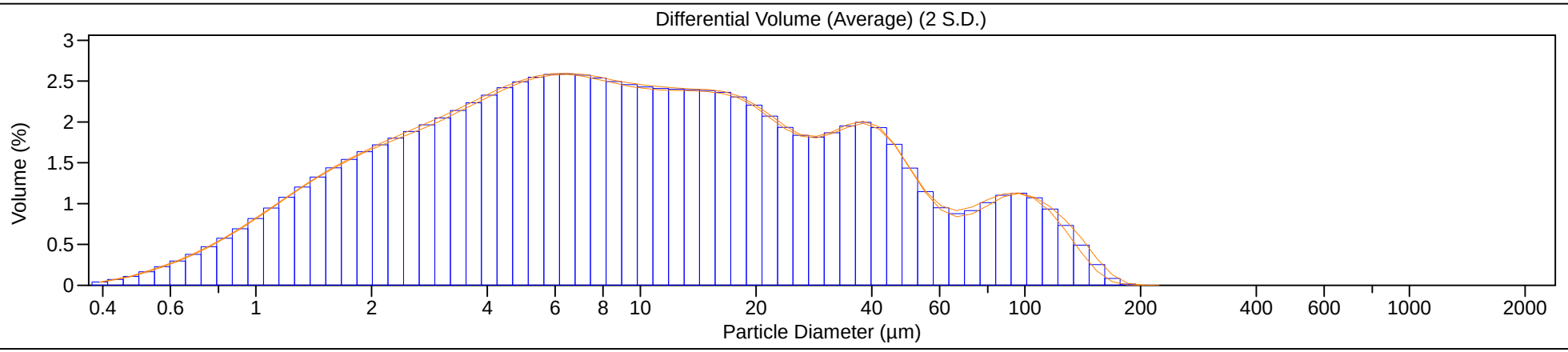
C:\LS13320\Projects\Heckathorne\9-2__351.$ls
C:\LS13320\Projects\Heckathorne\9-2__352.$ls

Volume Statistics (Arithmetic) 9-2__352.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 20.89 µm | S.D.: | 28.41 µm |
| Median: | 9.167 µm | Variance: | 807.1 µm$^2$ |
| Mean/Median ratio: | 2.279 | C.V.: | 136% |
| Mode: | 6.453 µm | Skewness: | 2.321 Right skewed |
| | | Kurtosis: | 5.495 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.685 µm | 3.584 µm | 9.167 µm | 25.32 µm | 55.85 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\10-1__162.$av |
| | 10-1__162.$av |
| File ID: | 10-1 |
| Operator: | Szesciorka |
| Comment 1: | Maurice River |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

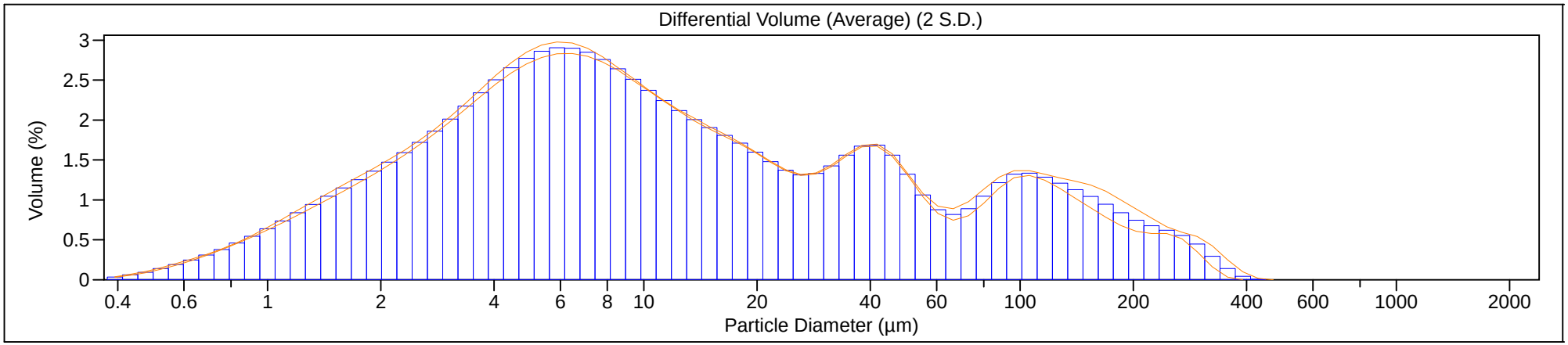
Average of 3 files:
C:\LS13320\Projects\Heckathorne\10-1__160.$ls
C:\LS13320\Projects\Heckathorne\10-1__161.$ls
C:\LS13320\Projects\Heckathorne\10-1__162.$ls

Volume Statistics (Arithmetic) 10-1__162.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 34.89 µm | S.D.: | 58.11 µm |
| Median: | 9.483 µm | Variance: | 3377 µm$^2$ |
| Mean/Median ratio: | 3.680 | C.V.: | 167% |
| Mode: | 5.878 µm | Skewness: | 2.679 Right skewed |
| | | Kurtosis: | 7.697 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.953 µm | 4.073 µm | 9.483 µm | 35.82 µm | 110.9 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\10-2__159.$av |
| | 10-2__159.$av |
| File ID: | 10-2 |
| Operator: | Szesciorka |
| Comment 1: | Maurice River |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

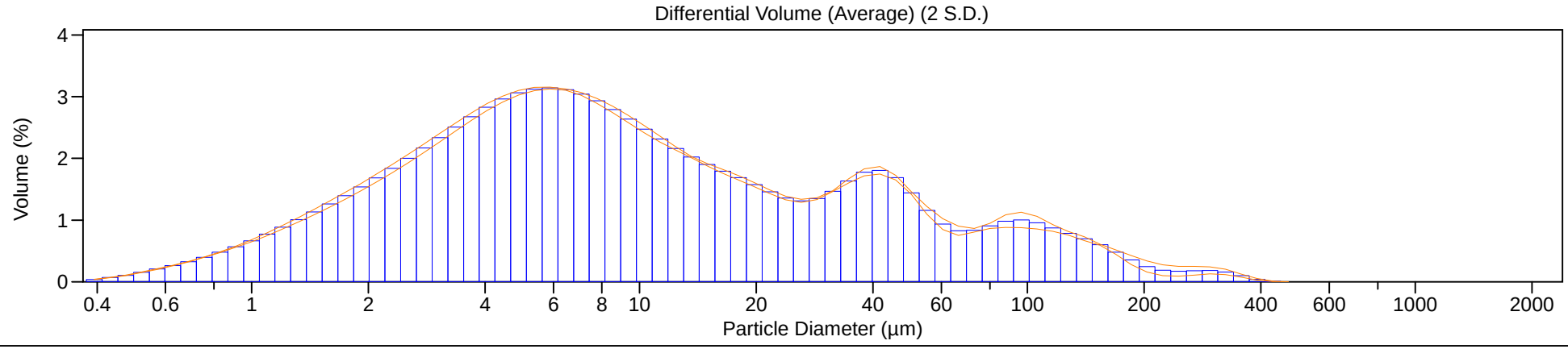
Average of 3 files:
C:\LS13320\Projects\Heckathorne\10-2__157.$ls
C:\LS13320\Projects\Heckathorne\10-2__158.$ls
C:\LS13320\Projects\Heckathorne\10-2__159.$ls

Volume Statistics (Arithmetic) 10-2__159.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 24.83 µm | S.D.: | 43.22 µm |
| Median: | 7.980 µm | Variance: | 1868 µm$^2$ |
| Mean/Median ratio: | 3.111 | C.V.: | 174% |
| Mode: | 5.878 µm | Skewness: | 3.652 Right skewed |
| | | Kurtosis: | 17.31 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.864 µm | 3.674 µm | 7.980 µm | 25.25 µm | 67.87 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\10-3__156.$av |
| | 10-3__156.$av |
| File ID: | 10-3 |
| Operator: | Szesciorka |
| Comment 1: | Maurice River |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

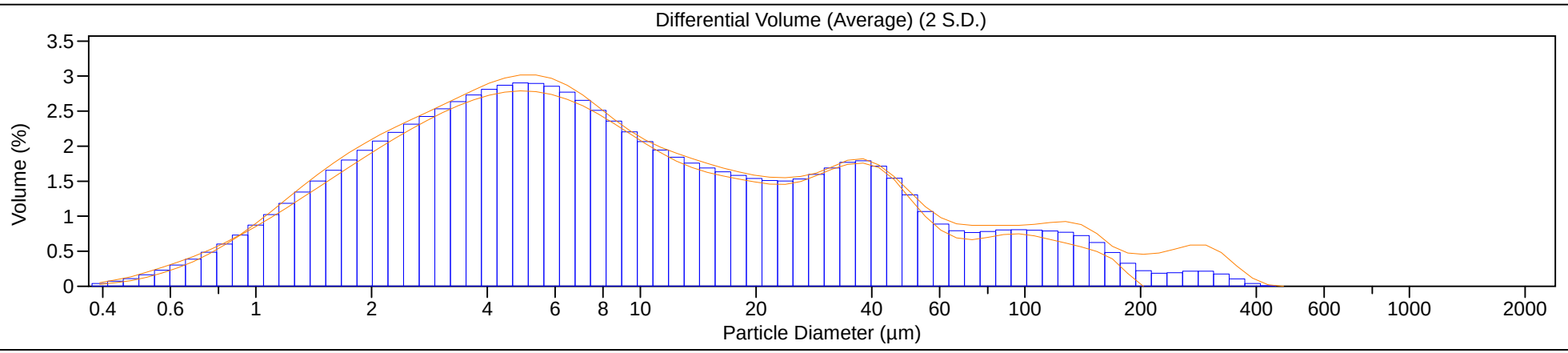
Average of 3 files:
C:\LS13320\Projects\Heckathorne\10-3__154.$ls
C:\LS13320\Projects\Heckathorne\10-3__155.$ls
C:\LS13320\Projects\Heckathorne\10-3__156.$ls

Volume Statistics (Arithmetic) 10-3__156.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 23.99 µm | S.D.: | 43.60 µm |
| Median: | 7.143 µm | Variance: | 1901 µm$^2$ |
| Mean/Median ratio: | 3.359 | C.V.: | 182% |
| Mode: | 4.878 µm | Skewness: | 3.782 Right skewed |
| | | Kurtosis: | 18.16 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.605 µm | 3.094 µm | 7.143 µm | 24.56 µm | 62.41 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\10-4__165.$av |
| | 10-4__165.$av |
| File ID: | 10-4 |
| Operator: | Szesciorka |
| Comment 1: | Maurice River |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

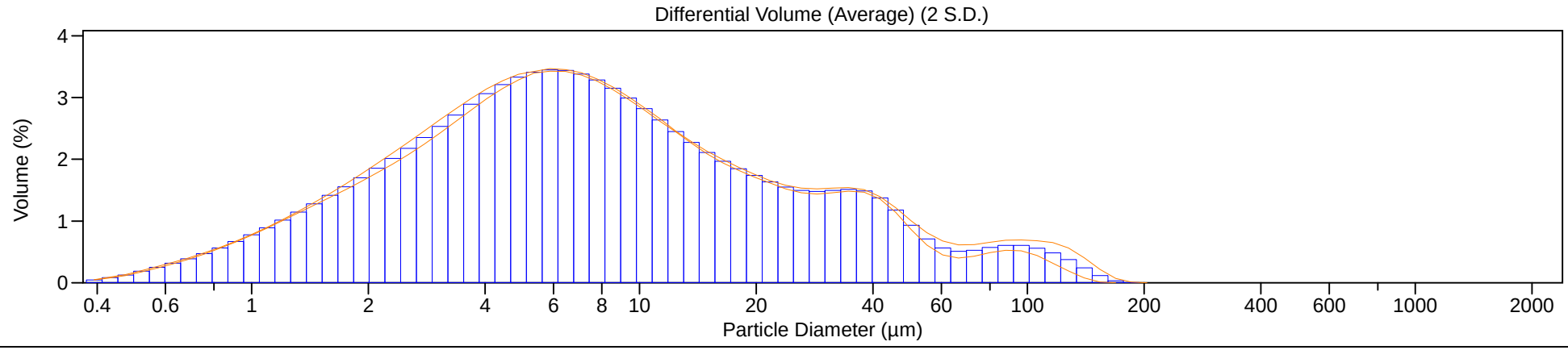
Average of 3 files:
C:\LS13320\Projects\Heckathorne\10-4__163.$ls
C:\LS13320\Projects\Heckathorne\10-4__164.$ls
C:\LS13320\Projects\Heckathorne\10-4__165.$ls

Volume Statistics (Arithmetic) 10-4__165.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 15.17 µm | S.D.: | 22.28 µm |
| Median: | 6.896 µm | Variance: | 496.4 µm$^2$ |
| Mean/Median ratio: | 2.200 | C.V.: | 147% |
| Mode: | 5.878 µm | Skewness: | 3.087 Right skewed |
| | | Kurtosis: | 11.01 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.708 µm | 3.343 µm | 6.896 µm | 16.12 µm | 38.34 µm |



# Beckman Coulter LS Particle Size Analyzer

6 Aug 2013

## Heckathorn

| | |
|---|---|
| File name: | C:\Users\Sam McWilliams\Desktop\sea_engineering\Sedflume\Heckathorne\Psd\10-5__168.$av |
| | 10-5__168.$av |
| File ID: | 10-5 |
| Operator: | Szesciorka |
| Comment 1: | Maurice River |
| Comment 2: | mixed, blended |
| Optical model: | garnet.rf780z |
| LS 13 320 SW | Aqueous Liquid Module |
| Run length: | 60 seconds |
| Pump speed: | 66 |
| Fluid: | water |

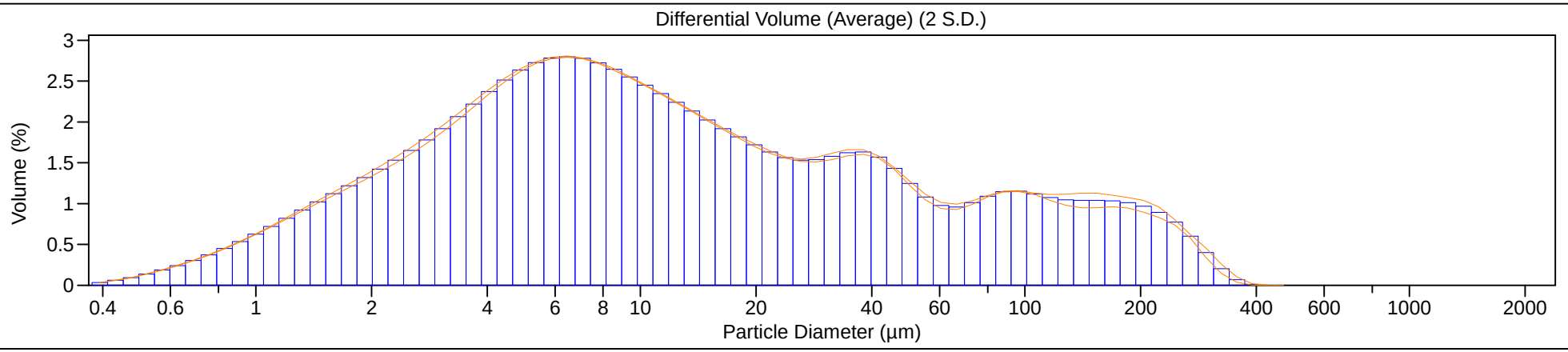
Average of 3 files:
C:\LS13320\Projects\Heckathorne\10-5__166.$ls
C:\LS13320\Projects\Heckathorne\10-5__167.$ls
C:\LS13320\Projects\Heckathorne\10-5__168.$ls

Volume Statistics (Arithmetic) 10-5__168.$av

Calculations from 0.375 µm to 2000 µm

| | | | |
|---|---|---|---|
| Volume: | 100% | | |
| Mean: | 35.38 µm | S.D.: | 58.03 µm |
| Median: | 10.09 µm | Variance: | 3367 µm$^2$ |
| Mean/Median ratio: | 3.505 | C.V.: | 164% |
| Mode: | 6.453 µm | Skewness: | 2.547 Right skewed |
| | | Kurtosis: | 6.516 Leptokurtic |

| <10% | <25% | <50% | <75% | <90% |
|---|---|---|---|---|
| 1.985 µm | 4.217 µm | 10.09 µm | 35.42 µm | 112.7 µm |



# Appendix E
# DDT Fate and Transport Study

# United Heckathorn Superfund Site, Richmond, California
# DDT Fate and Transport Study

**Final**

**May 2014**

**Prepared for:**
CH2M HILL under contract to EPA Region 9

**Prepared by:**
Sea Engineering, Inc.
200 Washington Street, Suite 101
Santa Cruz, CA 95060
Tel: (831) 421-0871

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# 1. Introduction

The United Heckathorn Superfund Site is located in Richmond Harbor on the east side of San Francisco Bay in Richmond, California (Figure 1). The site includes the former United Heckathorn facility where organochlorine pesticides were processed, packaged, and shipped. As a result of these activities, the adjacent waterways were adversely affected by releases from the former facility. A Record of Decision (ROD) that presented the selected remedial action for the site was issued in 1994 (USEPA, 1994). Remediation activities for the upland portion of the site consisted of excavation and offsite disposal of contaminated soil (from 1982 to 1993) and placement of concrete and geotextile/gravel caps (from 1998 to 1999) over approximately 4.5 acres of Levin Richmond Terminal Corporation's (LRTC) upland soils to prevent erosion and collect surface runoff. Remediation activities for the waterways were performed in 1996 and 1997 and consisted of (1) dredging and offsite disposal of sediment from the Lauritzen Channel and Parr Canal and (2) placement of clean sand in the channels to promote the recovery of the benthic community. However, post-dredging monitoring of surface water and sediment has indicated that the remediation levels specified in the ROD have not been maintained (EPA, 2012). A focused feasibility study (FFS) is being performed to address residual contamination in the channel sediment.

This report presents the results of a DDT[1] fate and transport study that was performed for the Lauritzen Channel as part of the FFS. The objectives of the study were as follows:

- Calculate the mass of DDT resuspended by vessel movements
- Develop a quantitative contaminant fate and transport conceptual site model (CSM) and DDT mass balance for the Lauritzen Channel
- Use the mass balance model to assess trends in DDT mass and concentration in sediment

The report synthesizes results of previous studies conducted at the study site. Section 1 is an introduction. Section 2 summarizes the refined CSM that incorporates the results of the source identification study (CH2MHILL, 2014), Tier 2 sediment transport study (SEI, 2014) and passive sampler studies (P. Gschwend & Burgess, 2012; P. M. Gschwend, 2014). Section 3 develops and presents a DDT mass analysis and mass balance for the Lauritzen Channel. The summary and conclusions are provided in Section 4.

[1] Dichlorodiphenyltrichloroethane; for the purposes of this report, "DDT" refers to the sum of all 4,4'- and 2,4'- isomers of DDT, DDD, and DDE.

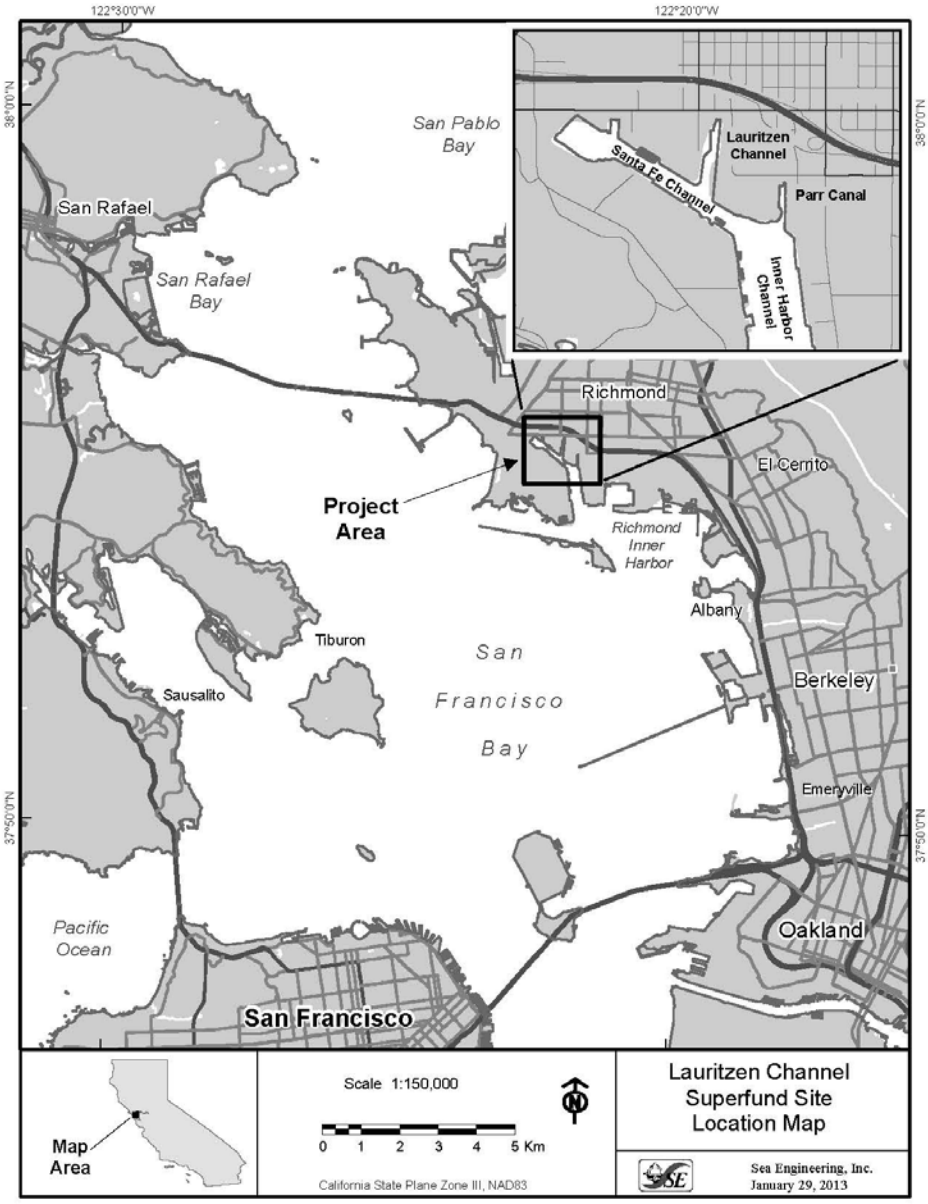


**Figure 1. Location of the United Heckathorn Superfund Site.**

# 2. Conceptual Site Model

The CSM provides the framework for evaluating DDT fate and transport. The CSM synthesizes available data, describes a mass balance (i.e., a simple representation of all inputs and outputs to a system), and describes inferred spatial and temporal transport patterns. The primary DDT sources and transport components are identified and described for the Lauritzen Channel in the source identification study and Tier 2 sediment transport study (CH2MHILL, 2014; Sea Engineering, 2014). The significant findings from these studies are summarized in the following sections.

## 2.1 Sources

The source identification study (CH2MHILL, 2014) characterized and quantified, to the extent possible, ongoing sources of contamination to the Lauritzen Channel. The study focused on identifying the sources of the DDT that have been consistently measured in sediment, surface water, and biota in the Lauritzen Channel since the remedy was completed in 1997. The potential ongoing sources of contamination that were evaluated included:

- Embankments (e.g., point source discharges from pipes, outfalls, and seeps; and/or erosion of DDT-contaminated embankment soils)
- Groundwater discharge from the upland portion of the site into the Lauritzen Channel
- DDT-contaminated wood pilings
- Storm water outfalls
- Sources outside of the Lauritzen Channel
- Dredging residuals (including both undisturbed [undredged] sediment, and material that was re-suspended during dredging, escaped from the dredge bucket, ran out of the scow, or sloughed into dredged areas); residuals also include contaminated embankment sediments that were not removed in either the upland or marine remedial actions)

The general conclusions for each potential source are listed in Table 1. Generally, while there are ongoing sources of DDT to the channel, they appear to be small relative to the mass of DDT in channel sediments. While some of the potential ongoing sources of contamination to the Lauritzen Channel could not be quantified, the mass balance analysis presented in Section 4 provides a suitable method for assessing their magnitude.

Important conclusions from the source identification study were drawn regarding the character of the primary source of sediment to the Lauritzen Channel (San Francisco Bay) and the primary source for the present day DDT in the channel. The available sediment chemistry data for areas outside of the Lauritzen Channel suggested that incoming material from the San Francisco Bay is a relatively clean source of sediment.[2] In light of the relatively small magnitude of the ongoing sources compared to the DDT mass currently found in the Lauritzen Channel sediments, the primary source to the sediment bed was concluded to be dredging residuals from the 1997 remedial efforts.

[2] The ambient threshold value for total DDT in San Francisco Bay sediments is 7 µg/kg for sediments with greater than 40% fines (Gandesbery and Hetzel, 1998).

**Table 1. Conclusions from the United Heckathorn Source Identification Study (CH2MHILL, 2014).**

**Conclusions of Source Identification Study**
*United Heckathorn Superfund Site, Richmond, California*

| Potential Ongoing Source | Character of Potential Source |
|---|---|
| Embankment Areas | Pipes and outfalls are unlikely to be significant sources of pesticides to the Lauritzen Channel during dry weather conditions because they do not convey dry weather flow. One seep that was sampled contained low levels of pesticides. Pipes and outfalls have not been inspected or sampled during wet weather conditions. Some of the identified and possible unidentified pipes and conveyances could have and may still act as preferential pathways for contaminant transport from upland areas with DDT-contaminated soil and groundwater to the Lauritzen Channel.<br><br>DDT contamination above the remediation goal is widespread along the eastern, northern, and northwestern shorelines of the channel. Although the shoreline is largely armored with rip rap, concrete, and sheetpile, fine-grained sediments are present in pockets in the rip rap and soils are eroding from under the sheetpile in some areas. |
| Groundwater Seepage | Estimated contribution to channel is approximately 170 g DDT per year, which is not sufficient to account for concentrations currently observed in sediments but continues to impact channel sediments, surface water, and biota. |
| Wood Pilings | Desorption is not a significant source of DDT to surface water or sediment. Mechanical weathering of the pilings could result in incorporation of DDT-contaminated particles into the sediment bed and potentially into the food web. |
| Stormwater Outfalls | The municipal storm drain system cannot be fully evaluated as an ongoing source of contamination until DDT-contaminated residual sediments are removed from the system.<br>The storm drain system that serves the upland cap on the Levin Richmond Terminal property is generally functioning as designed. Low levels of pesticides are periodically detected in stormwater samples. |
| Source Material Outside of the Lauritzen Channel | There were no sources of DDT outside of the Lauritzen Channel that were identified as having potential to act as an outside source to the site. |
| Areas Not Previously Dredged | Dredging residuals appear to be the primary source of present day contamination in the Lauritzen Channel. |

## 2.2 Sediment Transport Process Summary

The Lauritzen Channel is a low-energy, protected region with tidal velocities that are not likely to result in sediment resuspension. The low energy coupled with sediment input from San Francisco Bay result in a net sediment accumulation in the channel. Ongoing vessel operations in the channel are responsible for localized sediment bed resuspension (up to approximately 10 cm deep). The resuspended sediment is primarily deposited locally within the channel within a few 100 m from where it was resupended. In

the Tier 2 study, it was found that, on average, approximately 3.5% of resuspended sediment may also be tidally dispersed into the Santa Fe Channel.

The largest amount of sediment accumulation is in the berth on the east side of the Lauritzen Channel. The accumulation is occurring in the deep dredged region where currents are likely the lowest, causing the berth to behave as a sediment trap. Conversely, the west side of the channel, which experiences the highest vessel activity in relatively shallow regions, exhibits generally low accumulation of YBM. Finally, the head of the channel with low energy shallow water and moderate barge activity shows a moderate YBM accumulation and a mix of potential erosion and deposition. The general boundaries of these three regions (northern, eastern, and western) are illustrated in Figure 2.

While vessel resuspension is not a source of DDT to the Lauritzen Channel, it is responsible for the mixing of surface sediment, redistribution within the channel, and loss of DDT to the Santa Fe Channel. The Tier 2 sediment transport analysis showed that vessel activity can lead to sediment suspension by increasing near-bottom velocity. Vessel scour depth averages about 1.4 cm, with a maximum depth of about 10 cm (Sea Engineering, 2014). The wake caused by a vessel also has the potential of mobilizing sediment near or under piers and in shoreline areas throughout the channel as a whole; however, the mass of sediment suspended along the shorelines is very low in comparison to the sediment suspended behind a vessel.

The modeling simulations in the Tier 2 sediment transport analysis indicated that sediment deposition was negligible outside of the Lauritzen Channel one day after resuspension due to vessel activity. The results indicated that on average 96.5% of the sediment was deposited within Lauritzen Channel, resulting in an average loss of 3.5 % of resuspended sediment mass (Sea Engineering, 2014). Table 2 shows the average transport quantities for the vessel operations simulated in the Tier 2 sediment transport analysis. An average of 142 kg of sediment is resuspended during a typical vessel operation in the channel. Assuming one operation per day with a 3.5% loss of sediment to the Santa Fe Channel, approximately 1,800 kg of sediment is lost from the Lauritzen Channel due to vessel operations each year.

**Table 2. Transport quantities associated with vessel resuspension.**

| **Vessel Resuspension** | |
|---|---|
| Average Resuspension Mass (kg/event) | 142 |
| Average Percent Mass Lost (%/event) | 3.5 |
| Yearly Sediment Mass Lost (kg) | 1800 |

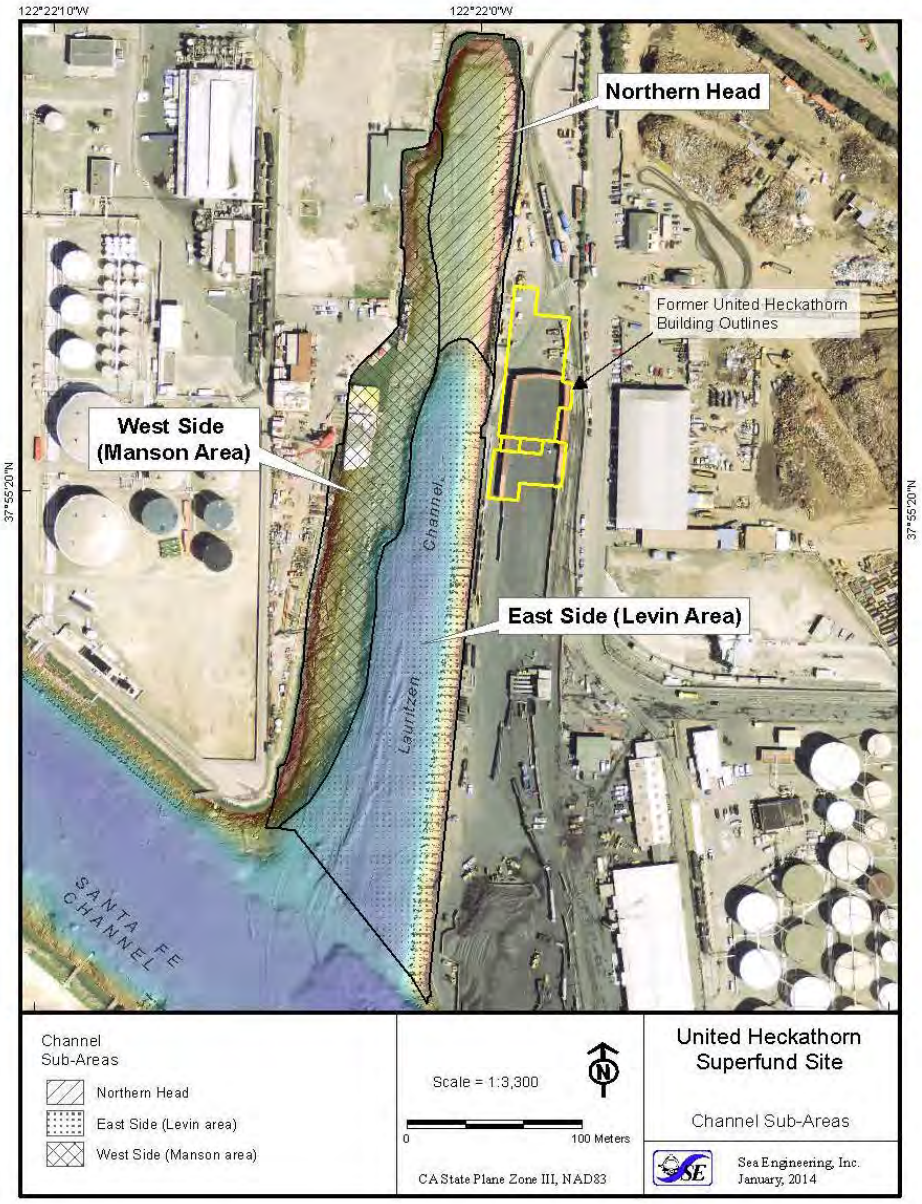


**Figure 2. Multibeam bathymetry and delineation of the three characterization areas.**

## 2.3 DDT Degradation

A long-term loss of DDT[3] occurs through natural degradation. Natural degradation involves the breakdown of DDT through physical, chemical and biological processes (Horsak, Bedient, Hamilton, & Thomas, 2006). Degradation rates and pathways for DDT vary widely depending on environmental conditions such as pH, availability of various nutrients and oxygen, temperature, and nature of the microbial populations. DDT undergoes goes aerobic and anaerobic degradation. Under anaerobic conditions, DDT typically degrades to DDD and its breakdown products, whereas DDE and its breakdown products are more typically found in aerobic systems (Walker, Schrieir, & Pucik, 2004; Yu, Lian, Liang, & Zeng, 2011).

The degradation rates of DDT in the Lauritzen Channel sediments are not known and cannot be determined without additional site-specific studies. However, high concentrations of DDT and its metabolites persist in sediment even though the pesticide processing activities at the site ended in 1966. Table 3 summarizes the relative contributions of the 2,4' and 4,4' isomers of DDT, DDD and DDE in surface sediment samples collected in 2013 from the characterization areas shown in Figure 2. Samples from the former plant site were collected along the embankment adjacent to the former United Heckathorn buildings (shown in yellow in Figure 2). These samples have the highest proportions of 4,4'-DDT (approximately 65%), indicating relatively non-degraded DDT deposits. For comparison, technical grade DDT contains 65-80% 4,4'-DDT (Metcalf, 1995). The most abundant metabolite in the northern head and west side of the channel is 4,4'-DDD (approximately 50%), indicating a more degraded contaminant mix, with degradation occurring under mostly anaerobic conditions. Given the limited information on degradation rates and the presence of non-degraded DDT, no loss term for DDT due to degradation is incorporated into the DDT mass balance presented in Section 3.

**Table 3. Average Composition of DDT and DDT Metabolites in Lauritzen Channel Surface Sediment**

| Area | Total DDT (µg/kg) | % 2,4'-DDD | % 2,4'-DDE | % 2,4'-DDT | % 4,4'-DDD | % 4,4'-DDE | % 4,4'-DDT |
|---|---|---|---|---|---|---|---|
| Former Plant Site | 32,401 | 4% | 0.5% | 12% | 14% | 7% | 64% |
| Northern Head[1] | 12,873 | 10% | 1% | 3% | 50% | 7% | 29% |
| West Side | 7,104 | 7% | 1% | 5% | 47% | 3% | 38% |
| East Side | 969 | 5% | 0.2% | 6% | 19% | 5% | 65% |

[1] Excluding one sample from the northwest corner of the channel with a total DDT concentration of 298,290 µg/kg composed of 90% 4,4'-DDT.

[3] Although the present report refers to DDT as the sum of all isomers, Sections 2.3 and 2.4 depart from this convention to discuss the individual isomers relevant to degradation.

## 2.4 Dissolved-phase DDT transport

The majority of the DDT in the Lauritzen Channel is associated with the particulate phase. However, adverse effects to biota from DDT may be more closely related to freely-dissolved concentrations in sediment porewater and surface water than to concentrations in bulk sediment. The freely-dissolved phase is the fraction of the total DDT load that is most available for exposure and uptake by aquatic organisms. Two passive sampler studies have been performed in the Lauritzen Channel to quantify the diffusive flux of DDT from the sediment bed to the overlying water column and infer dissolved DDT concentrations in porewater and surface water (P. Gschwend & Burgess, 2012; P. M. Gschwend, 2014). The results of the 2013 passive sampler study are provided in Appendix A. The key findings were as follows:

- Porewater and bottom water concentrations of DDT isomers and their degradation products in the Lauritzen Channel were found to be at similar levels in September 2013 as seen previously in March 2012, implying similar bed-to-water column diffusive fluxes.
- The 2013 water column data, inferred using passive samplers, could not be readily fit using a mass balance model that reflects only inputs via bed-to-water column diffusive fluxes and output via tidal flushing from a vertically well-mixed water column. The misfit between the measurements and this simple model suggests an important additional input of total DDT was occurring somewhere mid-channel or further south during the 2013 study. Such a source must be particularly enriched in non-degraded 4,4'-DDT relative to DDD and DDE and therefore cannot be explained by in-channel sediment resuspension.
- Comparison of water column concentrations inferred from passive samplers and mussel tissue suggests that mussels are accumulating DDT from both the seawater and resuspended solids in the water column. The results suggest that additional mussel accumulation is occurring due to resuspension from the sediment bed.

Overall the passive sampler study suggests that there is ongoing diffusion of DDT from the sediment, there is additional uptake of DDT from resuspended sediment, and that there is a source of non-degraded DDT from somewhere between the mid-channel and the mouth of the channel. The embankment adjacent to the former plant site is believed to be the source of the additional DDT. The low ratios of modeled to measured 4,4'-DDT (non-degraded DDT) surface water concentrations (Appendix A) correspond to the sections of the model that are adjacent to the former plant site. Although the mass balance model presented in Appendix A is relatively simple, the calculations are consistent with the observed sediment chemistry trends at the site. The 2013 sediment sampling data show that the embankment sediment adjacent to the former plant site has some of the highest total DDT concentrations in the Lauritzen Channel, and that 4,4'-DDT comprises the majority of the total DDT. The embankment is believed to be the source of the additional 4,4'-DDT seen in the surface water concentrations inferred from the passive samplers. As noted in the source identification study report (CH2M HILL, 2014), the previous removal actions along the embankment did not address sediment below about 0 feet mean lower low water (MLLW) or embankment soils with total DDT concentrations below 100 mg/kg. The dredging remedy extended only to the toe of the slope. Therefore, the high DDT concentrations that persist along the embankment adjacent to the former plant site appear to be

attributable to historical contamination that was not addressed in either the upland or the marine remedial actions.

## 3. DDT Mass Analysis

Hydrophobic contaminants, such as DDT, are strongly sorbed to sediment; therefore, the mass distribution of the contaminant in the sediment governs transport, both sorbed and dissolved phase. The highest DDT sediment concentrations in the Lauritzen Channel are under the Levin pier and along the shoreline by the former plant site, and at the head of the channel in an area that was apparently undredged during the 1997 remedial actions. Lower concentrations of DDT are present along the west side of the channel, consistent with the thinner YBM layer and higher potential for vessel resuspension in this region. Geophysical and chemical data in the Lauritzen Channel are available from coring efforts conducted in 1999, 2003, 2007, and 2013[4]. Geophysical properties and concentrations of DDT from the sediment core samples can be used to create interpolated distribution maps and enable calculation of the following parameters:

1. YBM thickness
2. Dry bulk density
3. YBM mass
4. DDT concentration and mass

These mass distributions can help elucidate patterns of long term sediment and contaminant fate and transport. The following sections outline the determination of DDT mass in the channel over the time periods for which adequate data are available.

The YBM thickness throughout the Lauritzen Channel was calculated in order to determine the volumes of sediment potentially containing DDT. Values for YBM thickness were determined from data supplied by CH2M HILL. YBM thickness values, determined from coring efforts and corrected for less than 100% core recovery, were manually contoured at 1 foot intervals and data were interpolated within the channel. The volume of YBM was calculated by multiplying total thickness by the area of each interpolated cell. The sediment accumulation results from the YBM core analysis are consistent with the Tier 2 sediment transport analysis. The highest accumulation is in the deep berth next to the Levin Terminal and the upper head of the channel. The western side next to the Manson facility has the lowest sediment accumulation consistent with areas of frequent vessel activity.

The sediment dry bulk density variation through the channel also was determined so that the YBM sediment mass could be determined. Sediment dry bulk density was directly measured for 10 Sedflume cores that were collected in summer 2013 (Sea Engineering, 2014). Bulk density analyses were performed at five depth intervals per core, within the top 30 cm of sediment. A depth-weighted average value was calculated for each of the cores by taking into account interval thickness variations. The mean weighted average of dry bulk density for the 10 Sedflume samples was 0.43 g/cm$^3$. However, due to the

[4] The 1999/2003 data were combined for analysis because the 2003 cores were intended to fill spatial data gaps in the 1999 core locations. The combined data set is referred to as 2001.

small number of cores and relatively shallow core depths (top 30 cm of sediment), these values could not be relied upon for accurate mass determination.

The CH2M HILL sediment chemistry cores from all previous sampling events penetrated through most or all of the YBM and were more spatially distributed than the Sedflume cores. Dry bulk density values were not directly measured from these chemistry cores, but were calculated using specific gravity and percent moisture data using a technique common for fine sediment (Roberts, Jepsen, Gotthard, & Lick, 1998). The overall weighted average value of dry bulk density determined from the CH2M HILL chemistry cores was 0.90 g/cm$^3$. A bulk density interpolation was developed using isopach surfaces as with the YBM calculations and used in the determination of sediment mass.

The dry mass of YBM sediment for the entire Lauritzen Channel was calculated by multiplying the YBM thickness (cm) by bulk density (g/cm$^3$). The product of area density of YBM (kg/cm$^2$) and area of each interpolated cell resulted in total mass of YBM. The grid cell values were summed and with unit conversions, provide total mass of YBM in kilograms (Table 3). The average sediment accumulation rate from the 2001 to 2013 time period was also calculated in kg/yr (Table 4).

**Table 4. Resultant sediment mass and deposition rates determined from the YBM analysis.**

| **Sediment Mass** | |
|---|---|
| Present Sediment Mass (kg) | 45,478,880 |
| Sediment Deposition (kg/yr) | 2,480,400 |
| Avg. Sediment Density (kg/m$^3$) | 900 |

Total DDT concentration values from each sediment sampling effort were spatially interpolated over the entire Lauritzen Channel. Total DDT mass was calculated by multiplying the YBM mass (kg) and total DDT concentration (mg/kg) to derive mg/grid cell. The grid cell values were then summed to give total kilograms of DDT. The total DDT mass for the entire channel in 2013 was estimated to be 344 kg. The change in YBM and DDT mass over time is shown in Table 5. The spatial distribution of DDT mass in 2013 is shown in Figure 3.

There are two primary sources of uncertainty in these calculations. The first source is the variation in coring locations between the three time periods. Without collocated cores, uncertainty arises due to the inconsistent sampling of the sediment thickness and DDT concentration patterns in the sediment. The second source is due to the interpolation between the coring locations in each effort. Interpolating across heterogeneous gradients introduces errors in the interpolated surface. While uncertainty arises from each of these sources, it is nonetheless informative to show the channel-wide temporal changes in derived DDT mass (Figure 4). The analysis shows a trend of increasing mass over time. The regression of DDT mass versus time indicates a potential net source of DDT to the sediment of about 5 kg/yr (least squares linear regression slope of 5). Compared with source values from the source identification study (e.g. groundwater contribution of about 170 g/yr, this source is large; however, the value provides an estimate of the magnitude of unquantified ongoing sources for a DDT mass balance in the Lauritzen Channel. These sources include embankment erosion and potential seepage from preferential pathways

along the shoreline (Table 1). Additionally, the 2013 water column study (P. M. Gschwend, 2014) also suggested at least one additional input of DDT was occurring somewhere mid-channel or further south that could contribute to this ongoing source.

**Table 5. Mass and volume calculations for the time period of evaluation.**

| Year | YBM Volume ($m^3$) | YBM Mass (kg) | Total DDT Mass (kg) |
|---|---|---|---|
| **2001** | 17,467 | 15,731,336 | 278 |
| **2007** | 29,255 | 26,319,230 | 379 |
| **2013** | 50,549 | 45,478,880 | 344 |

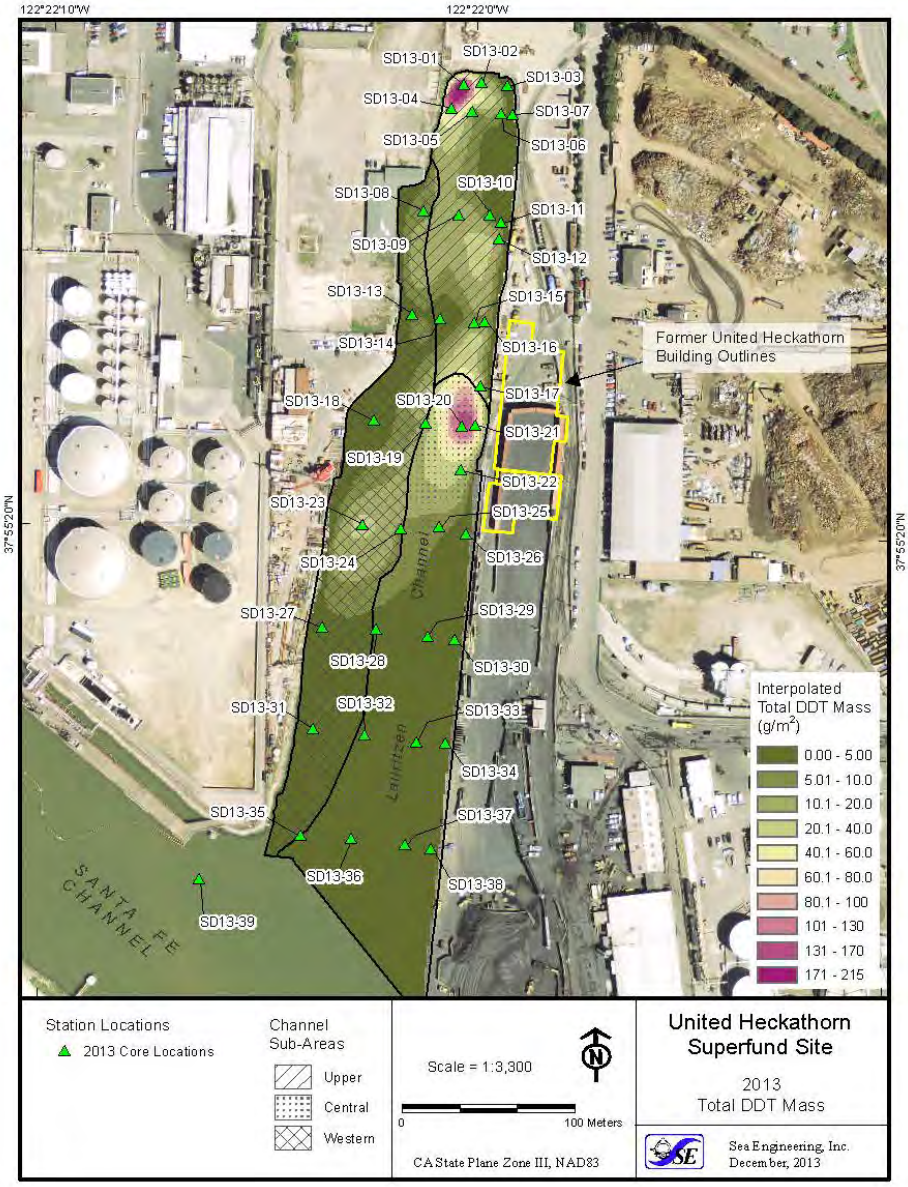


**Figure 3. Total DDT mass in the 2013 YBM.**

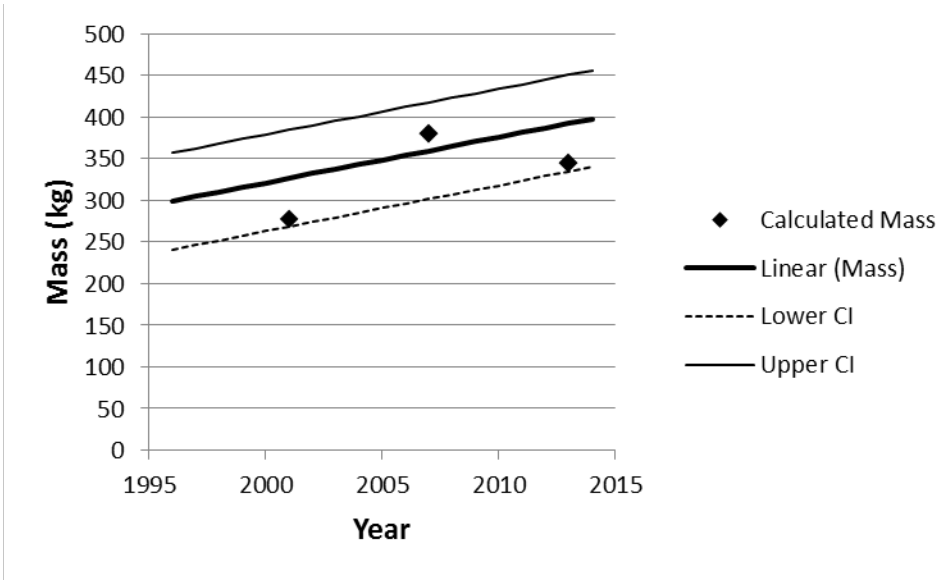


**Figure 4. Change in DDT mass over time with least squares linear regression and 95% confidence intervals (CI).**

# 4. DDT Mass Balance

A mass balance for DDT can be developed to account for the external inputs, outputs, and storage of DDT mass in the Lauritzen Channel due to the net effects of the transport processes discussed herein. The balance provides a useful tool for accounting for sources and evaluating the effects of any changes to the system. Essentially the balance can be described by:

$$DDT\ Mass\ Input - DDT\ Mass\ Output = \Delta DDT\ Mass$$

The goal of the DDT mass balance is to summarize the external inputs and outputs of DDT to the system and investigate the net result of these processes.

## 4.1 Sources and Losses

The source identification, passive sampler studies, and Tier 2 sediment transport studies provide information for the source and loss terms for the DDT mass balance. The source identification study identifies numerous sources of DDT, many of which are relatively small compared to the overall mass of DDT in the system (CH2MHILL, 2014). One notable input is from groundwater, which is an ongoing DDT source of 170 g/yr (0.17 kg/yr). Conservatively this can be assumed as a mass loading to the surface sediment. The sediment depositing in the Channel from San Francisco Bay also has an associated mass of DDT. Using the ambient threshold concentrations in the Bay from the Regional Water Quality Control Board (7 µg/kg) (Gandesbery & Hetzel, 1998), an ongoing source of 0.017 kg/yr was calculated.

One additional class of sources includes the municipal stormwater outfall and other pipe and embankment discharges, for which quantitative loading estimates are not available. While other lines of evidence (e.g. field observations) suggest that these inputs are not significant, they were included as a general category of other sources. Additionally, the 2013 water column study (P. M. Gschwend, 2014) also suggested at least one additional input of DDT was occurring somewhere mid-channel or further

south that could contribute to the channel DDT mass. The inclusion of these unquantified sources is discussed below.

The passive sampler analyses (P. Gschwend & Burgess, 2012; P. M. Gschwend, 2014) estimate the DDT flux from the sediment from a number of locations throughout the system, from the head to the mouth of the channel. By averaging the fluxes together and multiplying by the area of the channel, an estimate of average DDT diffusion from the channel can be made. Table 6 shows the result of these calculations and a diffusion loss of 0.15 kg/yr of DDT.

**Table 6. Estimates of DDT loss due to diffusion from the Lauritzen Channel sediment.**

| **DDT Diffusion** | |
|---|---|
| Average Diffusion (ng/$m^2$/day) | 9,647 |
| Area ($m^2$) | 42,142 |
| DDT Diffusion (kg/yr) | 0.15 |

The loss of DDT from the Lauritzen Channel due to vessel resuspension can be determined from the mass loss terms in Section 2.2. By multiplying the mass of sediment loss per year due to vessel resuspension (1,814 kg) by the average DDT concentration in surface sediment in the western region experiencing the loss (7,104 µg/kg), a loss term of 0.013 kg/yr from the channel sediment can be determined. While the resuspension and redistribution of sediment can increase diffusion from the sediment, this loss was assumed to be accounted for in the estimate of present day diffusion loss.

To account for the uncertainty in the inputs of DDT to the Lauritzen Channel sediment (e.g. from the embankments), the change in DDT mass over time (Figure 4) can be used. While the estimate of the change in DDT mass is uncertain, it shows a positive source of DDT to the system. The existence of the source is consistent with the unquantified sources from Table 1 and the 2013 water column study findings (P. M. Gschwend, 2014). The estimated load from the DDT mass analysis in Section 3 was about 5 kg/yr. This ongoing source is over an order of magnitude higher than all other sources and losses combined.

Table 7 presents a summary of all of the sources and sinks included in the mass balance analysis. It is important to note that the yearly magnitude of vessel resuspension loss, diffusive loss, and ground water sources are essentially insignificant when compared with the total mass of DDT remaining in the channel sediments. These values, even with associated uncertainty, support the conclusions in the source identification memo that ongoing sources are small and the majority of the mass of DDT in the channel sediments is from dredging residuals.

**Table 7. Mass balance terms for DDT recovery assessment.**

| DDT Balance Terms | |
|---|---|
| Calculated 2013 DDT Mass (kg) | 344 |
| Calculated 2013 DDT Concentration (ug/kg) | 7,564 |
| Vessel Resuspension Loss (kg/yr) | 0.013 |
| GW Load (kg/yr) | 0.17 |
| Diffusion Loss (ky/yr) | 0.15 |
| Deposition Load (kg/yr) | 0.017 |
| Other Estimated Load (kg/yr) | 5 |

## 4.2 Mass Balance Model

To determine the net effect of all of these terms, the mass balance as a function of time can be considered. The change in mass over time in the Lauritzen Channel sediment can be represented as:

$$\frac{dM_{DDT}}{dt} = S_{GW} + S_{dep} + S_{others} - L_{vessels} - L_{diff}$$

where $S_{GW}$ is the groundwater source, $S_{dep}$ is the source due to background DDT deposition from San Francisco Bay, $S_{others}$ is other or unquantified ongoing sources (5 kg/yr), $L_{vessels}$ is the loss of DDT from the channel due to vessels, and $L_{diff}$ is the loss due to diffusion. By integrating the above equation over time, the yearly change in total DDT mass in the Lauritzen Channel YBM can be calculated. Figure 5 presents a conceptual diagram of the yearly sources and losses of DDT mass to the Lauritzen Channel sediment. Figure 6 shows the results of the projected DDT mass as a result of the mass balance. The progression is linear due to the linearly increasing combination of constant source and loss terms.

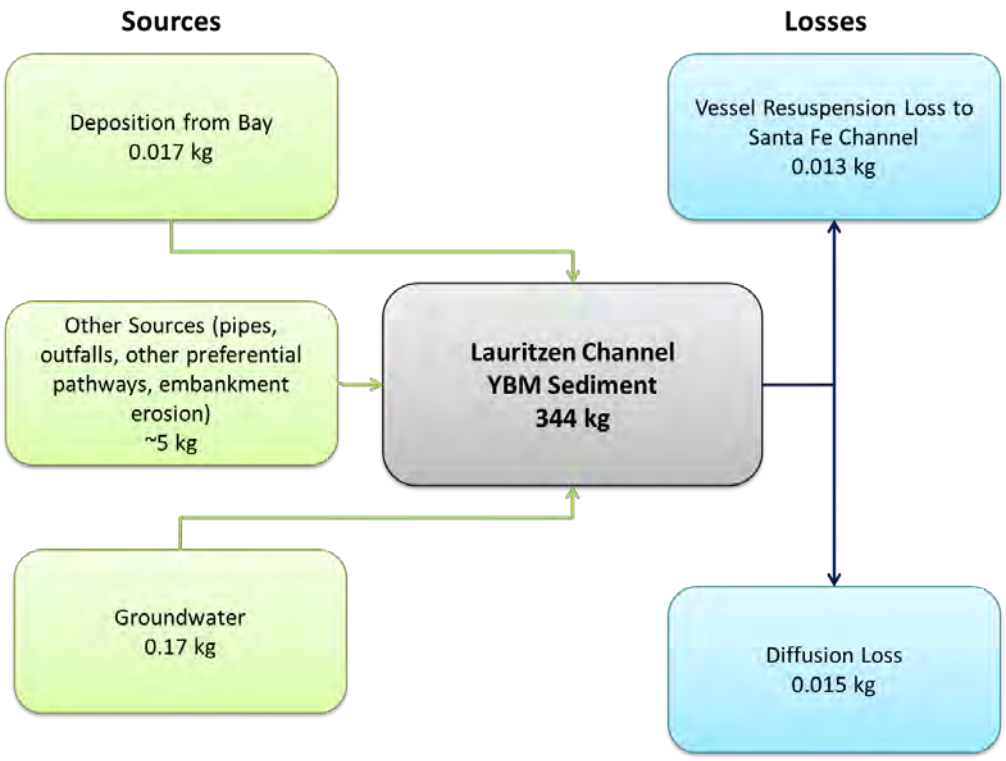


**Figure 5. Conceptual diagram of average yearly sources and losses of DDT mass to the Lauritzen Channel sediment.**

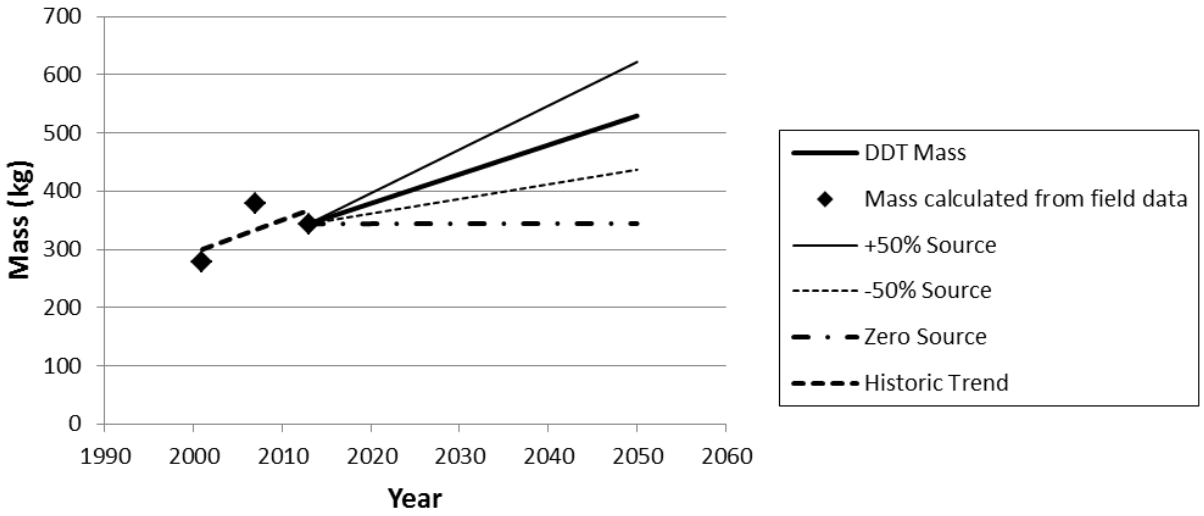


**Figure 6. Change in total DDT mass as a result of all sources to and losses from the system. Sensitivity to ongoing source terms is included.**

In the mass balance model, the mass of DDT increases primarily due to the other ongoing DDT sources of 5 kg/yr. Since this term is strictly derived from the DDT mass estimates, which have their own uncertainties, a sensitivity analysis was performed around these other ongoing DDT sources. For the sensitivity analysis the magnitude of the source was increased and decreased by 50% and was also set to

zero. As seen in Figure 6, the DDT mass projected for 2050 varies by almost a factor of two due to the +/- 50% change in mass due to the other sources.

As discussed, of primary interest for the FFS is the DDT concentration in sediment. To evaluate the net results of changing DDT mass and concentration from all sediment and DDT sources it was necessary to balance the sediment and DDT mass and then calculate the resulting DDT concentrations. The bulk contaminant concentration ($C_{CS}$) in terms of mass of DDT ($M_{DDT}$) divided by sediment mass ($M_{sed}$) can be expressed as:

$$C_{cs} = \frac{M_{DDT}}{M_{sed}}$$

The DDT mass values in sediment can be divided by the YBM mass to calculate a bulk DDT concentration in the YBM sediment. The sources and losses of sediment mass to the Lauritzen Channel sediment are shown in Figure 7 including upland sources of sediment determined in the Tier 2 investigation (Sea Engineering, 2014). Since these concentrations are bulk averages over the entire YBM they are different than the spatially interpolated concentrations in Section 3, but provide a representative comparison of mass and concentration. Figure 8 presents the computed bulk DDT concentration in the YBM for the Lauritzen Channel. It is important to note that the mass of the YBM also increases during time in these calculations, which dilutes the DDT mass. For all of the source sensitivity cases, the DDT concentrations continue to decrease due to a dilution from clean incoming sediment. The sensitivity analysis demonstrates that even with relatively large variations in the magnitude of the ongoing DDT source, the bulk concentrations of DDT in YBM are dominated by incoming sediment and continue to decrease. However, in all cases, the bulk DDT concentration remains above the sediment remediation goal from the 1994 ROD (USEPA, 1994) of 590 µg/kg at year 2050.

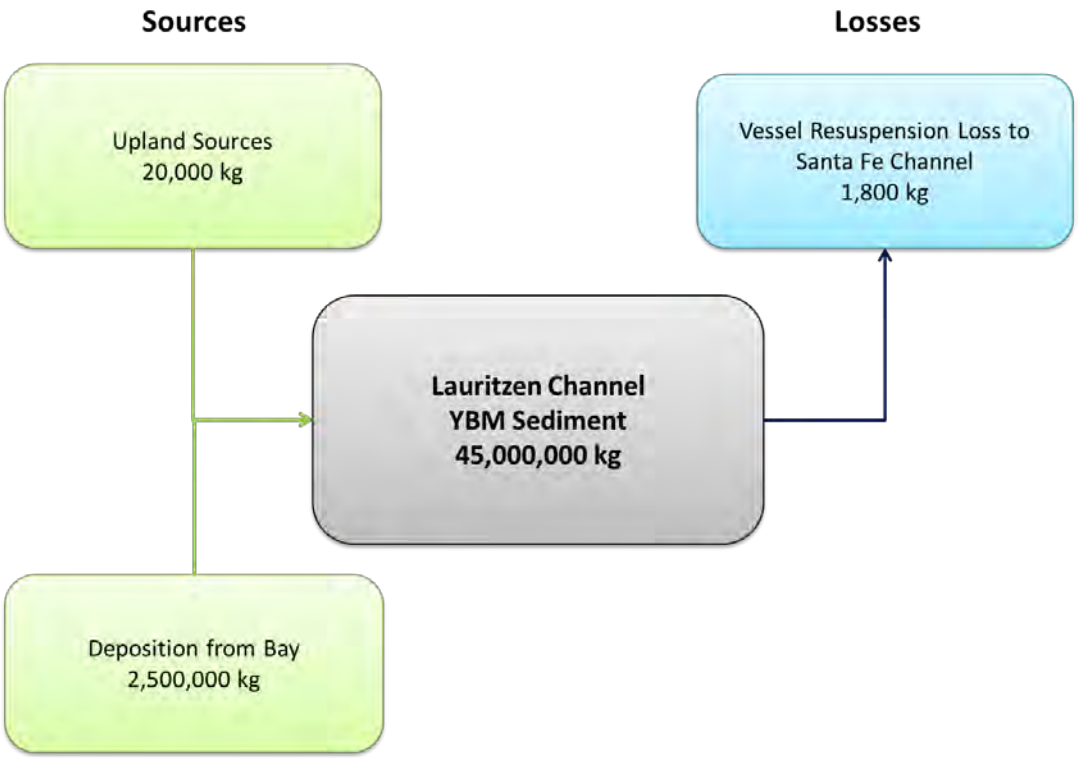


**Figure 7. Conceptual diagram of the sources and losses to the Lauritzen Channel sediment.**

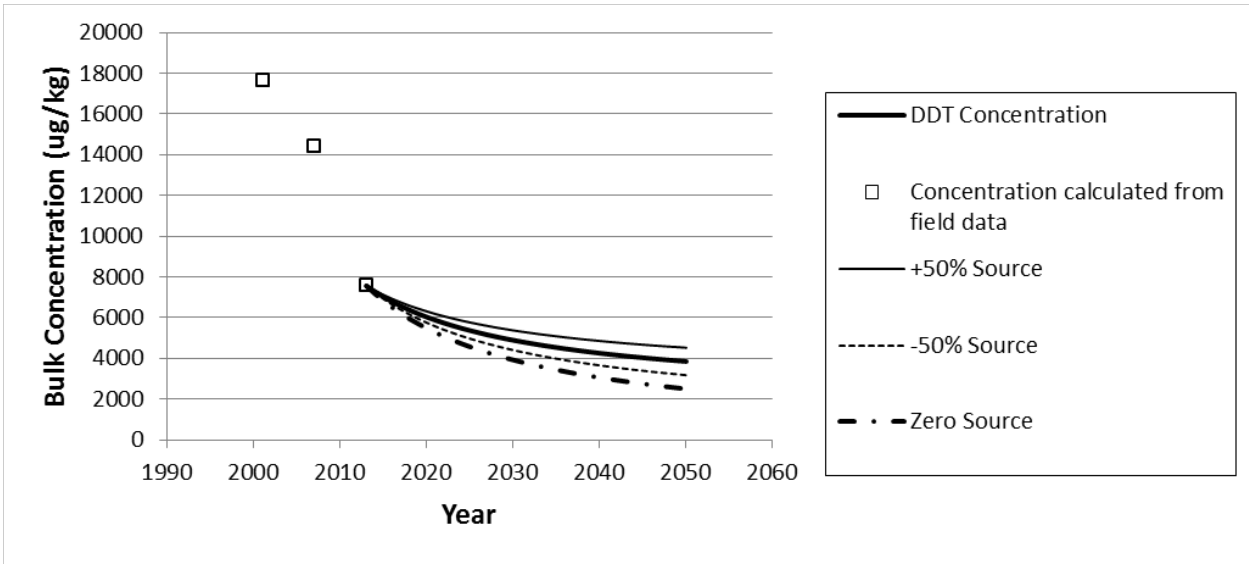


**Figure 8. Change in bulk YBM DDT concentration. Sensitivity to the unquantified source terms is included.**

# 5. Summary

This report presents the results of a DDT fate and transport study that was performed for the Lauritzen Channel as part of the FFS. The objectives were to develop a quantitative contaminant fate and transport CSM and DDT mass balance for the Lauritzen Channel based on available analyses and assess trends in DDT mass and concentration in the Channel.

Overall, the Tier 2 sediment transport analysis showed that the Lauritzen Channel is accumulating relatively clean sediment from San Francisco Bay. There are three distinct regions with different sediment transport and accumulation characteristics in the channel. The largest amount of sediment accumulation is in the deep dredged berth on the east side of the Lauritzen Channel. The west side of the channel, which experiences the highest vessel activity in relatively shallow regions, exhibits generally low sediment accumulation. The northern head of the channel has a moderate YBM accumulation and a mixed potential of erosion and deposition. The average DDT concentrations in the YBM sediment are decreasing in the channel.

Several passive sampler studies have been performed in the Lauritzen Channel to quantify the diffusive flux of DDT and infer dissolved DDT concentrations in porewater and surface water (P. Gschwend & Burgess, 2012; P. M. Gschwend, 2014). The results of the 2013 passive sampler study suggest that there is ongoing diffusion of DDT from the sediment, and that at least one important additional input of DDT is occurring mid-channel or further south, most likely along the embankment adjacent to the former plant site. The results also suggest that mussels are accumulating DDT from the water column and resuspended sediments in the water column.

The DDT mass balance model shows that bulk YBM DDT concentrations are projected to decrease, even when accounting for uncertainty in the magnitude of the ongoing sources to the system. The projected bulk YBM DDT concentrations remain over 2,000 µg/kg in 2050 despite +/-50% variation in DDT mass input. The magnitudes of sources and losses of DDT investigated in the mass balance support the conclusions of the source identification study that ongoing sources are relatively small compared to the DDT mass in channel sediments. The findings lead to the conclusion that dredge residuals are responsible for primary DDT mass in the channel. Even with the uncertainty associated with each line of evidence, the conclusions are well supported by comparison of the order of magnitude of sources, losses, and sedimentation.

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# Appendix A.
# Application of Polyethylene (PE) Passive Samplers to Assess DDTs in the Lauritzen Channel at the United Heckathorn Superfund Site in Richmond Harbor, San Francisco Bay

# Application of Polyethylene (PE) Passive Samplers to Assess DDTs in the Lauritzen Channel at the United Heckathorn Site in Richmond Harbor, San Francisco Bay

**Report to US EPA, Region 9, Attn: Rachelle Thompson** **May 27, 2014**

Philip M. Gschwend, Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, Cambridge MA 02139

**Summary**

1. Porewater and bottom water concentrations of DDT isomers and their degradates (herein altogether referred to as DDx) in the Lauritzen Channel were found to be at similar levels in September 2013 as seen previously in March 2012, implying similar sediment bed-to-water column diffusive fluxes.

2. The 2013 water column data, inferred using PE samplers, could not be readily fit using a mass balance model that reflects only inputs via bed-to-water column diffusive fluxes and output via tidal flushing from a vertically well-mixed water column. The misfit between the measurements and this simple model suggests an important additional input of DDx was occurring somewhere mid-channel or further south during Sept 2013. Such a source must be particularly enriched in DDT, as opposed to DDD and DDE; and so episodic resuspension of Channel sediments and release of DDx, while a likely additional mechanism moving DDx into the overlying water, cannot explain the modeling misfit since this source would input DDE, DDD, and DDT at about the same ratios as bed-to-water diffusion.

3. The 2013 water concentration data, inferred using PE passive samplers deployed in the water column, were consistently lower (*ca*. 5x) than levels inferred by assuming that mussel tissues reflect equilibrium with water concentrations. It is noteworthy that DDx measurements using filtered water samples were also much lower than indicated by the mussels. This discrepancy may suggest that mussels were accumulating DDx from both the seawater and resuspended solids in the water column. Perhaps in support of this hypothesis, some of the sediment bed PE samplers were found to be almost completely buried after their month-long deployments (i.e., little of the sampler was in the water column), implying significant disturbance of the sediment bed during September 2013.

**Introduction**

DDT and its derivatives (herein collectively referred to as DDx) continue to cause human and ecosystem health concerns in the vicinity of Richmond Harbor, California. In order to improve our ability to remediate this situation, we need to identify the continuing source(s) of these contaminants to the surface waters of that system. In 2012, we used passive polyethylene samplers, deployed in both the water column and sediment bed of the Lauritzen Channel, to identify the site sediments with the highest DDx porewater concentrations. These plastic films absorb DDx in proportion to these compounds' availabilities: (a) to move in this system (e.g., from the sediment bed into the overlying water column) and (b) to bioaccumulate in biota living in the area. The following summarizes our findings from our earlier February - March 2012 field deployment campaign.

1. All eight Lauritzen Channel sediment locations exhibited DDx concentration gradients that imply diffusive fluxes from the sediment bed to the overlying waters. A control site located outside the Channel did not show such gradients.

2. Polyethylene samplers indicated similar porewater concentrations of DDx extending at least 30 cm into the sediment at several sites distributed along the length of the channel.

3. Freely dissolved DDx concentrations in the water column, determined using polyethylene samplers, correlated strongly with values inferred from transplanted mussel-tissue concentrations, although the mussel-based water concentrations averaged about 2x the corresponding PE-inferred values.

4. A 3-box model of the DDx concentrations in the Lauritzen Channel water column, reflecting only diffusive fluxes of DDx out of the sediments and tidal flushing to remove these contaminants, indicated that continuing inputs from the undisturbed sediment bed were sufficient at that time to explain the freely dissolved DDE and DDD concentrations in the Channel water column. However, the same model and assumptions under-estimated DDT in the middle and southern portions of the Channel, perhaps suggesting a second DDT source was present in addition to diffusive inputs from the sediment beds.

In light of these findings, certain questions remained. Firstly, we needed to better define the boundaries between sediment areas with high, medium, and low DDx porewater concentrations. Such data would substantially improve our understanding and modelling of the effects of the sediment bed conditions. Further, this result would give us a better tool with which we can evaluate various "what if" remediation scenarios. Secondly, as long term post-remediation monitoring will likely be required for this site, even after it is cleaned up, we need to continue to evaluate the utility of PE sampling in the water column with respect to the question: can we use PE passive sampler observations as surrogates for mussel-based monitoring?

**Goals of the 2013 PE Passive Sampling**

1. To better delineate the most problematic sediments releasing DDx at the United Heckathorn site, we deployed a second round of PE samplers in the sediments and water column to measure DDx concentrations in the pore waters, bottom waters, and surface waters.

2. To improve our understanding of the fate of DDx at that site, we collaborated with colleagues at CH2M-Hill and Sea Engineering to develop a mass balance model that uses more accurate physical dimensions (e.g., Channel depths) and tidal data to test the hypothesis that diffusive fluxes of DDx from the sediments to the tidally flushed water column of the Lauritzen Channel could explain the loads of DDx in that surface water. Then, to test the accuracy of this simple DDx modeling, we compared model predictions of DDx concentrations in the Lauritzen Channel water column to our independent PE-based measures of dissolved DDx in that water.

3. Finally, to assess the efficacy of using PE samplers in place of mussel-based biomonitoring, we co-deploy PE samplers alongside transplanted mussels and compared the PE-based measures of freely-dissolved DDx concentrations to values obtained using conventional mussel-based monitoring methods.

**Methods**

PE samplers were prepared as described previously (Gschwend et al. 2012a). Briefly, the PE is solvent cleaned, loaded with performance reference compounds (PRCs), and then mounted in aluminum sheet metal frames for deployment across the sediment-water interface or in aluminum mesh bags for water column sampling.

On September 10 and 11, 2013, working with EPA divers, we deployed polyethylene devices (PEDs) in the sediment bed at 10 stations located in the Lauritzen Channel (Figure 1). These sample locations were chosen to fill in the spatial coverage that had been acquired during our previous efforts in March 2012. At every site, a portion of the sampler was purposefully left sticking up above the sediment bed to enable that portion of the PE strip to sample the bottom water. At one of the locations (09), duplicate samplers were deployed beside each other.

During the same field campaign, water column PE samplers were also deployed (Figure 2). These PE samplers were placed at five sites along the eastern edge of the Lauritzen Channel, at a location to the northwest in the Santa Fe Channel ("floating dock"), at a location in Parr Canal, and at a background site near Ford Point. Many of these water column samplers were located at the same stations where cages of transplanted mussels were deployed.

One month later (October 10, 2013), the EPA divers retrieved all the samplers. That same evening, the samplers were taken to the EPA Region 9 laboratory, cleaned of adhering sediment or biofilms, photographed, and cut out of the aluminum sheet metal sampler frames. Each piece of PE was placed in a VOA vial and labeled for transport back to MIT to begin extraction and analysis on the next day.

Once back at MIT, each sample was processed as described previously (Gschwend et al. 2012b). First, each PE strip was soaked in organic solvent with surrogate (recovery) standards added. The solvent was replaced two more times and the extracts combined in each case. The solvent was blown down and exchanged into hexane. Finally, the hexane extracts were transferred into auto-injector sample vials, injection standards were added, and finally they were analyzed via GCMS. Polyethylene that had not been deployed was analyzed in the same manner to ascertain the initial PRC concentrations. Following analyses, data were corrected for surrogate recoveries. Then measured losses of the PRCs were used to extrapolate measured target DDx loads to equilibrated levels. Finally, these results were converted to corresponding water concentrations by dividing the PE concentrations by each compound's polyethylene-water partition coefficient ($K_{pe\text{-}w}$, Table 1).

Table 1. Values of polyethylene-water, $K_{pe\text{-}w}$, (from Lohmann, 2012) and lipid-water, $K_{lip\text{-}w}$, (estimated from $K_{ow}$ values) used in this study.

| **compound** | **log $K_{pe\text{-}w}$** | **log $K_{lip\text{-}w}$** |
|---|---|---|
| 2,4'-DDE | 5.2 | 5.6 |
| 4,4'-DDE | 5.5 | 6.1 |
| 2,4'-DDD | 5.1 | 6.0 |
| 4,4'-DDD | 5.0 | 5.8 |
| 2,4"-DDT | 5.7 | 6.4 |
| 4,4'-DDT | 5.8 | 6.6 |

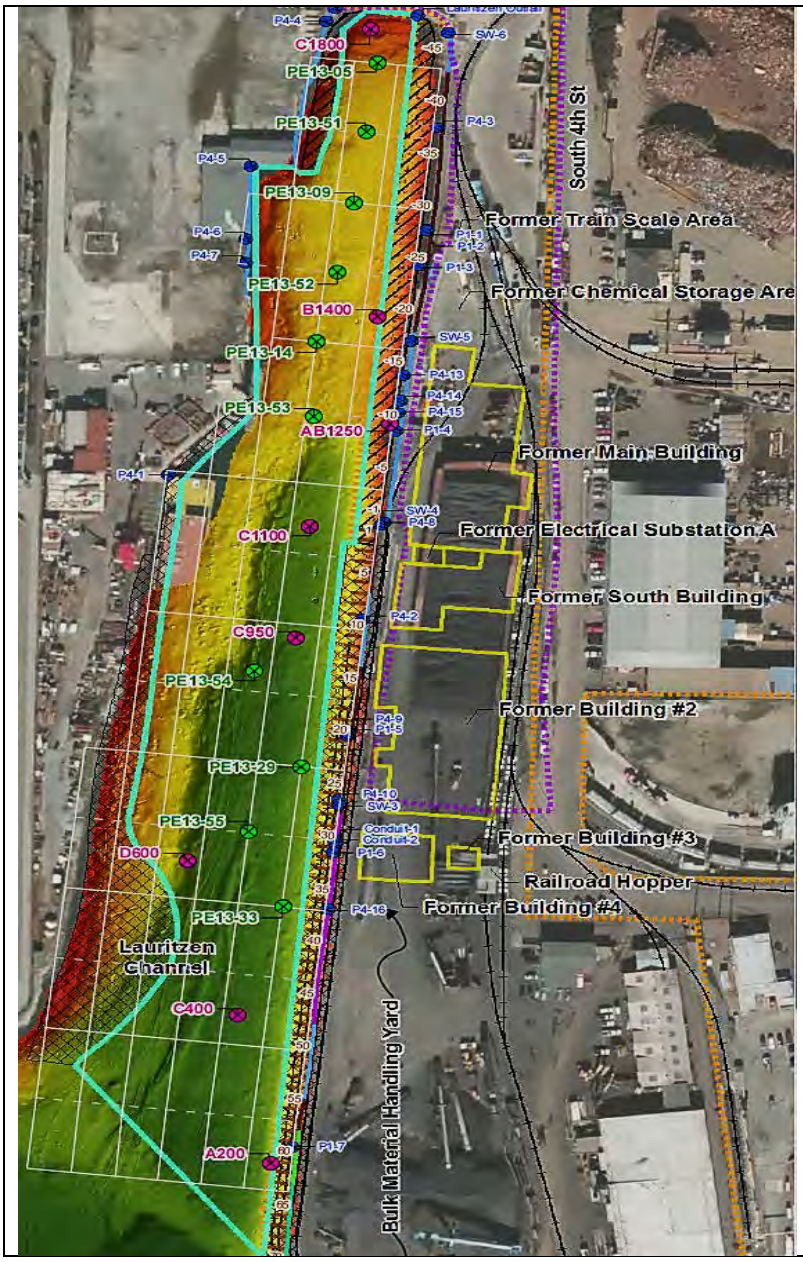


Figure 1. Map of the Lauritzen Channel showing both the 2013 sediment passive sampling sites (in green):
PE13-05
PE13-51
PE13-09 (sampler buried)
PE13-52 (sampler buried)
PE13-14
PE13-53
PE13-54
PE13-29
PE13-55
PE13-33

& the 2012 stations (in purple):
C1800,
B1400
AB1250
C1100
C950
D600
C400
A200.

**Results**

**Porewater and Bottom Water DDx Concentrations**

As seen in 2012, stations to the north in the Channel generally had higher porewater concentrations than stations to the south (Figure 3). Also as before, the two DDD isomers were most abundant (see Appendix A for all of the individual DDx concentrations). However, unlike 2012, the 2013 polyethylene sampler data did not always show elevated DDx porewater concentrations in the upper 5 cm of the bed (0-5 cm surface sediment), as compared to the bottom waters (0 to 5 cm bottom water) at all stations (Figure 3). This was particularly true for stations in the southern part of the Channel (stations 54, 29, and 55). Station D600, located near these three stations, previously showed a relatively weak bed-water gradient in 2012.

Figure 2. Stations at which PE passive samplers were deployed in the water column in September 2013 in the Lauritzen Channel: 303.7, 303.3, L02, L01, 303.2, in Parr Channel: 303.6, in the Santa Fe Channel: 303.4, and near Ford Point (not shown).

In light of these concentration data from 2012 and 2013 field campaigns, the Channel may be broken up into four sections based on each section's 4,4'-DDD porewater concentration (Appendix C):
(1) a southernmost section of 900 ft in which porewater 4,4'-DDD is generally about 10 ng 4,4'-DDD/L,
(2) a second portion (600 ft) in which porewater is between 10 and 100 ng 4,4'-DDD/L,
(3) a third short section (200 ft) in which porewater exceeds 100 ng 4,4'-DDD/L, and
(4) a short (100 ft) northernmost portion in which porewater exceeds 1000 ng 4,4'-DDD/L.

Dividing the Channel up this way, we made initial estimates of the bed-water fluxes for each section assuming a bottom water diffusive boundary layer thickness of 1 mm, consistent with relatively thick layers seen by others in lab studies (Steinberger and Honzo, 1999) and field work (Lorke et al., 2003). In so doing, one finds the northernmost section of the Channel has the largest local fluxes of all the DDx

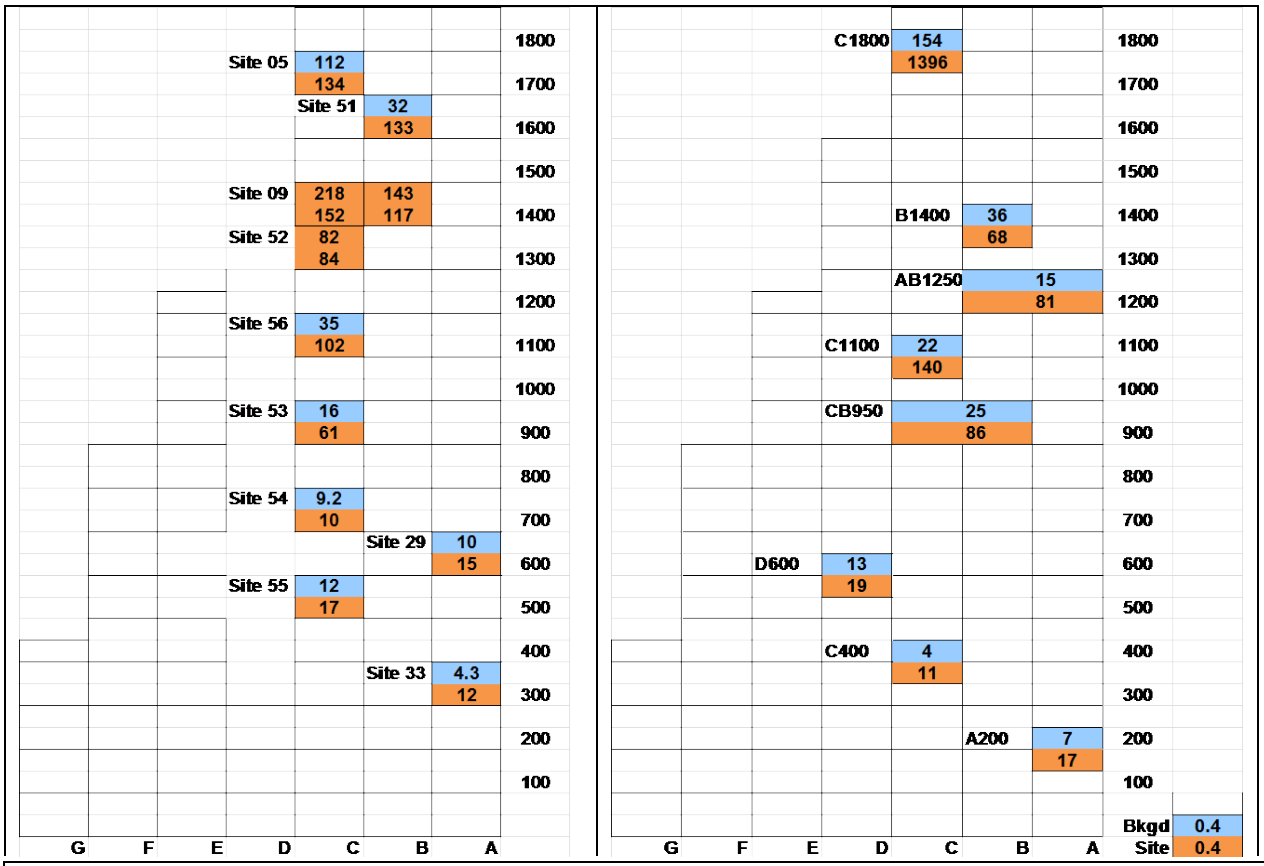


Figure 3. Porewater (brown) and bottom water (blue) concentrations of 4,4'-DDD (ng/L) , the most abundant DDx constituent, deduced using PE passive samplers in the field in September 2013 (left) and March 2012 (right). At sites 09 and 52 in 2013, PE samplers were found to have been fully buried in the sediment when the divers went to retrieve them, suggesting substantial sediment disturbance during their month-long deployment.

(Figure 4). If one multiplies each section's average local flux by the corresponding area of each section, then the greatest input of DDD is still in the northern part of the Channel ("section 4"), but the greatest DDE input is found in both section 4 and halfway down the Channel ("section 2"). Notably, the largest sediment bed-derived input of the parent DDx, DDT, is from section 2 (Figure 4, right panel). In all cases, fluxes into the water column on the order of milligrams/day are implied for each DDx; the absolute values could be higher (perhaps by as much as a factor of 10) if the assumed 1 mm diffusive boundary layer thickness was thinner at any places and times.

**Surface Water Concentrations**

Polyethylene samplers that were deployed in the upper water column at several sites (Figure 2) showed the freely dissolved DDx were individually present in the Lauritzen Channel water column at levels between 0.1 and 10 ng/L (Figure 5 and Appendix B). This range was also seen on the March 2012 sampling. As also found with the pore waters, the DDD isomers tended to occur at the highest concentrations of all the DDx. This implies that they were transported from sources in which the DDT isomers were reduced to the corresponding DDDs such as anoxic sediment beds.

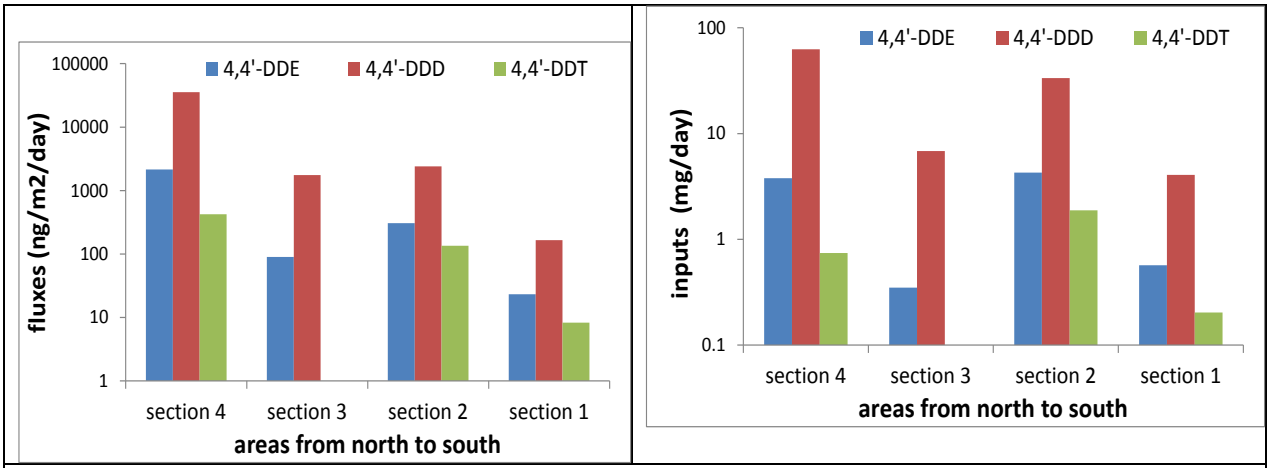


Figure 4. (left) Estimated bed-water fluxes (ng/m$^2$/day) of 4,4'-DDx using average porewater and bottom water concentrations seen in each section and a bottom boundary layer thickness of 1 mm. All three DDx have the highest local fluxes at the northern end of the Channel. (right) Aerially-integrated inputs (mg/day) of the three DDx for each section of the Channel show DDD has the largest input in the north, DDE has comparable total inputs from sections 2 and 4, and DDT has the highest input from section 2.

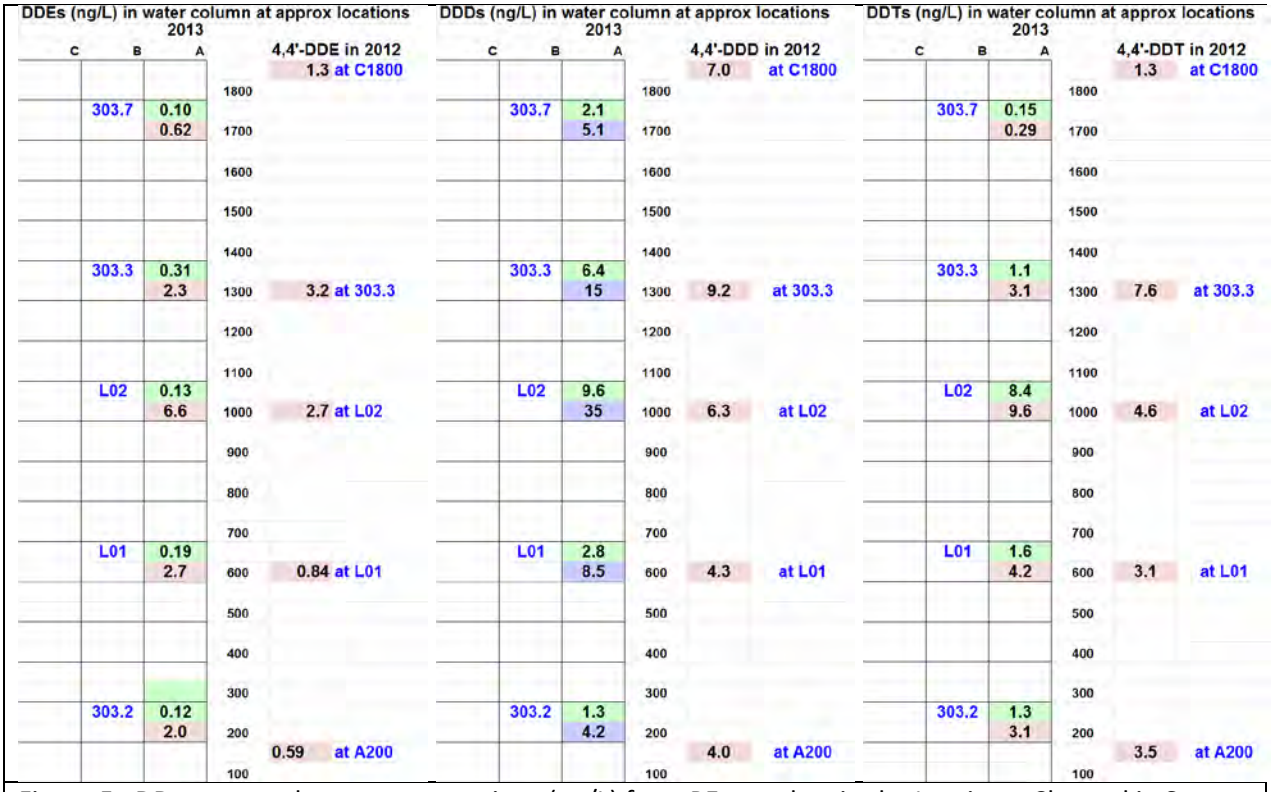


Figure 5. DDx water column concentrations (ng/L) from PE samplers in the Lauritzen Channel in Sept. 2013: DDEs are on the left grid, DDDs are in the middle grid, and DDTs are on the right grid. 2,4'-isomers are shaded green, while 4,4' isomers are shaded purple. Site identities are next to the data in blue font. Results for 4,4'-DDx in March 2012 are shown to the right of each map for comparison.

**Mass Balance Modeling of DDx in the Water Column of the Lauritzen Channel**

To test the hypothesis that diffusion of DDx out of the sediments into the overlying water column is the main continuing source of those DDx to the Channel's water column, a mass balance model was set up to compare the expected water column concentrations with what was measured. In this model, DDx diffusion from the bed sediments to the overlying water column is the only source of DDx to the Lauritzen Channel water column, and tidal flushing is the only sink from a vertically well mixed water column. Given the dramatic changes in porewater concentrations down the Channel from north to south (Appendix C), the Channel was taken to have four sections or "boxes of water": a northernmost box of about 100 ft length (section 4), a neighboring box of 200 ft length (section 3), and mid-channel box of 600 ft length (section 2), and a southern box of 900 ft length (section 1). With the help of Craig Jones (Sea Engineering), the areas, volumes, and tides moving in and out for these four sections were obtained (Table 2) and used in the model.

Table 2. Dimensions of the Lauritzen Channel used in modeling DDx. Data provided by Dr. Craig Jones, Sea Engineering.

| | width | length | ave depth | area | low tide volume | tidal volume |
|---|---|---|---|---|---|---|
| | (m) | (m) | (m) | ($m^2$) | ($m^3$) | ($m^3$) |
| section 1 (0-900 ft) | 90 | 274 | 7.25 | 24,528 | 172,737 | 70,271 |
| section 2 (900-1500 ft) | 76 | 183 | 5.43 | 13,890 | 72,322 | 31,881 |
| section 3 (1500-1700 ft) | 64 | 61 | 4.23 | 3,887 | 15,548 | 9,153 |
| section 4 (1700-head) | 52 | 34 | 2.97 | 1,761 | 4,639 | 2,782 |

In the first step of the model (Figure 6), the tide is assumed to move a "tidal volume" of water (Table 2) from outside the Channel into the southernmost box (section 1), from the southern box to section 2, and so on. Water outside the Lauritzen Channel is assumed to have concentrations like those at the Floating Dock (303.4) station (Appendix B), although sensitivity analyses on this assumption was also performed (Appendix D). Then DDx are assumed to diffuse from the bed below each box into the overlying water for 6 h (Figure 6). At slack tide, the boxes are assumed to become completely mixed. Outgoing tides reverse the flow, thereby flushing a portion (= tidal volumes shown in Table 2) of each box to the neighboring box to the south. After the tide has gone out, a 6-hour diffusive flux of DDx from the bed below each compartment occurs and the water is assumed to become well-mixed before the sequence repeats itself. Given the volumes and fluxes involved, the water column concentrations no longer changed after about 1 month of simulation time, and so this was taken as the "steady state" condition. It is worth noting that the sediment concentrations were so high that there is insignificant depletion of the sediment DDx load by diffusive losses to the overlying water. Also, the offshore water concentrations were held constant at their initial measured levels. Finally, this model did not operate with temporally changing conditions such as neap and spring tides.

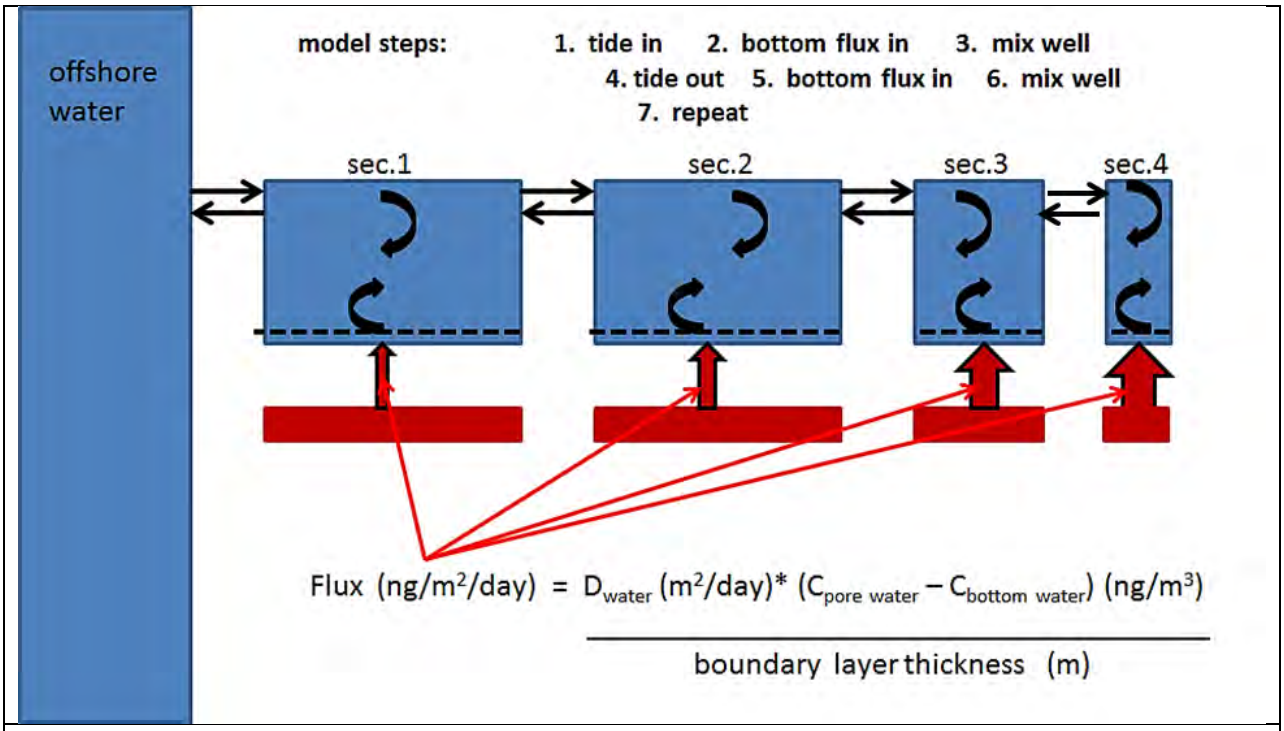


Figure 6. Depiction of mass balance model used to assess hypothesis that DDx diffusion out of sediment bed was primary source of those DDx to overlying water column. Tidal flushing to offshore water was assumed to be the only sink.

With bed-water fluxes (based on the PE data and an assumed 1 mm boundary layer thickness, after Steinberger and Hondzo, 1999; Lorke et al., 2003) and such tidal flushing, steady state water column concentrations were estimated for each section (Table 3). Not surprisingly, the northernmost box is estimated to have the highest DDx concentrations (e.g., 4,4'-DDD at about 24 ng/L), with more southerly boxes having somewhat lower levels. Given the pore water results, it is not surprising that the modeling results would cause us to expect water column DDD will be greater than water column DDE or DDT.

To evaluate the accuracy of this simple mass balance model, we contrasted the model-derived estimates with the PE-inferred truly dissolved concentrations (Table 4). In the "base case" (Table 3 and repeated in Table 4), DDx inputs are assumed to only occur by diffusion out of the sediment bed to the overlying

| | 4,4--DDE | 4,4'-DDD | 4,4'-DDT | total 4,4'-DDx |
|---|---|---|---|---|
| section 4 | 2.1 | 23.8 | 0.6 | 26.5 |
| section 3 | 1.3 | 9.6 | 0.4 | 11.3 |
| section 2 | 0.9 | 4.2 | 0.3 | 5.5 |
| section 1 | 0.8 | 2.0 | 0.3 | 3.1 |
| Santa Fe Channel (based on 303.4) | 0.68 | 1.1 | 0.26 | 2.04 |

Table 3. Modelled water column concentrations (ng/L) of three DDx and their sums assuming a 1 mm bottom boundary layer thickness everywhere in the Channel.

water through a bottom water boundary thickness of 1 mm everywhere. In this case, ratios of model-based concentrations to measured concentrations (using PE samplers) indicate that the northern sections have too strong of a source and the southern sections have too little input, especially for 4,4'-DDT. We note that this discrepancy is exacerbated if one assumes the water outside the Channel has concentrations like those at Ford Point or an average of Floating Dock and Ford Point (Appendix D). This may mean that diffusive transfer of DDx out of the sediments was the major source of DDx to the overlying seawater in the northern portion of the Channel, but in the south a stronger DDx input must be considered.

One simple adjustment to the model would be to allow the bottom boundary layer thickness to vary along the Channel (Table 4 and Appendix D). In the more sheltered northern sections of the Channel, this thickness might be thicker than in the south. Hence the model was rerun using thicker boundary layer in sections 3 and 4, but still using a thinner layer in sections 1 and 2 (Table 4, middle panel). This approach certainly changes the ratio of modeled-to-measured concentrations in section 3 to be much closer to 1, implying this adjustment may be justified. Yet, this change does not correct the large model vs. measurement discrepancies in sections 1 and 2, especially for DDT.

The low model/measure ratios in sections 1 and 2 imply one of the following: (a) flushing is too strong in such a box model, especially in the southernmost sections (e.g., due to numerical dispersion), (b) the water column is inaccurately represented as well mixed in September 2013, or (c) there is an additional DDx source in this part of the Channel. To begin to test this latter prospect, the bottom boundary layer thicknesses were held at the same values used in the previous case, but now additional inputs of the DDx into only section 1 were allowed (Table 4, bottom panel). In particular, the sediment diffusive fluxes of 0.6 mg 4,4'-DDE/day, 4 mg 4,4'-DDD/day, and 0.2 mg 4,4'-DDT/day in section 1 were increased by factors of 100, 300, and 1000, respectively, to 60 mg 4,4'-DDE/day, 1200 mg 4,4'-DDD/day, and 200 mg 4,4'-DDT/day. In so doing, the model/measure ratios moved much closer to 1 for sections 1 and 2. However, this simultaneously caused the ratios in section 3 to move well above 1, especially for DDT. Note that such an added source must be enriched in DDT relative to DDE and DDD as compared to diffusive inputs from sediments in section 1. Thus additional inputs due to resuspension and desorption of the bed sediments cannot supply such an enrichment in DDT as compared to DDE and DDD.

It seems likely that model adjustments involving boundary layer thicknesses and inclusion of a significant additional source of DDx in the southern portion of the Channel could enable the model to fit the Sept 2013 data. But it is not the point of this mass balance modeling to "fit the data". Rather, this simple modeling is already sufficient to suggest two key outcomes concerning the dominant sources of DDx to the surface water in the Lauritzen Channel. First, as suggested by both the March 2012 and September 2013 data, the sediment bed with the highest porewater concentrations in the northern part of the Channel may well be the most important source of DDx, especially DDE and DDD, in the water column in that part of the Channel. However, the September 2013 data point to an important additional source besides the sediment bed of DDx, especially DDT, into the southern portion of the Channel. In addition

Table 4. Model predicted concentrations (ng/L) and corresponding ratios of modelled/measured (based on PE) found making various modeling assumptions. Ratios are not shown for section 4 because no PE sampler was deployed in the water column of section 4 in the 2013 field campaign. bbl=bottom boundary layer thickness. "Base case" assumes bbl is 1 mm everywhere. "Change bbl" case allows a 1 cm thick bbl in sections 4 and 3, but retains a 1 mm bbl for sections 2 and 1. Finally, "add source" case increases the inputs to section 1 by a factor of 100 for DDE, a factor of 300 for DDD, and a factor of 1000 for DDT.

| **base case** | sec 4, bbl = 0.1 cm | sec 3, bbl = 0.1 cm | sec 2, bbl = 0.1 cm | sec 1, bbl = 0.1 cm |
|---|---|---|---|---|
| 4,4'-DDE | 2.1 | 1.3 | 0.9 | 0.8 |
| 4,4'-DDD | 24 | 9.6 | 4.2 | 2.0 |
| 4,4'-DDT | 0.6 | 0.4 | 0.3 | 0.3 |
| | | **model/measure** | **model/measure** | **model/measure** |
| 4,4'-DDE | | 2.0 | 0.2 | 0.3 |
| 4,4'-DDD | | 1.9 | 0.2 | 0.3 |
| 4,4'-DDT | | 1.4 | 0.04 | 0.08 |

| **change bbl** | sec 4, bbl = 1 cm | sec 3, bbl = 1 cm | sec 2, bbl = 0.1 cm | sec 1, bbl = 0.1 cm |
|---|---|---|---|---|
| 4,4'-DDE | 0.9 | 0.9 | 0.8 | 0.7 |
| 4,4'-DDD | 4.3 | 2.9 | 2.3 | 1.5 |
| 4,4'-DDT | 0.3 | 0.3 | 0.3 | 0.3 |
| | | **model/measure** | **model/measure** | **model/measure** |
| 4,4'-DDE | | 1.4 | 0.2 | 0.3 |
| 4,4'-DDD | | 0.6 | 0.1 | 0.2 |
| 4,4'-DDT | | 1.1 | 0.04 | 0.08 |

| **add source** | sec 4, bbl = 1 cm | sec 3, bbl = 1 cm | sec 2, bbl = 0.1 cm | sec 1, bbl = 0.1 cm |
|---|---|---|---|---|
| 4,4'-DDE | 1.4 | 1.4 | 1.3 | **1.2** |
| 4,4'-DDD | 15 | 14 | 13 | **11** |
| 4,4'-DDT | 2.1 | 2.1 | 2.1 | **1.9** |
| | | **model/measure** | **model/measure** | **model/measure** |
| 4,4'-DDE | | 2.2 | 0.3 | 0.5 |
| 4,4'-DDD | | 2.7 | 0.6 | 1.8 |
| 4,4'-DDT | | 7.4 | 0.3 | 0.5 |

to comparing modeled and measured concentrations, one can contrast the total masses of DDx measured in the Lauritzen Channel assuming the near-surface deployed water column samplers reflect vertically well-mixed concentrations. This calculation implies one must introduce more than 10x more DDT to the southern part of the Channel than is diffusing out of the sediment bed there (factor depends on how close to the mouth of the Channel the input occurs), even assuming a thin diffusive boundary layer of 0.2 mm thickness. (The same calculation for DDE and DDD implies only an additional source about 1x and 3x greater than diffusion for the bed, respectively.) And if the model is inaccurately representing a stratified water column, the high relative concentration of DDT in sampler L01 still suggests a non-sediment bed input of this compound to this surface water.

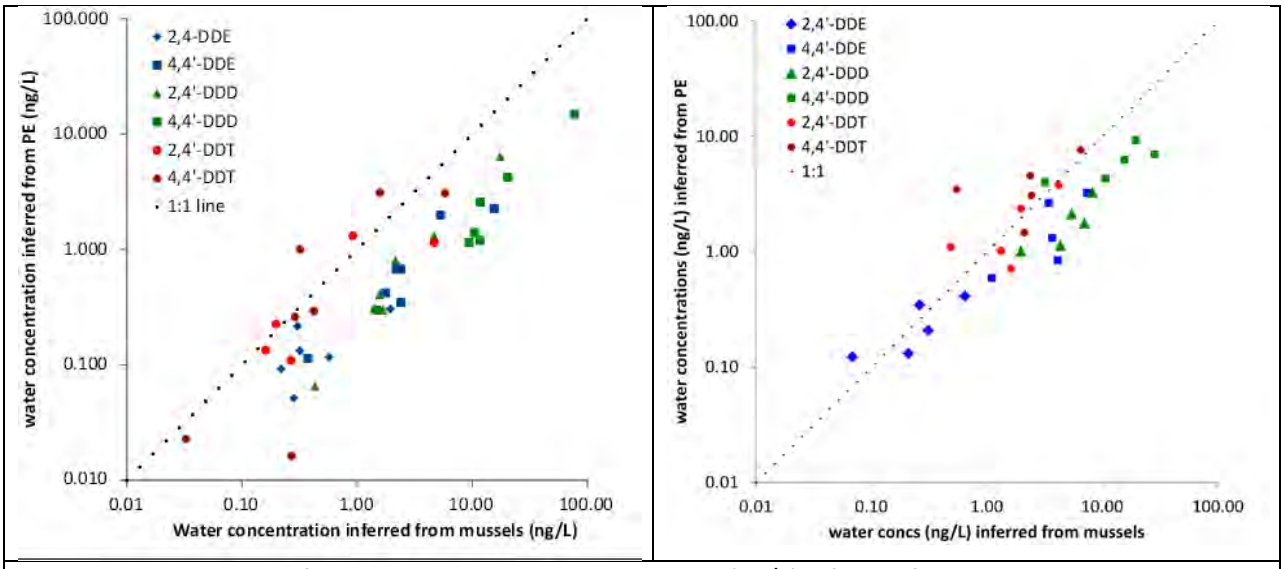


Figure 7. Comparison of water column DDx concentrations (ng/L) inferred from transplanted mussel tissues and from co-deployed PE samplers. (left) Data from September 2013 and (right) from March 2012.

This suggestion is supported by the particularly large discrepancy for DDT, seen in both the 2012 and 2013 data for the southern section, which implies a source of unreacted insecticide nearby. It is also noteworthy that the water column sampler deployed at the mid-Channel site, L02, exhibited the highest DDx concentrations. This sampler had a relatively low DDD-to-DDT ratio (about 2 to 1), especially compared to the water column sampler in the northern part of the Channel (station 303.7 had DDD-to-DDT at about 20 to 1). Finally, this water column sampler at L02 was the only one that did not become covered with a thick biofilm, perhaps implying that the DDx was at toxic at that location.

**Potential for Use of PE Samplers as Surrogates for Mussels**

Transplanted mussels, co-deployed with the PE samplers, also exhibited DDx levels in their tissues (CH2M-HILL, 2013a). Normalizing these tissue data to the mussels' lipid contents, and then dividing by each DDx's lipid-water partition coefficient (Table 1), allows a second independent estimate of the freely dissolved DDx at the site.

The mussel data suggest the dissolved DDx concentrations ranged from 0.1 to 100 ng/L, with DDD isomers predominating. On average, for the Sept. 2013 field observations, the total DDx based on the mussels was 5x larger than what was inferred from the PE data (Figure 7, left). Only a factor of 2x average offset was seen using the March 2012 data (Figure 7, right). The cause of these higher inferred water concentrations from the mussel data is unknown. It may involve inaccuracies in the $K_{lip\text{-}w}$ values used (Table 1), as these values are somewhat uncertain. The values in Table 1 would have to be biased low. But it may also involve uptake of DDx as a result of mussel ingestion of resuspended sediment bed solids. If this is correct, the mussel might "overestimate" the truly dissolved water column concentrations if the resuspended bed particles did not have enough time to equilibrate in the overlying water column. Moreover, the mussel monitoring might be especially sensitive to temporally varying

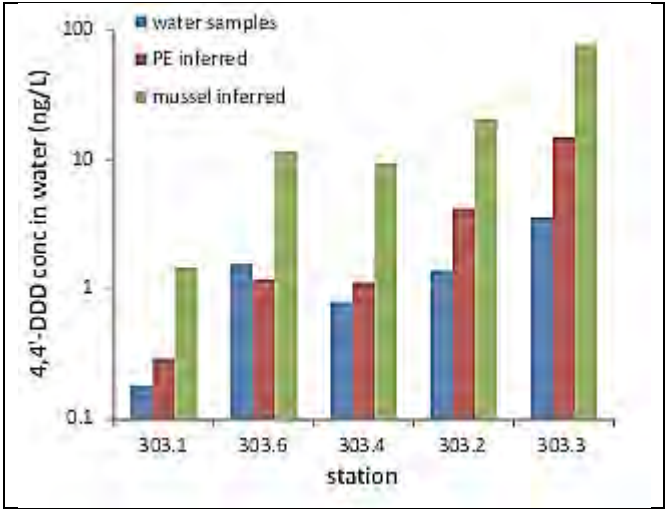


Figure 8. Average concentrations of 4,4'-DDD measured at five stations using filtered water samples (blue), PE water column samplers (red), and transplanted mussels (green).

intensities of sediment resuspension arising from changing tugboat activities in the Channel. We note that the samplers deployed at stations PE13-09 and PE13-52 in September 2013 had been substantially buried during that field campaign, perhaps also indicating the occurrence and importance of sediment disturbance during that period.

We also note that the average DDx concentrations in filtered water samples collected in September 2013 (CH2M_HILL, 2013b) were about half of the values inferred from PE and more than 10x less than mussel-inferred results (Figure 8). This trend was also seen in our first year of passive sampling at this Superfund site (September 2009) in which we reported: "Ratios of mussel-inferred concentrations to filtered water concentrations were 20±13 (and mussel to SPME ratios were 11±7). This may indicate that the mussels exhibit body burdens reflecting uptake from the frequently resuspended bed solids, and the DDT/DDD/DDE in those solids were not equilibrated with the water column." Burgess et al. (2010) have previously suggested this type of effect may explain the relationship between concentrations accumulated in transplanted mussels and passive samplers (e.g., PE) for PCBs at the New Bedford Harbor Superfund site.

Nonetheless, the PE data correlated well with the mussel data in both 2012 and 2013. Hence, if the goal is to monitor a site's changes over time, this result supports the suggestion that PE samplers can be substituted for mussels in future monitoring efforts. However, if one wants to accurately quantify the truly dissolved concentrations of hydrophobic substances like DDx, then we need a better understanding of the biases associated with (a) using single time point data from filtered water samples versus (b) time averaging with PE samplers and (c) inferences from filter feeding organisms like mussels as well as improved certainty with respect to their lipid-water partition coefficients.

**Conclusions**

The September 2013 data substantially filled in the map of DDx porewater concentrations in the Lauritzen Channel sediments. As a result, it appears that the heavily contaminated northern section of

the Channel has a much smaller footprint than thought based on only our 2012 data. This decreases its importance by about a factor of 2 as compared to the 2012 mapping. But since the most prominent DDx, 4,4'-DDD has about 90% of its flux into the water occurring in this very northernmost section, even more careful delineation of its extent may be merited.

The mass balance modeling supports the contention that diffusion out of the sediments is the dominant DDx source to the overlying water in the northern sections (sections 3 and 4). However, the same modeling points to at least one "missing source" of a DDT-rich DDx mixture somewhere mid-channel (section 2) or further south (section 1).

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Lorke, A., B. Muller, M. Maerki, and A. Wuest. Breathing sediments: The control of diffusive transport across the sediment-water interface by periodic boundary-layer turbulence. Limnol. Oceanogr. 48, 2077-2085, 2003.

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**Appendix A**. Bottom water (blue) and pore water (brown) concentrations (ng/L) found using PE samplers at 10 sites in the Lauritzen Channel. Site 9 shows results for two samplers deployed beside each other.

| | Site 51 | | Site 05 | |
|---|---|---|---|---|
| | H2O 0-7cm | SED 0-5cm | H2O 0-1cm | SED 0-5cm |
| | piling -38 | | piling -43 | |
| **2,4'-DDE** | 0.32 | 1.2 | 1.1 | 1.3 |
| **4,4'-DDE** | 2.5 | 9.7 | 8.4 | 7.5 |
| **2,4'-DDD** | 8.4 | 38 | 33 | 38 |
| **4,4'-DDD** | 32 | 133 | 112 | 134 |
| **2,4'-DDT** | 0.29 | < 0.1 | < 0.1 | < 0.2 |
| **4,4'-DDT** | 0.53 | 0.27 | 0.14 | < 0.2 |
| **∑ DDx** | **44** | **182** | **155** | **181** |

| | Site 52 | | Site 09-1 | | Site 09-2 | |
|---|---|---|---|---|---|---|
| | SED 0-5cm | SED 5-10cm | SED 0-5cm | SED 5-10cm | SED 0-5cm | SED 5-10cm |
| | piling -24 | | | piling -30 | | |
| **2,4'-DDE** | 1.0 | 0.9 | 1.9 | 1.2 | 1.3 | 0.9 |
| **4,4'-DDE** | 7.8 | 9.3 | 27 | 11 | 23 | 7.8 |
| **2,4'-DDD** | 29 | 25 | 67 | 51 | 41 | 49 |
| **4,4'-DDD** | 82 | 84 | 218 | 152 | 143 | 117 |
| **2,4'-DDT** | 0.4 | < 0.1 | < 0.1 | 1.0 | < 0.1 | < 0.1 |
| **4,4'-DDT** | < 0.1 | 0.20 | 2.02 | < 0.1 | < 0.1 | < 0.1 |
| **∑ DDx** | **120** | **119** | **316** | **216** | **207** | **175** |

| | Site 54 | | Site 53 | | Site 56 | |
|---|---|---|---|---|---|---|
| | H2O 0-5cm | SED 0-5cm | H2O 0-5cm | SED 0-5cm | H2O 0-5cm | SED 0-5cm |
| | piling 15 | | piling -10 | | piling -16 | |
| **2,4'-DDE** | 0.20 | 0.18 | 0.27 | 0.74 | 0.49 | 1.3 |
| **4,4'-DDE** | 2.1 | 1.9 | 2.4 | 6.6 | 4.7 | 11 |
| **2,4'-DDD** | 2.9 | 3.3 | 5.0 | 21 | 10 | 32 |
| **4,4'-DDD** | 9.2 | 10 | 16 | 61 | 35 | 102 |
| **2,4'-DDT** | 0.13 | 0.16 | < 0.1 | < 0.1 | 0.65 | < 0.1 |
| **4,4'-DDT** | 0.34 | 0.28 | 1.1 | 1.7 | 2.0 | 0.46 |
| **∑ DDx** | **15** | **15** | **25** | **92** | **53** | **147** |

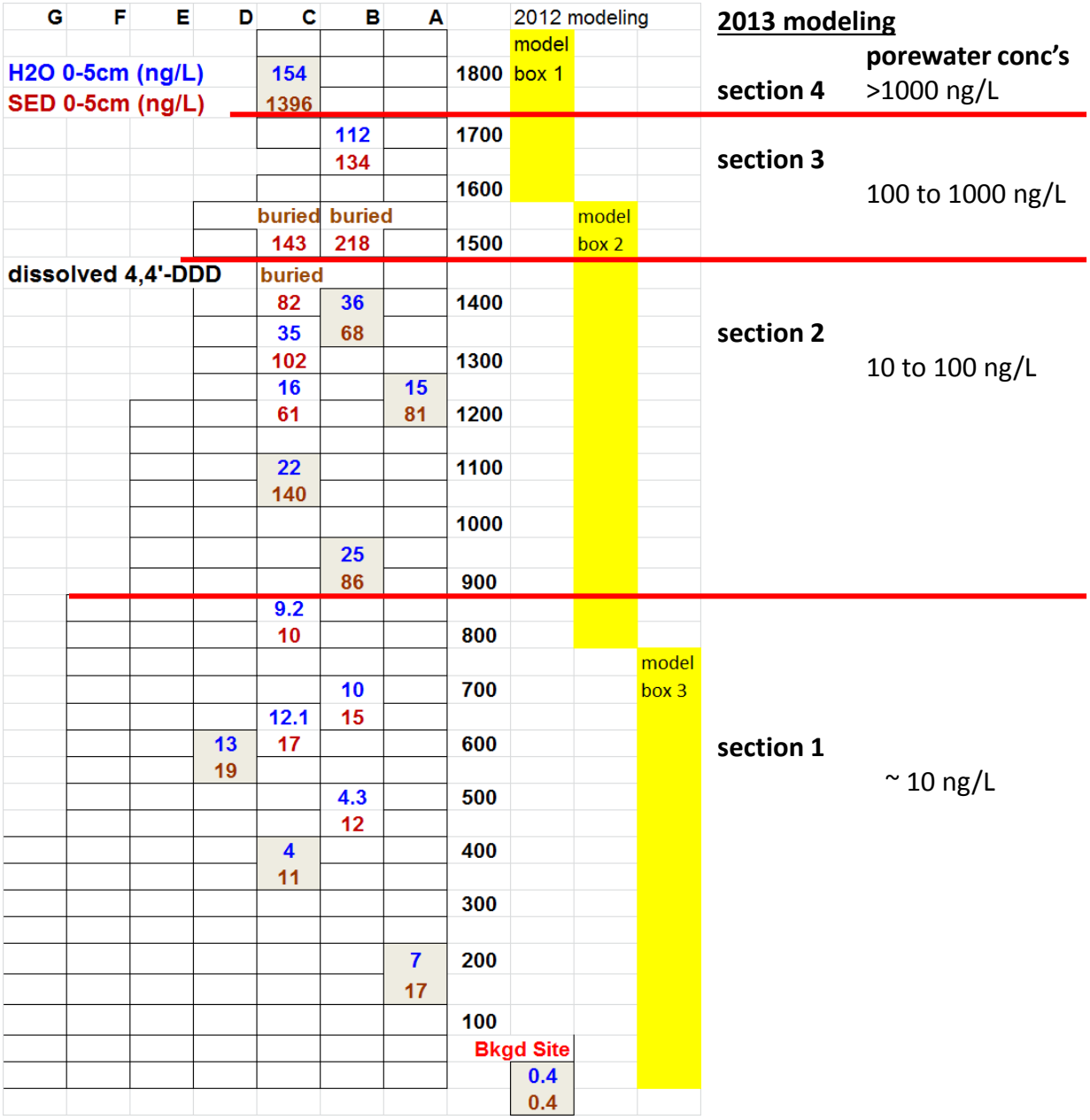
| | Site 33 | | Site 55 | | Site 29 | |
|---|---|---|---|---|---|---|
| | H2O 0-5cm | SED 0-5cm | H2O 0-5cm | SED 0-5cm | H2O 0-5cm | SED 0-5cm |
| | piling 37 | | piling 30 | | piling 24 | |
| **2,4'-DDE** | 0.16 | 0.34 | 0.16 | 0.28 | 0.46 | 0.37 |
| **4,4'-DDE** | 1.3 | 3.6 | 1.6 | 2.0 | 3.2 | 3.1 |
| **2,4'-DDD** | 1.3 | 3.5 | 3.5 | 5.0 | 3.2 | 4.9 |
| **4,4'-DDD** | 4.3 | 12 | 12.1 | 17 | 10 | 15 |
| **2,4'-DDT** | 0.12 | 0.06 | 0.02 | 0.03 | 0.33 | 0.02 |
| **4,4'-DDT** | 0.31 | 0.5 | 0.13 | 0.06 | 0.5 | 0.19 |
| **∑ DDx** | **7.5** | **20** | **17** | **24** | **17** | **24** |

**Appendix B**. Water column concentrations (ng/L) found using PE samplers. Note: the sampler for site **L02** was found underneath the pier; this sampler was the only one to show no signs of biological colonization.

| | Ford Pier 303.1 | Parr Canal 303.6 | floating dock 303.4 | Floating dock 303.4 - Deep | outer channel 303.2 | outer channel 303.2 - Deep |
|---|---|---|---|---|---|---|
| 2,4'-DDE | < 0.003 | 0.22 | 0.09 | 0.05 | 0.12 | 0.13 |
| 4,4'-DDE | 0.11 | 0.42 | 0.68 | 0.35 | 2.0 | 0.67 |
| 2,4'-DDD | 0.07 | 0.30 | 0.31 | 0.41 | 1.3 | 0.81 |
| 4,4'-DDD | 0.30 | 1.2 | 1.1 | 1.4 | 4.2 | 2.6 |
| 2,4'-DDT | < 0.001 | 0.11 | 0.13 | < 0.001 | 1.3 | 0.23 |
| 4,4'-DDT | 0.02 | 0.29 | 0.26 | 0.02 | 3.1 | 1.00 |
| sum DDx | 0.5 | 2.5 | 2.6 | 2.2 | 12.1 | 5.4 |

| | inside channel L01 | mid channel L02* | inner channel 303.3 | inner channel 303.3 - Dupl. | hot spot 303.7 |
|---|---|---|---|---|---|
| 2,4'-DDE | 0.19 | 0.13 | 0.31 | 0.32 | 0.10 |
| 4,4'-DDE | 2.7 | 6.6 | 2.3 | 2.3 | 0.62 |
| 2,4'-DDD | 2.8 | 9.6 | 6.4 | 5.5 | 2.1 |
| 4,4'-DDD | 8.5 | 35 | 15 | 13 | 5.1 |
| 2,4'-DDT | 1.6 | 8.4 | 1.1 | 2.1 | 0.15 |
| 4,4'-DDT | 4.2 | 9.6 | 3.1 | 7.2 | 0.29 |
| sum DDx | 20.0 | 69.7 | 28.0 | 30.5 | 8.3 |

**Appendix C**. Subdivision of the Lauritzen Channel into four sections for the 2013 modeling based on areas having similar porewater concentrations of 4,4'-DDD, the most abundant consituent of DDx in the sediments at this site.



**Appendix D**. Modeling sensitivity studies to input parameters: (a) bottom boundary layer thickness held constant over the whole Channel, (b) bottom boundary layer thickness allowed to vary with position in the Channel, and (c) Santa Fe Channel concentrations set equal to those found at station 303.4 (Floating Dock), at station 303.1 (Ford Point), or an average of these two. Improvements in fits can be judged by looking at how close the ratios of model/measure approach the value, 1.0.

**Sensitivity of Lauritzen Channel water column concentrations of specific 4,4' DDx isomers to the choice of bottom boundary layer thicknesses where all taken to be same.**

| | Modelled water concs (pg/L) 2 mm bbl | Model/Measure | Modelled water concs (pg/L) 1 mm bbl | Model/Measure | Modelled water concs (pg/L) 0.5 mm bbl | Model/Measure | Modelled water concs (pg/L) 0.1 mm bbl | Model/Measure |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| 4,4'-DDE | 1399 | | 2117 | | 3555 | | 15054 | |
| 4,4'-DDD | 12466 | | 23832 | | 46564 | | 228419 | |
| 4,4'-DDT | 414 | | 568 | | 875 | | 3337 | |
| | | | | | | | | |
| 4,4'-DDE | 969 | 1.56 | 1259 | 2.03 | 1838 | 2.96 | 6469 | 10.43 |
| 4,4'-DDD | 5356 | 1.05 | 9611 | 1.88 | 18122 | 3.55 | 86211 | 16.90 |
| 4,4'-DDT | 330 | 1.14 | 399 | 1.38 | 539 | 1.86 | 1654 | 5.70 |
| | | | | | | | | |
| 4,4'-DDE | 806 | 0.18 | 931 | 0.21 | 1182 | 0.27 | 3191 | 0.72 |
| 4,4'-DDD | 2644 | 0.11 | 4187 | 0.17 | 7274 | 0.30 | 31972 | 1.33 |
| 4,4'-DDT | 299 | 0.04 | 338 | 0.04 | 415 | 0.05 | 1036 | 0.12 |
| | | | | | | | | |
| 4,4'-DDE | 720 | 0.31 | 759 | 0.32 | 838 | 0.36 | 1472 | 0.63 |
| 4,4'-DDD | 1574 | 0.25 | 2047 | 0.32 | 2995 | 0.47 | 10575 | 1.67 |
| 4,4'-DDT | 272 | 0.07 | 285 | 0.08 | 310 | 0.08 | 509 | 0.14 |

**Sensitivity of Lauritzen Channel water column concentrations of specific 4,4' DDx isomers to the choice of bottom boundary layer thicknesses where allowed to vary from north to south.**

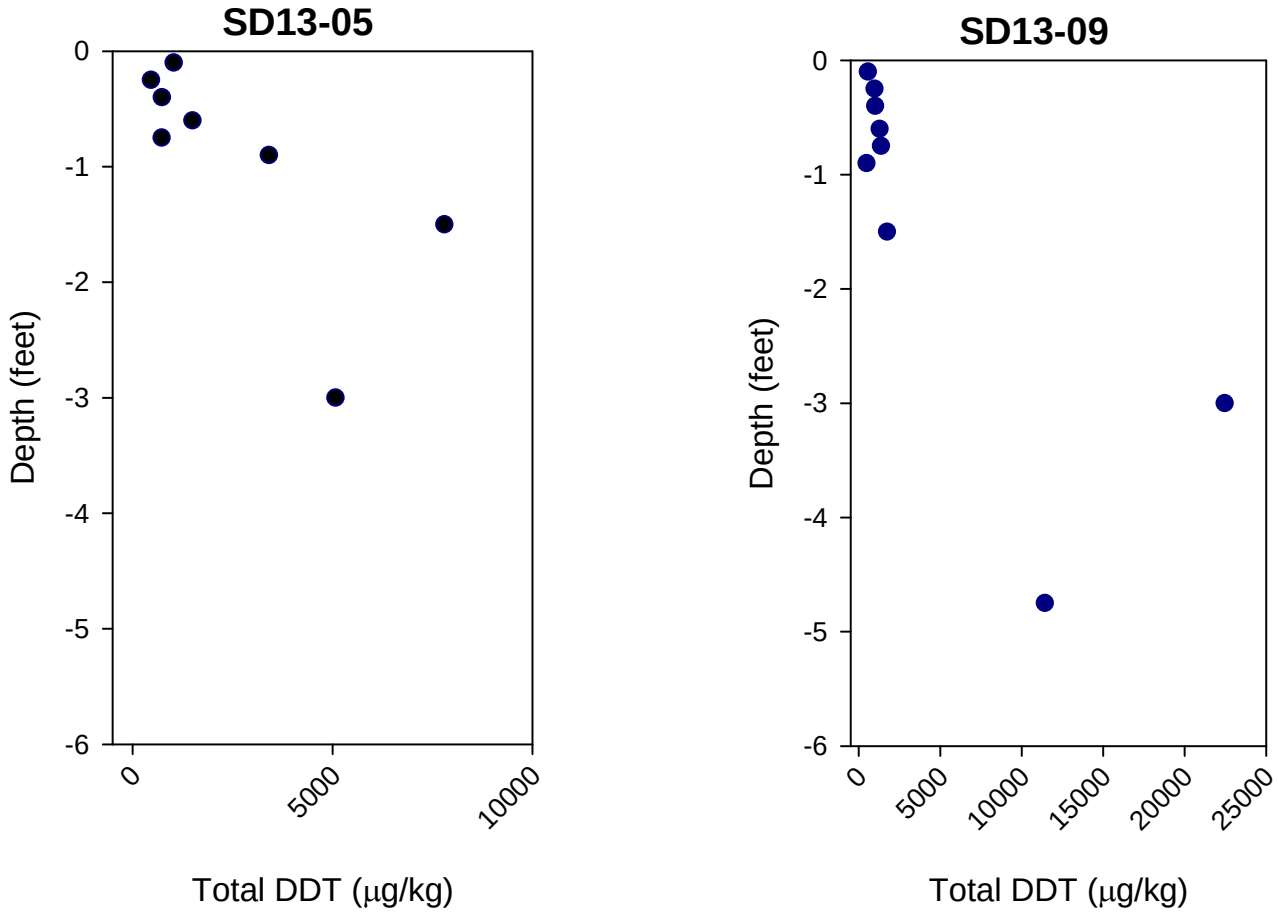
| | | | Modelled water concs (pg/L) 2, 1, 0.5, 0.1 mm bbls | Model/Measure | Modelled water concs (pg/L) 10, 10, 0.1, 0.1 mm bbls | Model/Measure |
|---|---|---|---|---|---|---|
| Measured water concs (pg/L) using PE (PRC corr'd) in fall 2013 | | | | | | |
| | section 4 | | | | | |
| 4,4'-DDE | | | 1660 | | 2155 | |
| 4,4'-DDD | | | 14708 | | 13771 | |
| 4,4'-DDT | | | 516 | | 872 | |
| | section 3 | | | | | |
| 4,4'-DDE | 620 | | 1229 | 1.98 | 2069 | 3.34 |
| 4,4'-DDD | 5100 | | 7564 | 1.48 | 12349 | 2.42 |
| 4,4'-DDT | 290 | | 432 | 1.49 | 855 | 2.95 |
| | section 2 | | | | | |
| 4,4'-DDE | 6600 | 2300 | 1040 | 0.23 | 1953 | 0.44 |
| 4,4'-DDD | 35000 | 13000 | 4519 | 0.19 | 11151 | 0.46 |
| 4,4'-DDT | 9600 | 7200 | 396 | 0.05 | 812 | 0.10 |
| | section 1 | | | | | |
| 4,4'-DDE | 2000 | 2700 | 821 | 0.35 | 1109 | 0.47 |
| 4,4'-DDD | 4200 | 8500 | 2366 | 0.37 | 4467 | 0.70 |
| 4,4'-DDT | 3100 | 4200 | 313 | 0.09 | 444 | 0.12 |

**Sensitivity of Lauritzen Channel water column concentrations of specific 4,4' DDx isomers to assumed Santa Fe Channel concentrations: (a) using Floating Dock values, (b) using Ford Point values, (c) using average of Floating Dock and Ford Point values.**

| | Modelled water concs (pg/L) | Model/Measure | Modelled water concs (pg/L) | Model/Measure | Modelled water concs (pg/L) | Model/Measure |
|---|---|---|---|---|---|---|
| | Floating Dock, 1 mm bbls | | Ford Point, 1 mm bbls | | ave Floating and Ford, 1 mm bbls | |
| | | | | | | |
| 4,4'-DDE | 2117 | | 1547 | | 1832 | |
| 4,4'-DDD | 23831 | | 23031 | | 23432 | |
| 4,4'-DDT | 568 | | 328 | | 448 | |
| | | | | | | |
| 4,4'-DDE | 1259 | 2.03 | 689 | 1.11 | 974 | 1.57 |
| 4,4'-DDD | 9610 | 1.88 | 8810 | 1.73 | 9211 | 1.81 |
| 4,4'-DDT | 399 | 1.38 | 159 | 0.55 | 279 | 0.96 |
| | | | | | | |
| 4,4'-DDE | 931 | 0.21 | 361 | 0.08 | 646 | 0.15 |
| 4,4'-DDD | 4186 | 0.17 | 3386 | 0.14 | 3787 | 0.16 |
| 4,4'-DDT | 338 | 0.04 | 98 | 0.01 | 218 | 0.03 |
| | | | | | | |
| 4,4'-DDE | 759 | 0.32 | 189 | 0.08 | 474 | 0.20 |
| 4,4'-DDD | 2047 | 0.32 | 1247 | 0.20 | 1647 | 0.26 |
| 4,4'-DDT | 285 | 0.08 | 45 | 0.01 | 165 | 0.05 |

# Appendix F
# Coarse Interval Profiles

# Core Profiles

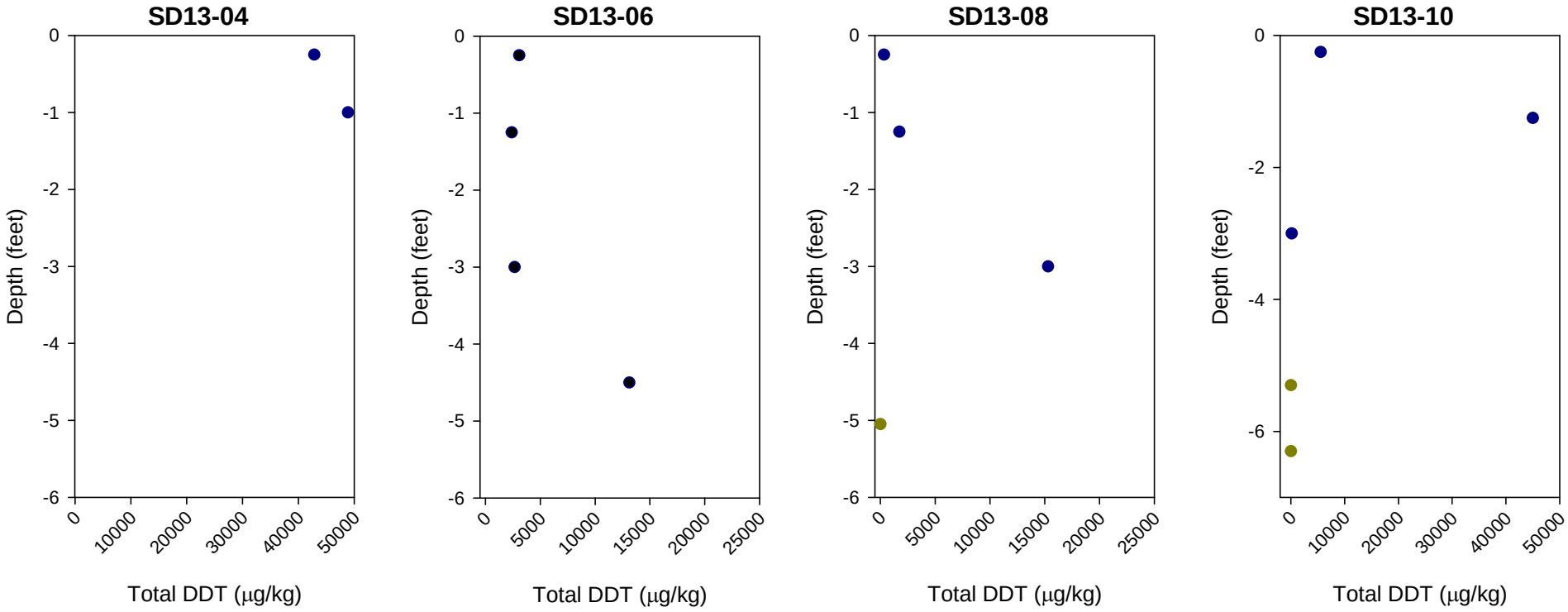



- Younger Bay Mud
- Older Bay Mud

**FIGURE F-1**
**SD13-05 and SD13-09**
**Core Profiles**
*United Heckathorn Superfund Site, Richmond, California*

CH2MHILL

# Core Profiles




Younger Bay Mud
Older Bay Mud

**FIGURE F-2**
**SD13-04, SD13-06, SD13-08, and SD13-10 Core Profiles**
*United Heckathorn Superfund Site, Richmond, California*

CH2MHILL

# Core Profiles

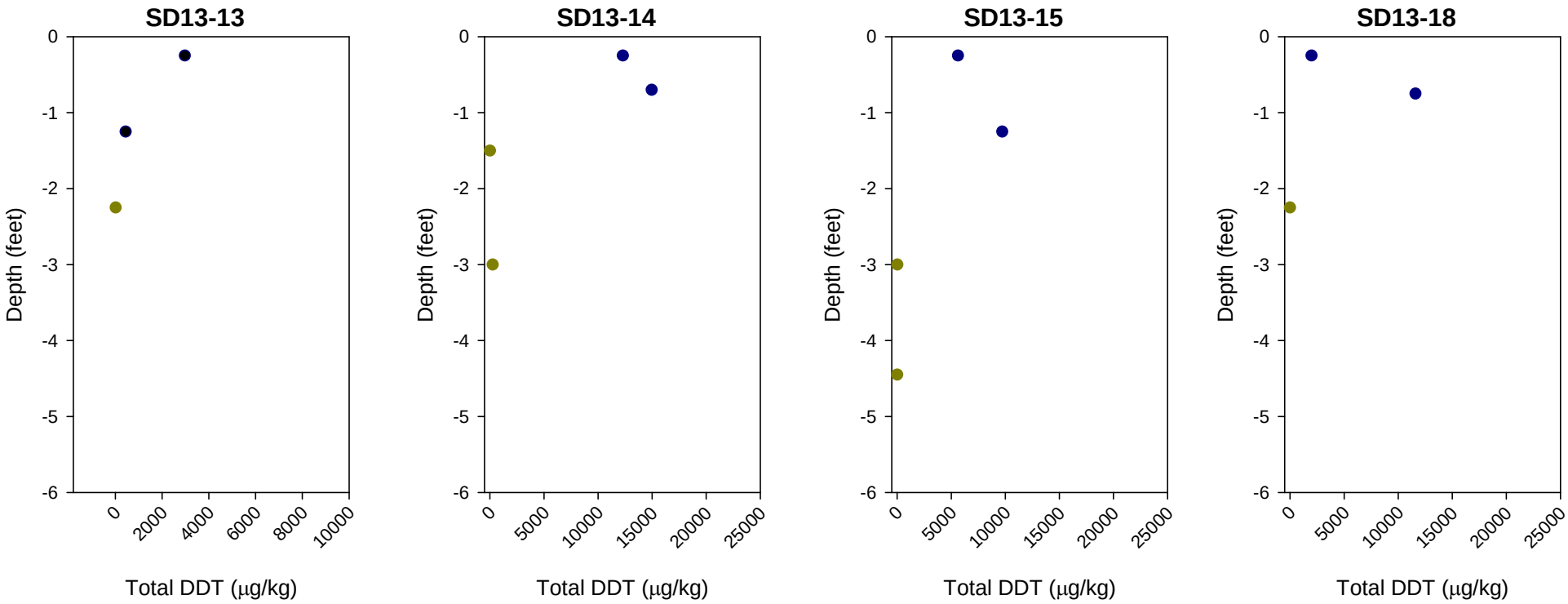
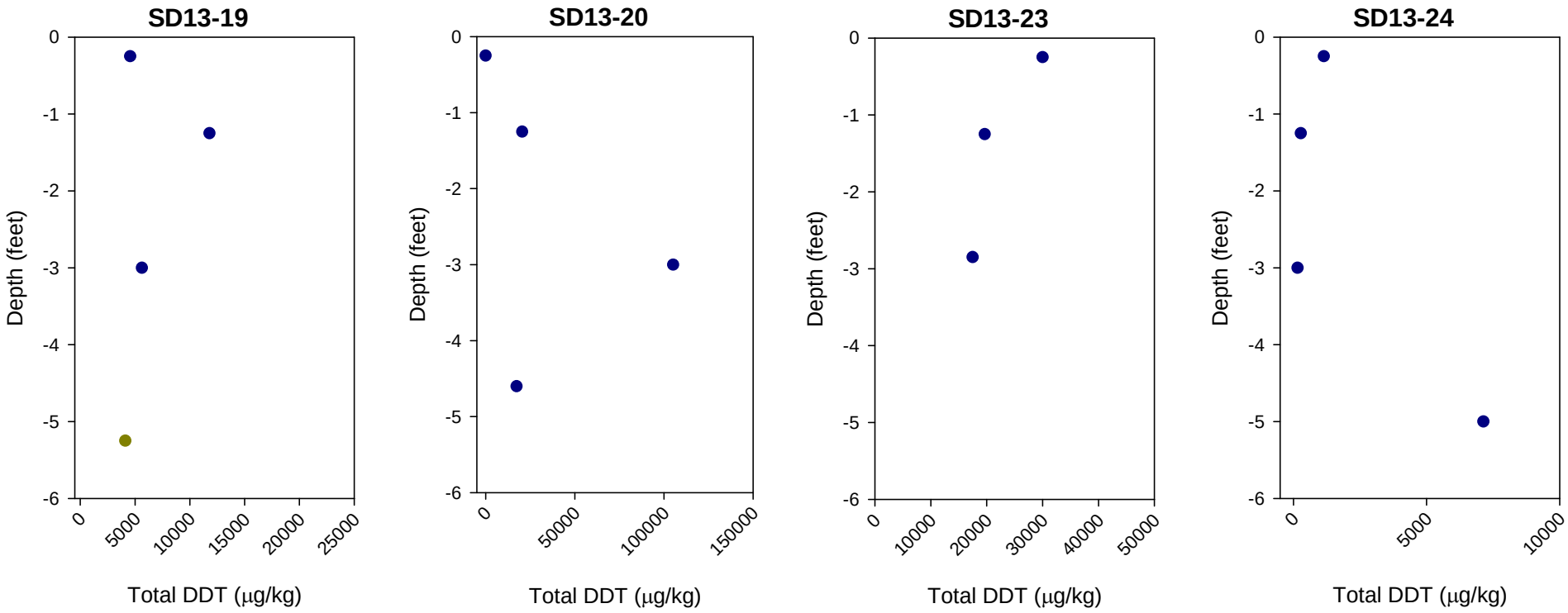



**FIGURE F-3**
**SD13-13, SD13-14, SD13-15, and SD13-18 Core Profiles**
*United Heckathorn Superfund Site, Richmond, California*

CH2MHILL

# Core Profiles

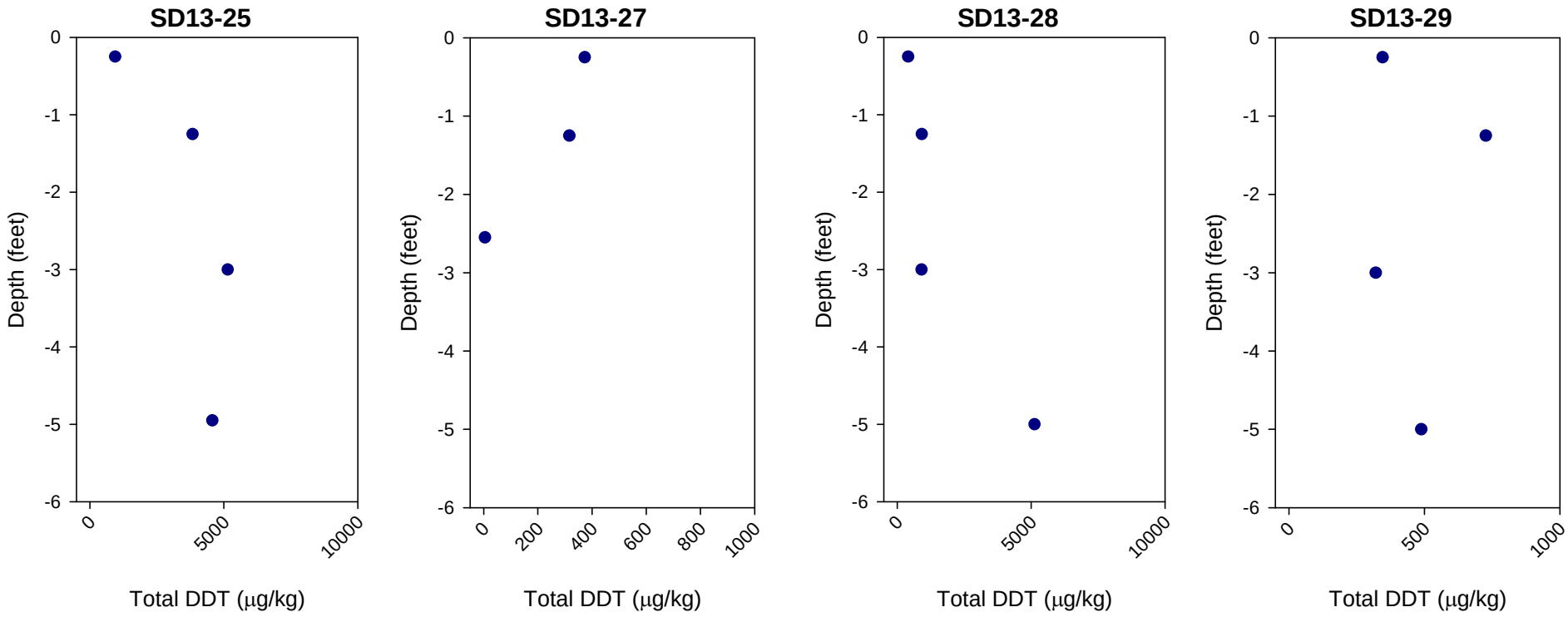



Younger Bay Mud
Older Bay Mud

**FIGURE F-4**
**SD13-19, SD13-20, SD13-23, and SD13-24 Core Profiles**
*United Heckathorn Superfund Site, Richmond, California*

CH2MHILL

# Core Profiles

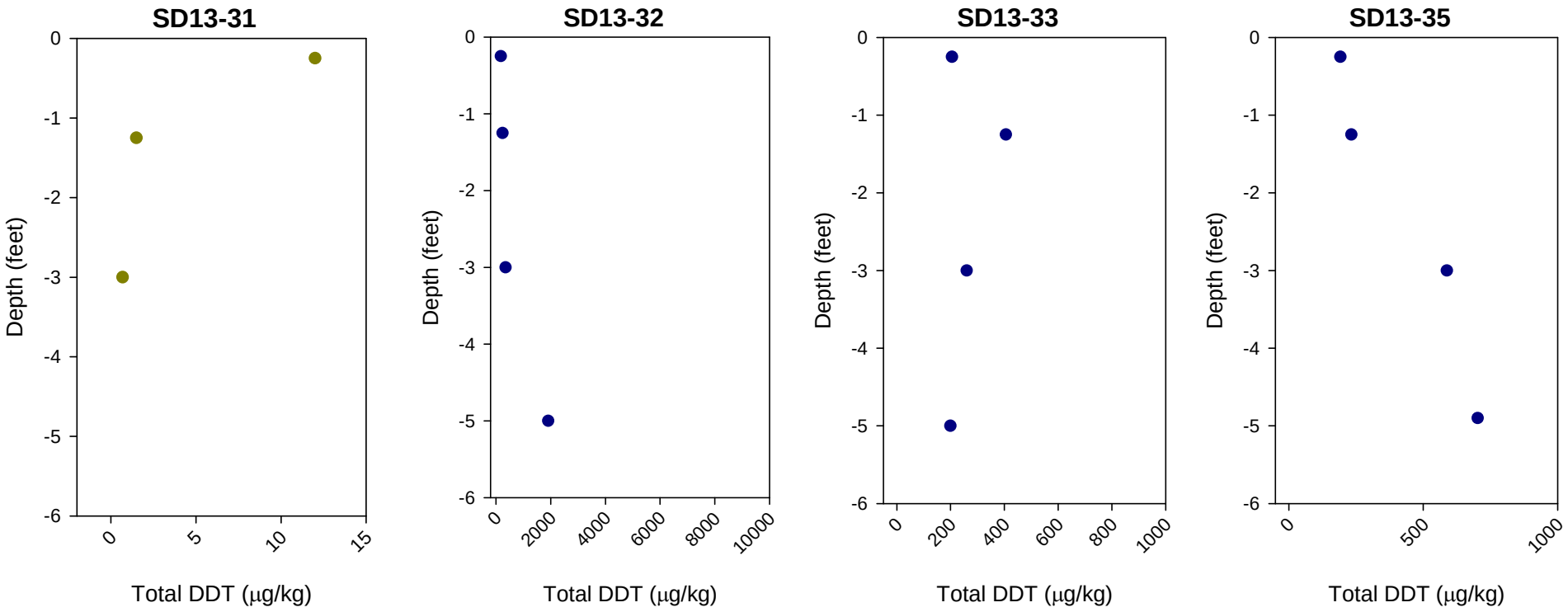



Younger Bay Mud
Older Bay Mud

**FIGURE F-5**
**SD13-25, SD13-27, SD13-28, and SD13-29 Core Profiles**
*United Heckathorn Superfund Site, Richmond, California*

CH2MHILL

# Core Profiles

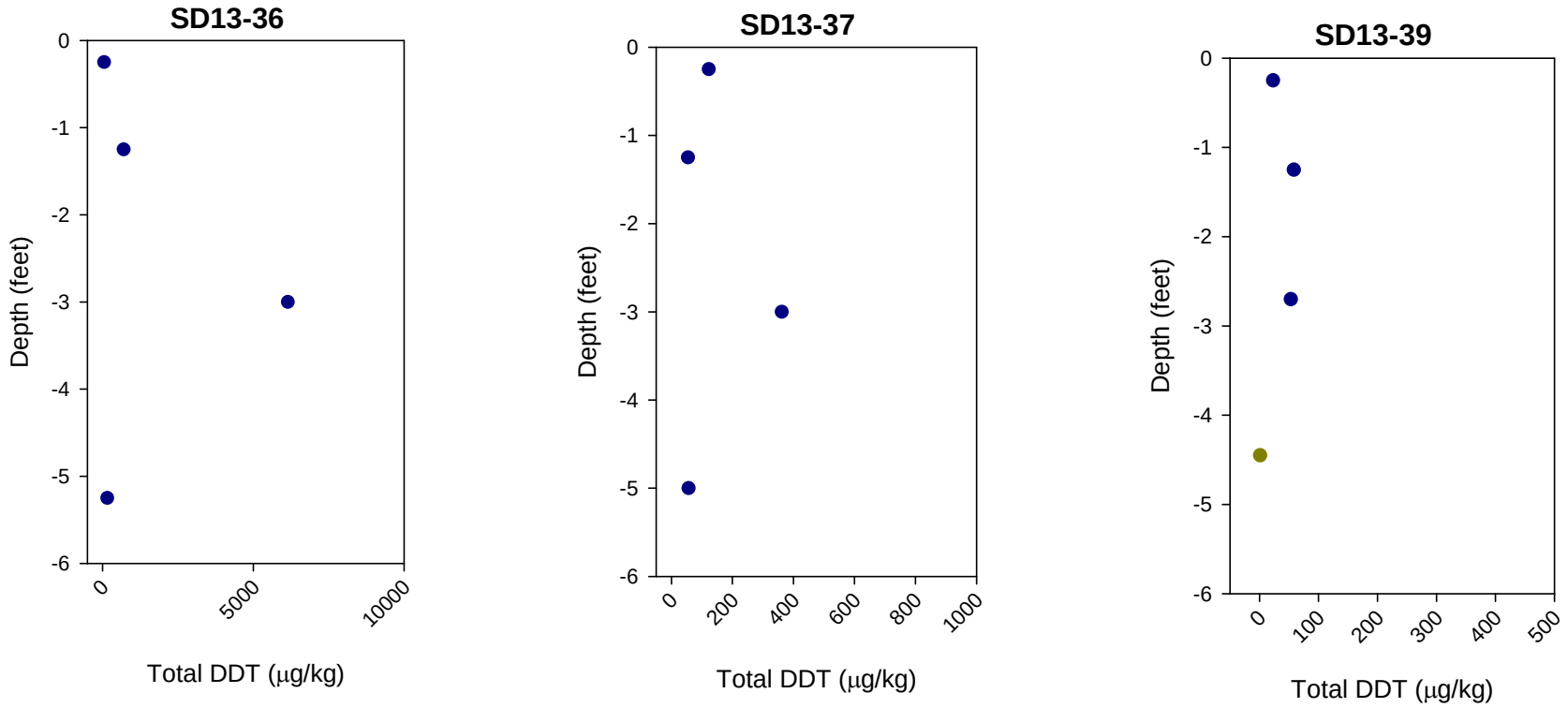



Younger Bay Mud
Older Bay Mud

**FIGURE F-6**
**SD13-31, SD13-32, SD13-33, and SD13-35 Core Profiles**
*United Heckathorn Superfund Site, Richmond, California*

CH2MHILL

# Core Profiles

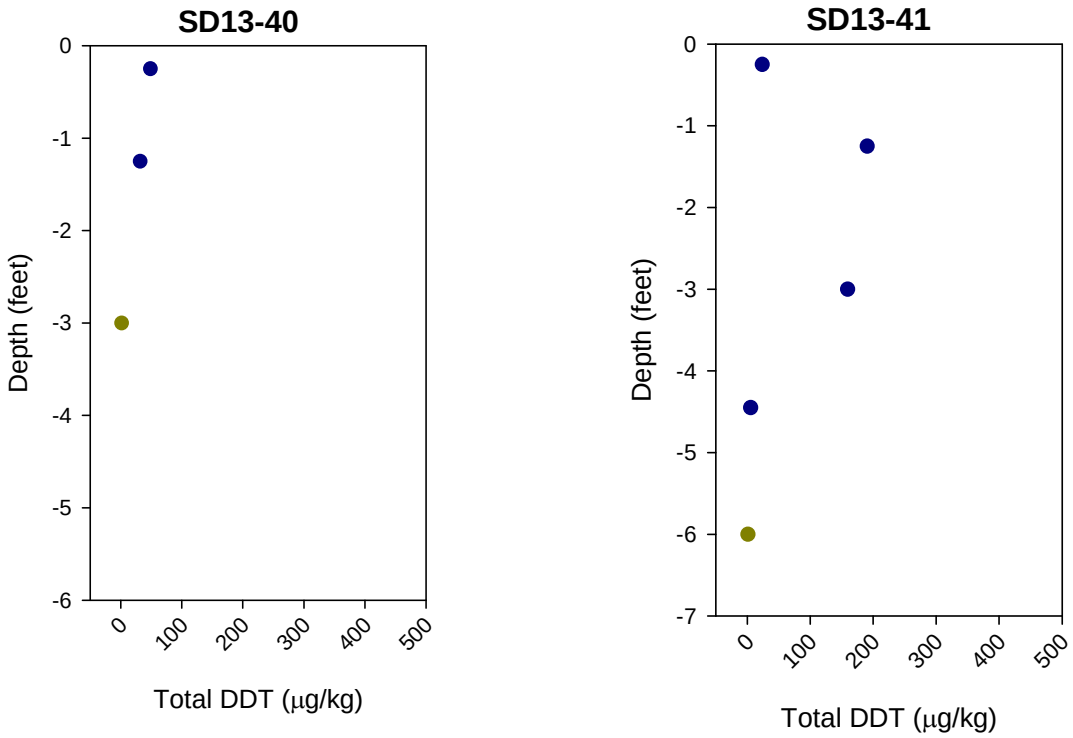



- Younger Bay Mud
- Older Bay Mud

**FIGURE F-7**
**SD13-36, SD13-37, and SD13-39**
**Core Profiles**
*United Heckathorn Superfund Site, Richmond, California*

CH2MHILL

# Core Profiles




- Younger Bay Mud
- Older Bay Mud

**FIGURE F-8**
**SD13-40 and SD13-41**
**Core Profiles**
*United Heckathorn Superfund Site, Richmond, California*

CH2MHILL

# Appendix G
# Estimated Costs for Remedial Alternatives

# Estimated Costs

This appendix presents the detailed cost estimates developed for the remedial alternatives summarized in the FFS report. The No Action Alternative (Alternative 1) has no associated costs and therefore is not discussed in this appendix.

## Acronyms and Abbreviations

| | |
|---|---|
| ea | each |
| FOGM | fuel oil grease maintenance |
| ft | foot or feet |
| $ft^2$ | square foot or feet |
| $ft^3$ | cubic foot or feet |
| gal | gallon(s) |
| gal/day | gallons(s) per day |
| gal/job | gallons(s) per job |
| gal/mo | gallons(s) per month |
| gpm | gallons per minute |
| H&S | health and safety |
| hrs | hours |
| in/mo | inch(es) per month |
| K/mo | thousand per month |
| lb | pound(s) |
| LF | linear foot or feet |
| LS | lump sum |
| min | minute(s) |
| mo | month |
| NA | not applicable |
| O&M | operations and maintenance |
| OT | overtime |
| PAC | powdered activated carbon |
| PM | project management |
| PRP | potentially responsible party |
| RCRA | Resource Conservation and Recovery Act |
| RFR | required for running |
| ROM | rough order of magnitude |
| ST | standard time |

| | |
|---|---|
| ton/day | ton(s) per day |
| ton/job | ton(s) per job |
| ton/mo | ton(s) per month |
| ton/$yd^3$ | ton(s) per cubic yard |
| TSCA | Toxic Substances Control Act |
| TSS | total suspended solids |
| USACE | U.S. Army Corps of Engineers |
| USEPA | U.S. Environmental Protection Agency |
| VOC | volatile organic compound |
| WWT | wastewater treatment plant |
| $yd^2$ | square yard |
| $yd^3$ | cubic yard(s) |
| $yd^3$ | cubic yards |
| yr | year |

# Introduction

At the Feasibility Study stage, the design of the remedial action is still conceptual, and the cost estimate is considered to be order-of-magnitude. As the project progresses and the design becomes more complete, the accuracy of the cost estimate increases. Costs prepared at the Feasibility Study stage of a remediation project can increase or decrease during final design and/or implementation. The order-of-magnitude cost estimates presented herein provide an accuracy of +50 percent to -30 percent. They are based on the assumptions outlined in Section 2 of this appendix and were prepared using the U.S. Environmental Protection Agency's (USEPA) *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (USEPA, 2000). This estimate is limited to the conditions existing at its issuance and is not a guaranty of actual price or cost. Uncertain market conditions such as, but not limited to, local labor or contractor availability, wages, other work, material market fluctuations, price escalations, force majeure events, and developing bidding conditions, may affect the accuracy of this estimate.

The cost summary tables include capital costs and operations and maintenance (O&M) costs. Capital costs consist of direct and indirect costs. Direct costs include the cost of construction, equipment, land and site development, treatment, transportation, and disposal. Indirect costs include engineering expenses, license, and permit costs. Annual O&M costs are the post-construction costs required for the continued effectiveness of the remedy. Components of annual O&M costs include the cost of maintenance materials and labor, monitoring, and periodic site inspections.

Expenditures that occur over different periods were analyzed using present-worth, which discounts all future costs to a base year. Present-worth analysis allows the cost of remedial action alternatives to be compared on the basis of a single figure representing the amount of money that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the life of the remedial project. Assumptions associated with the present-worth calculations include a discount rate of 7 percent (USEPA, 2000), cost estimates in the planning years in constant dollars, a 30-year period for O&M, and less than 1 year of construction to implement the remedy.

The cost estimates are in 2014 dollars and were prepared on the basis of the site information available at the time of preparation of this report and the components of the conceptual remedial alternatives presented herein. Additional investigation activities and evaluations will be performed during the remedial design.

The cost estimates were prepared using vendor quotes, technology reference documents, and actual costs from other sediment remediation projects available at the time of preparation of this report. Quantities were priced using a detailed built up approach. Crews were built up using Davis Bacon labor rates (U.S. Department of Labor, 2014) for Contra Costa County California; construction equipment were based on historical rental rates; and material was based on like proposals. Production rates and labor costs for engineering and construction management were based on CH2M HILL's experience. Other items were based on RS Means Cost Data and bids received for recent similar work.

In summary, the cost estimates were prepared to compare the various remedial alternatives. The actual cost of the selected remedial alternative will depend on a number of factors, including:

- Final sediment volumes removed and sent to offsite landfill for removal
- Final cap design and associated material volumes
- Shoreline source control measures prevent recontamination of the channel from upland sources of contamination
- Competitive market conditions
- Actual labor and material costs

Although these factors will affect the cost of each remedial action alternative, they are not expected to affect the relative cost differences between alternatives for the purpose of comparing alternatives. The final costs will, however, likely vary from the estimates presented in this report, so funding needs must be carefully reviewed before specific financial decisions are made or final budget is established.

# Summary of Alternatives and Key Assumptions

This section presents a summary of the primary components of each remedial alternative and the associated assumptions that were integral to the cost estimates. In some cases numbers have been rounded for presentation purposes. Additional details including unit rates and quantities used are provided in the cost estimate backup tables.

## Alternative 2

Dredge East Side and West Side, Cap Northern Head, Implement Source Control Measures, Utilize Offsite Landfill Disposal, Implement Long-Term Monitoring, and Implement Institutional Controls

### Dredge East Side and West Side

- 58,000 cubic yards ($yd^3$) dredged material, 100 percent of the East and West Side Areas of Lauritzen Channel. After completion of dredging activities, a 6-inch sand layer would be placed throughout the dredged areas.
  - West Side: 3.0 acres (132,000 square feet [$ft^2$]), 17,000 $yd^3$
  - East Side: 4.0 acres (175,000 $ft^2$), 41,000 $yd^3$
- Mechanical dredging using an environmental bucket
- 6 inches post-dredge residual sand cover
- Scows for material transport would be staged outside the remedial cell
- Estimated dredge production rates and volumes
  - Tight area dredging production rate 1,250 $yd^3$/day, 10 percent of total sediment volume (5,800 $yd^3$), 5 days to complete
  - Open area dredging production rate 1,500 $yd^3$/day, 90 percent of total sediment volume (52,200 $yd^3$), 35 days to complete

- Water treatment estimate, 3,950,000 gallons
  - Volume water recovered from scows (95 percent of free water in scows after dredging), rainwater, pressure wash water, backwash water from water treatment system
  - Wastewater treatment system capacity 75 gallons per minute (gpm)
  - Treatment 24 hours/day, 90 percent uptime/day
- Dredged material solidification/stabilization, 94,500 tons
  - Dredged sediment would be transported in the scow to the onsite staging area
  - 87,000 tons of sediment (in-situ bulk density 1.5 tons/ $yd^3$ x 58,000 $yd^3$)
  - 500 tons free water incorporated in sediment (5 percent of free water in scows after dredging)
  - 7,000 tons Portland cement (8 percent by weight)

### Cap Northern Head

- 100 percent of Northern Head Area of Lauritzen Channel (1.4 acres / 61,000 $ft^2$)
- 3 inches active material (AquaGate + powdered activated carbon (PAC) [10 percent activated carbon])
- 6 inches residual sand cover
- 12 inch riprap armor layer
- Cap materials placed by clamshell bucket (barge-mounted or land-based)
- Final cap design determined during remedial design

### Source Control Measures

- Northern End Shoreline Area
  - 135 linear feet (LF) sheet piling
  - Sediment excavation and filling to remove shallow nearshore sediments and prepare the slope for capping
  - Cap materials placed by clamshell bucket (barge-mounted or land-based)
  - 3 inches active material (AquaGate + PAC [10 percent activated carbon]) on retained side of sheet piling
  - 4,400 $ft^2$ geotextile, 6 inches residual sand cover, 325 tons riprap
- Northern Piles Area
  - 320 LF sheet piling
  - Removal and/or cutting (1-foot recess below grade) of vertical timber piles to clear the slope
  - Cap materials placed by clamshell bucket (barge-mounted or land-based)
  - 3 inches active material (AquaGate + PAC [10 percent activated carbon]) on retained side of sheet piling
  - 5,500 $ft^2$ geotextile, 6 inches residual sand cover, 400 tons riprap
- Southern Piles Area
  - 410 LF sheet piling
  - Removal and/or cutting (1-foot recess below grade) of vertical timber piles to clear the slope
  - Removal of the former pier section located at Bent -7 to Bent -8
  - Cap materials placed by clamshell bucket (barge-mounted or land-based)
  - 3 inches active material (AquaGate + PAC [10 percent activated carbon]) on retained side of sheet piling
  - 5,500 $ft^2$ geotextile, 6 inches residual sand cover, 760 tons riprap
- Levin Pier Shoreline Area

  - 300 LF sheet piling
  - Pier piles left in place
  - Cap materials placed by clamshell bucket (barge-mounted or land-based)
  - 3 inches active material (AquaGate + PAC [10 percent activated carbon]) on retained side of sheet piling
  - 5,500 $ft^2$ geotextile, 6 inches residual sand cover, 420 tons riprap
- Remove and/or seal non-functional pipes and outfalls along the eastern shoreline
- One-time removal of sediment from the City of Richmond storm drain system
  - 1,000 tons residual sediment over 400 LF of drain pipe
  - Sediment to be processed with dredged material from Lauritzen Channel

### Offsite Landfill Disposal

- Disposal of dredged material and debris, 95,350 tons
  - 94,500 tons of stabilized sediment
  - 850 tons of debris (0.1 percent by weight of stabilized sediment mass from tight areas and 1.0 percent by weight of stabilized sediment mass from open areas)
- All sediment and debris Class 1 non-Resource Conservation and Recovery Act (RCRA) waste
- Offsite RCRA Subtitle D Landfill
- Transport via rail

### Long-term Monitoring and Institutional Controls

- Long-term monitoring would be performed to provide cap and sheet piling integrity and performance (along shoreline and Northern Head Area)
- Institutional controls would be implemented to specify limitation on anchoring, mooring, dredging, and construction to minimize damage to the cap and sheet piling (along shoreline and capped area of Northern Head area).

## Alternative 3

Dredge East Side, West Side, and Portion of Northern Head, Cap Portion of Northern Head, Implement Source Control Measures, Utilize Offsite Landfill Disposal, Implement Long-term Monitoring, and Implement Institutional Controls

### Dredge East Side, West Side, and Portion of Northern Head

- 64,000 $yd^3$ dredged material, 100 percent of East and West Side Areas of Lauritzen Channel and 75 percent of Northern Head Area of Lauritzen Channel. After completion of dredging activities, a 6-inch sand layer would be placed throughout the dredged areas.
  - West Side: 3.0 acres (132,000 $ft^2$), 17,000 $yd^3$
  - East Side: 4.0 acres (175,000 $ft^2$), 41,000 $yd^3$
  - Northern Head: 1.0 acre (44,000 $ft^2$), 6,000 $yd^3$
- Mechanical dredging using an environmental bucket
- 6 inches post-dredge residual sand cover
- Scows for material transport staged outside the remedial cell
- Estimated dredge production rates and volumes

  - Tight area dredging production rate 1,250 $yd^3$ /day, 10 percent of total sediment volume (6,400 $yd^3$), 5 days to complete
  - Open area dredging production rate 1,500 $yd^3$ /day, 90 percent of total sediment volume (57,600 $yd^3$), 38 days to complete
- Water treatment estimate, 4,350,000 gallons
  - Volume water recovered from scows (95 percent of free water in scows after dredging), rainwater, pressure wash water, backwash water from water treatment system
  - Wastewater treatment system capacity 75 gpm
  - Treatment 24 hours/day, 90 percent uptime/day
- Dredged material solidification/stabilization, 104,000 tons
  - Dredged sediment would be transported in the scow to the onsite staging area
  - 96,000 tons of sediment (in-situ bulk density 1.5 tons/ $yd^3$ x 64,000 $yd^3$)
  - 550 tons free water Incorporated in sediment (5 percent of free water in scows after dredging)
  - 7,700 tons Portland cement (8 percent by weight)

### Cap Portion of Northern Head

- 25 percent of Northern Head Area of Lauritzen Channel (0.4 acre / 17,000 $ft^2$)
- 3 inches active material (AquaGate + PAC [10 percent activated carbon])
- 6 inches residual sand cover
- 12 inch riprap armor layer
- Cap materials placed by clamshell bucket (barge-mounted or land-based)
- Final cap design determined during remedial design

### Source Control Measures

- Northern End Shoreline Area
  - 135 LF sheet piling
  - Sediment excavation and filling to remove shallow nearshore sediments and prepare the slope for capping
  - Cap materials placed by clamshell bucket (barge-mounted or land-based)
  - 3 inches active material (AquaGate + PAC [10 percent activated carbon]) on retained side of sheet piling
  - 4,400 $ft^2$ geotextile, 6 inches residual sand cover, 325 tons riprap
- Northern Piles Area
  - 320 LF sheet piling
  - Removal and/or cutting (1-foot recess below grade) of vertical timber piles to clear the slope
  - Cap materials placed by clamshell bucket (barge-mounted or land-based)
  - 3 inches active material (AquaGate + PAC [10 percent activated carbon]) on retained side of sheet piling
  - 5,500 $ft^2$ geotextile, 6 inches residual sand cover, 400 tons riprap
- Southern Piles Area
  - 410 LF sheet piling
  - Removal and/or cutting (1-foot recess below grade) of vertical timber piles to clear the slope
  - Removal of the former pier section located at Bent -7 to Bent -8
  - Cap materials placed by clamshell bucket (barge-mounted or land-based)

  - 3 inches active material (AquaGate + PAC [10 percent activated carbon]) on retained side of sheet piling
  - 5,500 $ft^2$ geotextile, 6 inches residual sand cover, 760 tons riprap
- Levin Pier Shoreline Area
  - 300 LF sheet piling
  - Pier piles left in place
  - Cap materials placed by clamshell bucket (barge-mounted or land-based)
  - 3 inches active material (AquaGate + PAC [10 percent activated carbon]) on retained side of sheet piling
  - 5,500 $ft^2$ geotextile, 6 inches residual sand cover, 420 tons riprap
- Remove and/or seal non-functional pipes and outfalls along the eastern shoreline
- One-time removal of sediment from the City of Richmond storm drain system
  - 1,000 tons residual sediment over 400 LF of drain pipe
  - Sediment to be processed with dredged material from Lauritzen Channel

### Offsite Landfill Disposal

- Disposal of dredged material and debris, 105,000 tons
  - 104,000 tons of stabilized sediment
  - 1,000 tons of debris (0.1 percent by weight of stabilized sediment mass from tight areas and 1.0 percent by weight of stabilized sediment mass from open areas)
- All sediment and debris Class 1 non-RCRA Waste
- Offsite RCRA Subtitle D Landfill
- Transport via rail

### Long-term Monitoring and Institutional Controls

- Long-term monitoring would be performed to provide cap and sheet piling integrity and performance (along shoreline and Northern Head Area)
- Institutional controls would be implemented to specify limitation on anchoring, mooring, dredging, and construction to minimize damage to the cap and sheet piling (along shoreline and capped area of Northern Head area).

## Alternative 4

Dredge East Side, West Side, and Northern Head, Implement Source Control Measures, Utilize Offsite Landfill Disposal, Implement Long-term Monitoring, and Implement Institutional Controls

### Dredge East Side, West Side, and Portion of Northern Head

- 66,000 $yd^3$ dredged material, 100 percent of East and West Side Areas of Lauritzen Channel and 100 percent of Northern Head Area of Lauritzen Channel. After completion of dredging activities, a 6-inch sand layer would be placed throughout the dredged areas.
  - West Side: 3.0 acres (132,000 $ft^2$), 17,000 $yd^3$
  - East Side: 4.0 acres (175,000 $ft^2$), 41,000 $yd^3$
  - Northern Head: 1.4 acre (61,000 $ft^2$), 8,000 $yd^3$
- Mechanical dredging using an environmental bucket
- 6 inches post-dredge residual sand cover

- Scows for material transport staged outside the remedial cell
- Estimated dredge production rates and volumes
  - Tight area dredging production rate 1,250 $yd^3$/day, 10 percent of total sediment volume (6,600 $yd^3$), 5 days to complete
  - Open area dredging production rate 1,500 $yd^3$/day, 90 percent of total sediment volume (59,400 $yd^3$), 40 days to complete
- Water treatment estimate, 4,500,000 gallons
  - Volume water recovered from scows (95 percent of free water in scows after dredging), rainwater, pressure wash water, backwash water from water treatment system
  - Wastewater treatment system capacity 75 gpm
  - Treatment 24 hours/day, 90 percent uptime/day
- Dredged material solidification/stabilization, 107,550 tons
  - Dredged sediment would be transported in the scow to the onsite staging area
  - 99,000 tons of sediment (in-situ bulk density 1.5 tons/ $yd^3$ x 66,000 $yd^3$)
  - 550 tons free water incorporated in sediment (5 percent of free water in scows after dredging)
  - 8,000 tons Portland cement (8 percent by weight)
- Final cap design determined during remedial design

### Source Control Measures

- Northern End Shoreline Area
  - 135 LF sheet piling
  - Sediment excavation and filling to remove shallow nearshore sediments and prepare the slope for capping
  - Cap materials placed by clamshell bucket (barge-mounted or land-based)
  - 3 inches active material (AquaGate + PAC [10 percent activated carbon]) on retained side of sheet piling
  - 4,400 $ft^2$ geotextile, 6 inches residual sand cover, 325 tons riprap
- Northern Piles Area
  - 320 LF sheet piling
  - Removal and/or cutting (1-foot recess below grade) of vertical timber piles to clear the slope
  - Cap materials placed by clamshell bucket (barge-mounted or land-based)
  - 3 inches active material (AquaGate + PAC [10 percent activated carbon]) on retained side of sheet piling
  - 5,500 $ft^2$ geotextile, 6 inches residual sand cover, 400 tons riprap
- Southern Piles Area
  - 410 LF sheet piling
  - Removal and/or cutting (1-foot recess below grade) of vertical timber piles to clear the slope
  - Removal of the former pier section located at Bent -7 to Bent -8
  - Cap materials placed by clamshell bucket (barge-mounted or land-based)
  - 3 inches active material (AquaGate + PAC [10 percent activated carbon]) on retained side of sheet piling
  - 5,500 $ft^2$ geotextile, 6 inches residual sand cover, 760 tons riprap
- Levin Pier Shoreline Area
  - 300 LF sheet piling

  - Pier piles left in place
  - Cap materials placed by clamshell bucket (barge-mounted or land-based)
  - 3 inches active material (AquaGate + PAC [10 percent activated carbon]) on retained side of sheet piling
  - 5,500 $ft^2$ geotextile, 6 inches residual sand cover, 420 tons riprap
- Remove and/or seal non-functional pipes and outfalls along the eastern shoreline
- One-time removal of sediment from the City of Richmond storm drain system
  - 1,000 tons residual sediment over 400 LF of drain pipe
  - Sediment to be processed with dredged material from Lauritzen Channel

### Offsite Landfill Disposal

- Disposal of dredged material and debris, 108,550 tons
  - 107,550 tons of stabilized sediment
  - 1,000 tons of debris (0.1 percent by weight of stabilized sediment mass from tight areas and 1.0 percent by weight of stabilized sediment mass from open areas)
- All sediment and debris Class 1 non-RCRA waste
- Offsite RCRA Subtitle D Landfill
- Transport via rail

### Long-term Monitoring and Institutional Controls

- Long-term monitoring would be performed to provide cap and sheet piling integrity and performance (along shoreline)
- Institutional controls would be implemented to specify limitation on anchoring, mooring, dredging, and construction to minimize damage to the cap and sheet piling (along shoreline).

# Summary of Detailed Cost Estimate Tables

This appendix contains the following tables:

G-1 Summary of Representative Total Cost Ranges
G-2a Detailed Cost Estimate – Alternative 2
G-2b Detailed Cost Estimate – Alternative 3
G-2c Detailed Cost Estimate – Alternative 4
G-3a Summary of Data Assumptions - Alternative 2
G-3b Summary of Data Assumptions - Alternative 3
G-3c Summary of Data Assumptions - Alternative 4
G-4a Dredging Assumptions - Alternative 2
G-4b Dredging Assumptions - Alternative 3
G-4c Dredging Assumptions - Alternative 4
G-5a Water Treatment Assumptions - Alternative 2
G-5b Water Treatment Assumptions - Alternative 3
G-5c Water Treatment Assumptions - Alternative 4
G-6 Short-term Monitoring Assumptions (Alternatives 2, 3, and 4)

# References

U.S. Department of Labor. 2014. Davis Bacon Wage Determinations. http://www.wdol.gov/dba.aspx.

U.S. Environmental Protection Agency (USEPA). 2000. *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study.* EPA 540-R-00-002/OSWER 9344.0-75. July.

**TABLE G-1**
**Summary of Representative Total Cost Ranges**
*United Heckathorn Superfund Site, Richmond, California*

| Alternative Description | Capital Cost Including Transportation & Disposal | Transportation & Disposal Cost | Present Worth Operations and Maintenance Cost | Class 4 ROM Estimated Total Cost | Class 4 ROM Cost Estimate High Range + 50% | Class 4 ROM Cost Estimate Low Range - 30% |
|---|---|---|---|---|---|---|
| **Alternative 1** - No Action | $0 | $0 | $0 | $0 | $0 | $0 |
| **Alternative 2** - Dredge East Side and West Side, Cap Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-Term Monitoring, and Institutional Controls | $21,322,139 | $9,505,385 | $410,464 | $21,732,604 | $32,598,906 | $15,212,823 |
| **Alternative 3** - Dredge East Side, West Side, and Portion of Northern Head, Cap Portion of Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls | $22,372,344 | $10,510,579 | $203,362 | $22,575,706 | $33,863,559 | $15,802,994 |
| **Alternative 4** - Dredge East Side, West Side, and Northern Head, Source Control Measures, Offsite Landfill Disposal, Long-term Monitoring, and Institutional Controls | $22,588,170 | $10,834,055 | $123,133 | $22,711,303 | $34,066,955 | $15,897,912 |

**TABLE G-2a**
**Detailed Cost Estimate - Alternative 2**
*United Heckathorn Superfund Site, Richmond, California*

| Item/Activity | | Quantity | Unit | | Unit Cost | | Cost | Comments |
|---|---|---|---|---|---|---|---|---|
| **1.0 WORK PLANNING, REPORTING AND PROJECT MANAGEMENT** | | | | | | | | |
| 1.01 | Work Plan (Agency Submittal and/or Internal) | 1 | LS | $ | 50,000 | $ | 50,000 | |
| 1.02 | Permitting (Water Quality, USACE [404]) | 1 | LS | $ | 70,000 | $ | 70,000 | |
| 1.03 | Quality Management (Plan and Audit) | 1 | LS | $ | 12,500 | $ | 12,500 | |
| 1.04 | Health and Safety (Plan, Activity Hazard Analyses, Audit) | 1 | LS | $ | 20,000 | $ | 20,000 | |
| 1.05 | Project Chartering (Team Charter, Miscellaneous Meetings) | 1 | LS | $ | 13,500 | $ | 13,500 | |
| 1.06 | Procurement of Subcontractors (Prequalification, RFP Development, Bid Evaluation, Contracting, Close Outs) | 1 | LS | $ | 40,000 | $ | 40,000 | |
| 1.07 | Waste Management (Plan Development, Sampling, Characterization, Landfill Acceptance) | 1 | LS | $ | 15,000 | $ | 15,000 | |
| 1.08 | Data Management (Lab Contractor, Sample Tracking, Data Verification, Uploading, Tables) | 1 | LS | $ | 15,000 | $ | 15,000 | |
| 1.10 | Project Management | 1 | LS | $ | 65,000 | $ | 65,000 | 4 Months in Field ($12.5K/mo) & 2 Months Out ($7.5K/mo) |
| 1.11 | Contingency | 20% | | | | $ | 60,200 | |
| **Subtotal Planning, Reporting, Project Management** | | | | | | **$** | **361,200** | |
| **2.0 DESIGN** | | | | | | | | |
| 2.01 | Pre-design Data Collection | 1 | LS | $ | 125,000 | $ | 125,000 | |
| 2.02 | Modeling (Scour, Fate and Transport, Hydraulic, etc.,) | 1 | LS | $ | 125,000 | $ | 125,000 | |
| 2.03 | Regulatory Review - Permitting | 1 | LS | $ | 50,000 | $ | 50,000 | |
| 2.04 | Remedial Design (Includes Basis of Design, Intermediate, and Final) | 1 | LS | $ | 450,000 | $ | 450,000 | |
| 2.05 | Contingency | 20% | | | | $ | 150,000 | |
| **Subtotal Design** | | | | | | **$** | **900,000** | |
| **3.0 CONSTRUCTION** | | | | | | | | |
| **3.1 Pre Start-up Sampling & Testing** | | | | | | **$** | **36,250** | |
| | Pre-construction Bathymetric Survey and Survey | 5 | day | $ | 6,850.00 | $ | 34,250.00 | Based on 10 Days at $6850/Day - From Cost Estimator |
| | Waste Profile Analysis | 1 | LS | $ | 2,000.00 | $ | 2,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| **3.2 Mobilization** | | | | | | **$** | **265,000** | |
| | Permits | 1 | LS | $ | 35,000.00 | $ | 35,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Pre-construction Submittals | 1 | LS | $ | 75,000.00 | $ | 75,000.00 | Includes H&S, Specs, Drawings, Site Plans, Labor, and PM |
| | Mechanical Dredge Mobilization | 1 | LS | $ | 75,000.00 | $ | 75,000.00 | Experience from Typical Contractor Bids |
| | Barge Mooring Mobilization | 1 | LS | $ | 15,000.00 | $ | 15,000.00 | Experience from Typical Contractor Bids |
| | Stabilization Mobilization | 1 | LS | $ | 50,000.00 | $ | 50,000.00 | Experience from Typical Contractor Bids |
| | Civil Construction Mobilization | 1 | LS | $ | 15,000.00 | $ | 15,000.00 | Experience from Typical Contractor Bids |
| **3.3 Pre-dredge Activities** | | | | | | **$** | **552,786** | |
| | Office Trailers (2) | 4 | mo | $ | 800.00 | $ | 6,400.00 | Unit Cost/Lump sum Based on Project Team Experience, 2 Office Trailers |
| | Office Trailer Set Up | 1 | LS | $ | 3,000.00 | $ | 3,000.00 | Unit Cost / Lump sum Based on Project Team Experience, 2 Office Trailers |
| | Sanitation Facilities | 4 | mo | $ | 3,000.00 | $ | 12,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Trash | 4 | mo | $ | 1,000.00 | $ | 4,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Perimeter Chain Link Fencing | 1000 | LF | $ | 56.00 | $ | 56,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Haul Road Construction | 11200 | $sf^2$ | $ | 1.84 | $ | 20,608.00 | Unit Cost for Haul Road Construction Based on Project Team Experience |
| | Site Preparation Asphalt Pad Install for Stabilization (300 x 300) | 10,000 | $yd^2$ | $ | 24.10 | $ | 241,000.00 | Means 32 12 16 - Cost Estimator - Area Will Be Provided by Client (PRP) |
| | Install Sumps | 3 | ea | $ | 5,000.00 | $ | 15,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Site Preparation Asphalt Pad Install for WWT (100 x 100) | 1,111 | $yd^2$ | $ | 24.10 | $ | 26,777.78 | Means 32 12 16 - Cost Estimator - Area Will Be Provided by Client (PRP) |
| | Install Sumps | 2 | ea | $ | 5,000.00 | $ | 10,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Temporary Site Utilities (Phone & Electric) | 4 | mo | $ | 2,000.00 | $ | 8,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Electrical Connection Allowance | 1 | LS | $ | 5,000.00 | $ | 5,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Erosion and Sediment Controls Installation | 1 | LS | $ | 60,000.00 | $ | 60,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Barge Mooring Area Construction | 0 | LS | $ | 200,000.00 | $ | - | Unit Cost / Lump sum Based on Project Team Experience |
| | Construct Dredge Offloading Areas/River Access structures | 1 | LS | $ | 50,000.00 | $ | 50,000.00 | Unit Cost / Lump sum Based on Project Team Experience |

**TABLE G-2a**
**Detailed Cost Estimate - Alternative 2**
*United Heckathorn Superfund Site, Richmond, California*

| Item/Activity | Quantity | Unit | Unit Cost | Cost | Comments |
|---|---|---|---|---|---|
| Post-decontamination Equipment Wipe Samples | 1 | LS | $ 10,000.00 | $ 10,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| Pre-construction Sampling | 1 | LS | $ 15,000.00 | $ 15,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| Establish Required Vertical Control Points | 1 | LS | $ 10,000.00 | $ 10,000.00 | Allowance - Based on Project Team Experience |
| **3.4 Turbidity Curtains** | | | | **$ 72,900** | |
| Turbidity Curtain | 10,000 | $sf^2$ | $ 7.29 | $ 72,900.00 | Unit Cost of $\$7.29/ft^2$ Based on Project Team Experience |
| **3.5 Monitoring Costs** | | | | **$ 191,710** | |
| Water Quality Monitoring | 1 | LS | $ 170,910.00 | $ 170,910.00 | See Table G-6 |
| Air Monitoring | 4 | mo | $ 3,600.00 | $ 14,400.00 | Air Monitoring for VOCs and Particulates |
| Air Monitoring Sample Analysis | 4 | mo | $ 1,600.00 | $ 6,400.00 | Air Monitoring for VOCs and Particulates |
| **3.6 Dredging: Sediment Removal and Disposal** | | | | **$ 15,964,470** | |
| Scows four (4) 30 ft x 100 ft | 12 | mo | $ 4,500.00 | $ 54,000.00 | Experience from Typical Contractor Bids |
| Mechanical Dredging of Sediment - Tight Areas | 5,800 | $yd^3$ | $ 22.86 | $ 132,595.74 | See Table G-3a |
| Mechanical Dredging of Sediment - Open Areas | 52,200 | $yd^3$ | $ 19.04 | $ 993,792.63 | |
| Reagent Mixing, Stabilization of Tight Dredging Sediments | 5,800 | $yd^3$ | $ 20.11 | $ 116,656.97 | See Table G-3a |
| Reagent Mixing, Stabilization of Open Area Dredging Sediments | 52,200 | $yd^3$ | $ 20.11 | $ 1,049,912.71 | See Table G-3a |
| Loading, Transport and Disposal of Tight Area Dredging Sediments | 9,449 | ton | $ 10.67 | $ 100,812.46 | See Table G-3a |
| Loading, Transport and Disposal of Open Area Dredging Sediments | 85,889 | ton | $ 10.67 | $ 916,385.28 | See Table G-3a |
| Off-loading & Placing Dredge Material on Mixing Pad | 58,000 | $yd^3$ | $ 5.00 | $ 290,000.00 | |
| Transport and Disposal of Sediments | 95,149 | ton | $ 99.90 | $ 9,505,385.10 | |
| Aqua Gate - Material | 776 | ton | $ 495.00 | $ 384,120.00 | Quote |
| Aqua Gate - Shipping | 36 | load | $ 5,085.00 | $ 183,060.00 | Quote |
| Aqua Gate - Installation | 776 | ton | $ 75.00 | $ 58,200.00 | Based on Project Team Experience |
| Dust and Odor Control | 45 | day | $ 150.00 | $ 6,750.00 | Experience from Typical Contractor Bids - Cost Estimator |
| Bathymetry Surveys (Periodic) | 12 | day | $ 3,000.00 | $ 36,000.00 | I Day per Week, Multibeam, 6,800 Verbal from Surveying Company |
| Confirmation Sampling | 1 | LS | $ 100,000.00 | $ 100,000.00 | Based on Project Team Experience |
| Clean, Demolish, and Dispose of Asphalt Pad (300 x 300) | 2,333 | ton | $ 30.00 | $ 70,000.00 | Experience from Typical Contractor Bids |
| 6" Residual Sand Cover - Material Costs | 3,377 | ton | $ 22.00 | $ 74,285.32 | Based on Project Team Experience |
| 6" Residual Sand Cover - Equipment, Handling and Spreading | 5 | day | $ 4,000.00 | $ 19,294.89 | Based on Project Team Experience |
| Northern End Shoreline Area - Sheet Pile | 135 | LF | $ 1,200.00 | $ 162,000.00 | Based on Project Team Experience |
| Northern End Shoreline Area - Rip Rap | 325 | ton | $ 40.00 | $ 13,000.00 | Based on Project Team Experience |
| Northern End Shoreline Area - Geotextile | 4,368 | SF | $ 0.40 | $ 1,747.20 | Based on Project Team Experience |
| Northern End Piles Area - Piles Removal | 10 | ea | $ 750.00 | $ 7,500.00 | Based on Project Team Experience |
| Northern Pile Area - Sheet Pile | 318 | LF | $ 1,200.00 | $ 381,600.00 | Based on Project Team Experience |
| Northern Pile Area - Rip Rap | 400 | ton | $ 40.00 | $ 16,000.00 | Based on Project Team Experience |
| Northern Pile Area - Geotextile | 5,461 | $ft^2$ | $ 0.40 | $ 2,184.40 | Based on Project Team Experience |
| Northern Pile Area - Piles Removal | 70 | ea | $ 750.00 | $ 52,500.00 | Based on Project Team Experience |
| Southern Pile Area - Sheet Pile | 406 | LF | $ 1,200.00 | $ 487,200.00 | Based on Project Team Experience |
| Southern Pile Area - Rip Rap | 760 | ton | $ 40.00 | $ 30,400.00 | Based on Project Team Experience |
| Southern Pile Area - Geotextile | 10,232 | $ft^2$ | $ 0.40 | $ 4,092.80 | Based on Project Team Experience |
| Southern Pile Area - Piles Removal | 50 | ea | $ 750.00 | $ 37,500.00 | Based on Project Team Experience |
| Levin Pier Shoreline Area - Sheet Pile | 299 | LF | $ 1,200.00 | $ 358,800.00 | Based on Project Team Experience |
| Levin Pier Shoreline Area - Rip Rap | 414 | ton | $ 40.00 | $ 16,560.00 | Based on Project Team Experience |
| Levin Pier Shoreline Area - Geotextile | 5,586 | $sf^2$ | $ 0.40 | $ 2,234.40 | Based on Project Team Experience |
| Levin Pier Shoreline Area - Piles Removal | 0 | ea | $ 750.00 | $ - | Based on Project Team Experience |
| Removal of Residual Sediment from the City of Richmond Municipal Storm Drain System | 400 | LF | $ 500.00 | $ 200,000.00 | |
| Transportation and Disposal Residual Sediment from the City of Richmond Municipal Storm Drain System | 1,000 | ton | $ 99.90 | $ 99,900.00 | |

**TABLE G-2a**
**Detailed Cost Estimate - Alternative 2**
*United Heckathorn Superfund Site, Richmond, California*

| Item/Activity | Quantity | Unit | Unit Cost | Cost | Comments |
|---|---|---|---|---|---|
| **3.7 Dredging: Water Treatment** | **3,483,096** | **gal** | **$ 0.07** | **$ 346,595** | |
| Mobilization | 1 | LS | $ 35,000.00 | $ 50,000.00 | 10 Loads @ 1500, 4 Men 5 days @ 80, Crane @ 1200 for 1 Day |
| Water Treatment Operations | 3,483,096 | gal | $ 0.07 | $ 243,816.75 | |
| Decontamination and Demobilization | 1 | LS | $ 45,000.00 | $ 45,000.00 | 10 Pieces @ 4500 |
| Clean, Demolish, and Dispose of Asphalt Pad (100 x 100) | 259 | ton | $ 30.00 | $ 7,777.78 | Means 32 12 16, Based on Project Team Experience |
| **3.8 Post-dredging Activities** | | | | **$ 118,333** | |
| Post-Construction Bathymetric Survey and Survey | 5 | day | $ 6,800.00 | $ 34,000.00 | 5 Days @ $6800/Day |
| Haul Road Removal and Disposal | 311 | ton | $ 30.00 | $ 9,333.33 | Unit Cost and Quantities by Cost Estimator |
| Barge Mooring Removal | 1 | LS | $ 40,000.00 | $ 40,000.00 | Experience on Similar Projects |
| Miscellaneous Structure Removal | 1 | LS | $ 20,000.00 | $ 20,000.00 | Based on Project Team Experience |
| Post Construction Sampling | 1 | LS | $ 15,000.00 | $ 15,000.00 | Based on Project Team Experience |
| **3.9 Demobilization** | | | | **$ 205,000** | |
| Record Drawings | 1 | LS | $ 20,000.00 | $ 20,000.00 | Based on Project Team Experience |
| Subcontract Project Closeout | 1 | LS | $ 30,000.00 | $ 30,000.00 | Based on Project Team Experience |
| Demobilize Equipment | 1 | LS | $ 155,000.00 | $ 155,000.00 | Based on Project Team Experience |
| **Subtotal Mobilization, Construction, Operation, Maintenance, and Demobilization** | | | | **$ 17,753,044** | |
| **3.10 Construction Project Add-ons** | | | | | |
| Performance and Payment Bonds | 2% | | $ 17,753,044 | $ 355,061 | Based on Project Team Experience |
| Project Management and Overhead Costs | 5% | | $ 17,753,044 | $ 887,652 | EPA 2000, Page 5-12 |
| Remedial Design | 0% | | $ 17,753,044 | $ - | EPA 2000, Page 5-12 |
| Construction Management | 6% | | $ 17,753,044 | $ 1,065,183 | EPA 2000, Page 5-12 |
| Contingency | 0% | | $ 17,753,044 | $ - | Contingency Included in Sub Costs |
| **Subtotal Construction Project Add-ons** | | | | **$ 2,307,896** | |

| | | |
|---|---|---|
| **TOTAL CONSTRUCTION ROM COSTS (Current Costs)** | **$ 20,060,939** | Class 4 ROM with Accuracy of +50%/-30%. |
| **TOTAL PROJECT PLANNING AND MANAGEMENT COSTS** | **$ 361,200** | From Above |
| **TOTAL DESIGN COSTS** | **$ 900,000** | From Above |
| **Total CAPITAL COST** | **$ 21,322,139** | |
| **TOTAL O&M COST** | **$ 410,464** | |
| **TOTAL ALL ROM COSTS (Current Costs)** | **$ 21,732,604** | |
| **Upper ROM Range (+50%)** | **$ 32,598,906** | |
| **Lower ROM Range (-30%)** | **$ 15,212,823** | |

**TABLE G-2a**
**Detailed Cost Estimate - Alternative 2**
*United Heckathorn Superfund Site, Richmond, California*

| Item/Activity | Quantity | Unit | Unit Cost | Cost | Comments |
|---|---|---|---|---|---|

| PRESENT VALUE ANALYSIS | YEAR | Total Cost | Total Cost Per Year | Discount Factor (7%) | Present Value |
|---|---|---|---|---|---|
| CAPITAL COST | 0 | $ 21,322,139 | $21,322,139 | 1.000 | $21,322,139 |
| PERIODIC COST | 1 | $156,345 | **$145,401** | 0.930 | $135,223 |
| PERIODIC COST | 2 | $145,401 | $135,223 | 0.930 | $0 |
| PERIODIC COST | 3 | $135,223 | $125,757 | 0.930 | $0 |
| PERIODIC COST | 4 | $125,757 | $116,954 | 0.930 | $0 |
| PERIODIC COST | 5 | $116,954 | $108,767 | 0.930 | $0 |
| PERIODIC COST | 6 | $108,767 | **$101,154** | 0.930 | $94,073 |
| PERIODIC COST | 7 | $101,154 | $94,073 | 0.930 | $0 |
| PERIODIC COST | 8 | $94,073 | $87,488 | 0.930 | $0 |
| PERIODIC COST | 9 | $87,488 | $81,364 | 0.930 | $0 |
| PERIODIC COST | 10 | $81,364 | $75,668 | 0.930 | $0 |
| PERIODIC COST | 11 | $75,668 | **$70,371** | 0.930 | $65,445 |
| PERIODIC COST | 12 | $70,371 | $65,445 | 0.930 | $0 |
| PERIODIC COST | 13 | $65,445 | $60,864 | 0.930 | $0 |
| PERIODIC COST | 14 | $60,864 | $56,604 | 0.930 | $0 |
| PERIODIC COST | 15 | $56,604 | $52,641 | 0.930 | $0 |
| PERIODIC COST | 16 | $52,641 | **$48,957** | 0.930 | $45,530 |
| PERIODIC COST | 17 | $48,957 | $45,530 | 0.930 | $0 |
| PERIODIC COST | 18 | $45,530 | $42,343 | 0.930 | $0 |
| PERIODIC COST | 19 | $42,343 | $39,379 | 0.930 | $0 |
| PERIODIC COST | 20 | $39,379 | $36,622 | 0.930 | $0 |
| PERIODIC COST | 21 | $36,622 | **$34,059** | 0.930 | $31,674 |
| PERIODIC COST | 22 | $34,059 | $31,674 | 0.930 | $0 |
| PERIODIC COST | 23 | $31,674 | $29,457 | 0.930 | $0 |
| PERIODIC COST | 24 | $29,457 | $27,395 | 0.930 | $0 |
| PERIODIC COST | 25 | $27,395 | $25,478 | 0.930 | $0 |
| PERIODIC COST | 26 | $25,478 | **$23,694** | 0.930 | $22,036 |
| PERIODIC COST | 27 | $23,694 | $22,036 | 0.930 | $0 |
| PERIODIC COST | 28 | $22,036 | $20,493 | 0.930 | $0 |
| PERIODIC COST | 29 | $20,493 | $19,059 | 0.930 | $0 |
| PERIODIC COST | 30 | $19,059 | **$17,724** | 0.930 | $16,484 |
| | | | | | **$410,464** |
| | | | | | $21,322,139 |
| **TOTAL PRESENT VALUE FOR ALTERNATE 2** | | | | | **$21,732,604** |

**TABLE G-2b**
**Detailed Cost Estimate - Alternative 3**
*United Heckathorn Superfund Site, Richmond, California*

| Item/Activity | | Quantity | Unit | Unit Cost | Cost | Comments |
|---|---|---|---|---|---|---|
| **1.0** | **WORK PLANNING, REPORTING, AND PROJECT MANAGEMENT** | | | | | |
| 1.01 | Work Plan (Agency Submittal and/or Internal) | 1 | LS | $ 50,000 | $ 50,000 | |
| 1.02 | Permitting (Water Quality, USACE [404]) | 1 | LS | $ 70,000 | $ 70,000 | |
| 1.03 | Quality Management (Plan and Audit) | 1 | LS | $ 12,500 | $ 12,500 | |
| 1.04 | Health and Safety (Plan, Activity Hazard Analyses, Audit) | 1 | LS | $ 20,000 | $ 20,000 | |
| 1.05 | Project Chartering (Team Charter, Miscellaneous Meetings) | 1 | LS | $ 13,500 | $ 13,500 | |
| 1.06 | Procurement of Subcontractors (Prequalification, RFP Development, Bid Evaluation, Contracting, Close Outs) | 1 | LS | $ 40,000 | $ 40,000 | |
| 1.07 | Waste Management (Plan Development, Sampling, Characterization, Landfill Acceptance) | 1 | LS | $ 15,000 | $ 15,000 | |
| 1.08 | Data Management (Lab Contractor, Sample Tracking, Data Verification, Uploading, Tables) | 1 | LS | $ 15,000 | $ 15,000 | |
| 1.10 | Project Management | 1 | LS | $ 65,000 | $ 65,000 | 4 Months in Field ($12.5K/mo) & 2 Months Out ($7.5K/mo) |
| 1.11 | Contingency | 20% | | | $ 60,200 | |
| **Subtotal Planning, Reporting, Project Management** | | | | | **$ 361,200** | |
| **2.0** | **DESIGN** | | | | | |
| 2.01 | Predesign Data Collection | 1 | LS | $ 125,000 | $ 125,000 | |
| 2.02 | Modeling (Scour, Fate and Transport, Hydraulic, etc.,) | 1 | LS | $ 125,000 | $ 125,000 | |
| 2.03 | Regulatory Review - Permitting | 1 | LS | $ 50,000 | $ 50,000 | |
| 2.04 | Remedial Design (Includes Basis of Design, Intermediate, and Final) | 1 | LS | $ 450,000 | $ 450,000 | |
| 2.05 | Contingency | 20% | | | $ 150,000 | |
| **Subtotal Design** | | | | | **$ 900,000** | |
| **3.0** | **CONSTRUCTION** | | | | | |
| **3.1** | **Pre Start-up Sampling & Testing** | | | | **$ 36,250** | |
| | Pre-construction Bathymetric Survey and Survey | 5 | day | $ 6,850.00 | $ 34,250 | Based on 10 Days at $6850/Day - from Cost Estimator |
| | Waste Profile Analysis | 1 | LS | $ 2,000.00 | $ 2,000 | Unit Cost / Lump sum Based on Project Team Experience |
| **3.2** | **Mobilization** | | | | **$ 265,000** | |
| | Permits | 1 | LS | $ 35,000.00 | $ 35,000 | Unit Cost / Lump sum Based on Project Team Experience |
| | Pre-construction Submittals | 1 | LS | $ 75,000.00 | $ 75,000 | Includes H&S, Specs, Drawings, Site Plans, Labor, and PM |
| | Mechanical Dredge Mobilization | 1 | LS | $ 75,000.00 | $ 75,000 | Experience from Typical Contractor Bids |
| | Barge Mooring Mobilization | 1 | LS | $ 15,000.00 | $ 15,000 | Experience from Typical Contractor Bids |
| | Stabilization Mobilization | 1 | LS | $ 50,000.00 | $ 50,000 | Experience from Typical Contractor Bids |
| | Civil Construction Mobilization | 1 | LS | $ 15,000.00 | $ 15,000 | Experience from Typical Contractor Bids |
| **3.3** | **Pre-dredge Activities** | | | | **$ 552,786** | |
| | Office Trailers (2) | 4 | mo | $ 800.00 | $ 6,400 | Unit Cost / Lump sum Based on Project Team Experience, 2 Office Trailers |
| | Office Trailer Set Up | 1 | LS | $ 3,000.00 | $ 3,000 | Unit Cost / Lump sum Based on Project Team Experience, 2 Office Trailers |
| | Sanitation Facilities | 4 | mo | $ 3,000.00 | $ 12,000 | Unit Cost / Lump sum Based on Project Team Experience |
| | Trash | 4 | mo | $ 1,000.00 | $ 4,000 | Unit Cost / Lump sum Based on Project Team Experience |
| | Perimeter Chain Link Fencing | 1000 | LF | $ 56.00 | $ 56,000 | Unit Cost / Lump sum Based on Project Team Experience |
| | Haul Road Construction | 11200 | $ft^2$ | $ 1.84 | $ 20,608 | Unit Cost for Haul Road Construction Based on Project Team Experience |
| | Site Preparation Asphalt Pad Install for Stabilization (300 x 300) | 10,000 | $yd^2$ | $ 24.10 | $ 241,000 | Means 32 12 16 - Cost Estimator - Area Will Be Provided by Client (PRP) |
| | Install Sumps | 3 | ea | $ 5,000.00 | $ 15,000 | Unit Cost / Lump sum Based on Project Team Experience |
| | Site Preparation Asphalt Pad Install for WWT (100 x 100) | 1,111 | $yd^2$ | $ 24.10 | $ 26,778 | Means 32 12 16 - Cost Estimator - Area Will Be Provided by Client (PRP) |
| | Install Sumps | 2 | ea | $ 5,000.00 | $ 10,000 | Unit Cost / Lump sum Based on Project Team Experience |
| | Temporary Site Utilities (Phone & Electric) | 4 | mo | $ 2,000.00 | $ 8,000 | Unit Cost / Lump sum Based on Project Team Experience |
| | Electrical Connection Allowance | 1 | LS | $ 5,000.00 | $ 5,000 | Unit Cost / Lump sum Based on Project Team Experience |
| | Erosion and Sediment Controls Installation | 1 | LS | $ 60,000.00 | $ 60,000 | Unit Cost / Lump sum Based on Project Team Experience |
| | Barge Mooring Area Construction | 0 | LS | $ 200,000.00 | $ - | Unit Cost / Lump sum Based on Project Team Experience |
| | Construct Dredge Offloading Areas/River Access structures | 1 | LS | $ 50,000.00 | $ 50,000 | Unit Cost / Lump sum Based on Project Team Experience |
| | Post Decontamination Equipment Wipe Samples | 1 | LS | $ 10,000.00 | $ 10,000 | Unit Cost / Lump sum Based on Project Team Experience |

**TABLE G-2b**
**Detailed Cost Estimate - Alternative 3**
*United Heckathorn Superfund Site, Richmond, California*

| Item/Activity | Quantity | Unit | Unit Cost | Cost | Comments |
|---|---|---|---|---|---|
| Pre-construction Sampling | 1 | LS | $ 15,000.00 | $ 15,000 | Unit Cost / Lump sum Based on Project Team Experience |
| Establish Required Vertical Control Points & Tide Gauges | 1 | LS | $ 10,000.00 | $ 10,000 | Allowance - Based on Project Team Experience |
| **3.4 Turbidity Curtains** | | | | **$ 72,900** | |
| Turbidity Curtain | 10,000 | SF | $ 7.29 | $ 72,900 | Unit Cost of $7.29/ft$^2$ Based on Project Team Experience |
| **3.5 Monitoring Costs** | | | | **$ 191,710** | |
| Water Quality Monitoring | 1 | LS | $ 170,910.00 | $ 170,910 | See Table G-6 |
| Air Monitoring | 4 | mo | $ 3,600.00 | $ 14,400 | Air Monitoring for VOCs and Particulates |
| Air Monitoring Sample Analysis | 4 | mo | $ 1,600.00 | $ 6,400 | Air Monitoring for VOCs and Particulates |
| **3.6 Dredging: Sediment Removal and Disposal** | | | | **$ 16,719,915** | |
| Scows four (4) 30 ft x 100 ft | 12 | mo | $ 4,500.00 | $ 54,000 | Experience from Typical Contractor Bids |
| Mechanical Dredging of Sediment - Tight Areas | 6,400 | yd$^3$ | $ 22.86 | $ 146,313 | See Table G-3b |
| Mechanical Dredging of Sediment - Open Areas | 57,600 | yd$^3$ | $ 17.25 | $ 993,793 | |
| Reagent Mixing, Stabilization of West Dredging Sediments | 6,400 | yd$^3$ | $ 19.02 | $ 121,757 | See Table G-3b |
| Reagent Mixing, Stabilization of East Dredging Sediments | 57,600 | yd$^3$ | $ 19.02 | $ 1,095,812 | See Table G-3b |
| Loading, Transport and Disposal of West Dredging Sediments | 10,426 | ton | $ 10.67 | $ 111,241 | See Table G-3b |
| Loading, Transport and Disposal of East Dredging Sediments | 93,836 | ton | $ 10.67 | $ 1,001,172 | See Table G-3b |
| Off-loading & Placing Dredge Material on Mixing Pad | 64,000 | yd$^3$ | $ 5.00 | $ 320,000 | |
| Transport and Disposal of Sediments | 105,211 | tons | $ 99.90 | $ 10,510,579 | |
| Aqua Gate - Material | 383 | ton | $ 495.00 | $ 189,585 | Quote |
| Aqua Gate - Shipping | 18 | load | $ 5,085.00 | $ 91,530 | Quote |
| Aqua Gate - Installation | 383 | ton | $ 75.00 | $ 28,725 | Based on Project Team Experience |
| Dust and Odor Control | 45 | day | $ 150.00 | $ 6,750 | Experience from Typical Contractor Bids - Cost Estimator |
| Bathymetry Surveys (Periodic) | 12 | day | $ 3,000.00 | $ 36,000 | I Day per Week, Multibeam, 6,800 Verbal from Surveying Company |
| Confirmation Sampling | 1 | LS | $ 100,000.00 | $ 100,000 | Based on Project Team Experience |
| Clean, Demolish, and Dispose of Asphalt Pad (300 x 300) | 2,333 | ton | $ 30.00 | $ 70,000 | Experience from Typical Contractor Bids |
| 6" Residual Sand Cover - Material Costs | 1,665 | ton | $ 22.00 | $ 36,641 | Based on Project Team Experience |
| 6" Residual Sand Cover - Equipment, Handling and Spreading | 2 | day | $ 4,000.00 | $ 9,517 | Based on Project Team Experience |
| Northern End Shoreline Area - Sheet Pile | 135 | LF | $ 1,200.00 | $ 162,000 | Based on Project Team Experience |
| Northern End Shoreline Area - Rip Rap | 325 | ton | $ 40.00 | $ 13,000 | Based on Project Team Experience |
| Northern End Shoreline Area - Geotextile | 4,368 | SF | $ 0.40 | $ 1,747 | Based on Project Team Experience |
| Northern End Piles Area - Piles Removal | 10 | ea | $ 750.00 | $ 7,500 | Based on Project Team Experience |
| Northern Pile Area - Sheet Pile | 318 | LF | $ 1,200.00 | $ 381,600 | Based on Project Team Experience |
| Northern Pile Area - Rip Rap | 400 | ton | $ 40.00 | $ 16,000 | Based on Project Team Experience |
| Northern Pile Area - Geotextile | 5,461 | ft$^2$ | $ 0.40 | $ 2,184 | Based on Project Team Experience |
| Northern Pile Area - Piles Removal | 10 | ea | $ 750.00 | $ 7,500 | Based on Project Team Experience |
| Southern Pile Area - Sheet Pile | 406 | LF | $ 1,200.00 | $ 487,200 | Based on Project Team Experience |
| Southern Pile Area - Rip Rap | 760 | ton | $ 40.00 | $ 30,400 | Based on Project Team Experience |
| Southern Pile Area - Geotextile | 5,461 | SF | $ 0.40 | $ 2,184 | Based on Project Team Experience |
| Southern Pile Area - Piles Removal | 10 | ea | $ 750.00 | $ 7,500 | Based on Project Team Experience |
| Levin Pier Shoreline Area - Sheet Pile | 299 | LF | $ 1,200.00 | $ 358,800 | Based on Project Team Experience |
| Levin Pier Shoreline Area - Rip Rap | 420 | ton | $ 40.00 | $ 16,800 | Based on Project Team Experience |
| Levin Pier Shoreline Area - Geotextile | 5,461 | SF | $ 0.40 | $ 2,184 | Based on Project Team Experience |
| Levin Pier Shoreline Area - Piles Removal | 0 | ea | $ 750.00 | $ - | Based on Project Team Experience |
| Removal of Residual Sediment from the City of Richmond Municipal Storm Drain yd2stem | 400 | LF | $ 500.00 | $ 200,000 | |
| Transportation and Disposal Residual Sediment from the City of Richmond Municipal Storm Drain yd2stem | 1,000 | ton | $ 99.90 | $ 99,900 | |
| **3.7 Dredging: Water Treatment** | **3,626,795** | **gal** | | **$ 356,653** | |
| Mobilization | 1 | LS | $ 35,000.00 | $ 50,000 | 10 Loads @ 1500, 4 Men 5 Days @ 80, Crane @ 1200 for 1 Day |

**TABLE G-2b**
**Detailed Cost Estimate - Alternative 3**
*United Heckathorn Superfund Site, Richmond, California*

| Item/Activity | Quantity | Unit | Unit Cost | Cost | Comments |
|---|---|---|---|---|---|
| Water Treatment Operations | 3,626,795 | gal | $ 0.07 | $ 253,876 | |
| Decontamination and Demobilization | 1 | LS | $ 45,000.00 | $ 45,000 | 10 Pieces @ 4500 |
| Clean, Demolish, and Dispose of Asphalt Pad (100 x 100) | 259 | ton | $ 30.00 | $ 7,778 | Means 32 12 16, Based on Project Team Experience |
| **3.8 Post-dredging Activates** | | | | **$ 118,333** | |
| Post-Construction Bathymetric Survey and Survey | 5 | day | $ 6,800.00 | $34,000.00 | 5 Days @ $6800/Day |
| Haul Road Removal and Disposal | 311 | ton | $ 30.00 | $9,333.33 | Unit Cost and Quantities by Cost Estimator |
| Barge Mooring Removal | 1 | LS | $ 40,000.00 | $40,000.00 | Experience on Similar Projects |
| Miscellaneous Structure Removal | 1 | LS | $ 20,000.00 | $20,000.00 | Based on Project Team Experience |
| Post Construction Sampling | 1 | LS | $ 15,000.00 | $15,000.00 | Based on Project Team Experience |
| **3.9 Demobilization** | | | | **$ 205,000** | |
| Record Drawings | 1 | LS | $ 20,000.00 | $ 20,000 | Based on Project Team Experience |
| Subcontract Project Closeout | 1 | LS | $ 30,000.00 | $ 30,000 | Based on Project Team Experience |
| Demobilize Equipment | 1 | LS | $ 155,000.00 | $ 155,000 | Based on Project Team Experience |
| **Subtotal Mobilization, Construction, Operation, Maintenance, and Demobilization** | | | | **$ 18,518,548** | |
| **3.10 Construction Project Add-ons** | | | | | |
| Performance and Payment Bonds | 2% | | $ 18,518,548 | $ 370,371 | Based on Project Team Experience |
| Project Management and Overhead Costs | 0% | | $ 18,518,548 | $ - | EPA 2000, Page 5-12 |
| Remedial Design | 6% | | $ 18,518,548 | $ 1,111,113 | EPA 2000, Page 5-12 |
| Construction Management | 6% | | $ 18,518,548 | $ 1,111,113 | EPA 2000, Page 5-12 |
| Contingency | 0% | | $ 18,518,548 | $ - | Contingency Included in Sub Costs |
| **Subtotal Construction Project Add-ons** | | | | **$ 2,592,597** | |

| | | |
|---|---|---|
| **TOTAL CONSTRUCTION ROM COSTS (Current Costs)** | **$ 21,111,144** | Class 4 ROM with Accuracy of +50%/-30%. |
| **TOTAL PROJECT PLANNING AND MANAGEMENT COSTS** | **$ 361,200** | From Above |
| **TOTAL DESIGN COSTS** | **$ 900,000** | From Above |
| **Total CAPITAL COST** | **$ 22,372,344** | |
| **TOTAL O&M COST** | **$ 203,362** | |
| **TOTAL ALL ROM COSTS (Current Costs)** | **$ 22,575,706** | |
| **Upper ROM Range (+50%)** | **$ 33,863,559** | |
| **Lower ROM Range (-30%)** | **$ 15,802,994** | |

**TABLE G-2b**
**Detailed Cost Estimate - Alternative 3**
*United Heckathorn Superfund Site, Richmond, California*

| Item/Activity | Quantity | Unit | Unit Cost | Cost | Comments |
|---|---|---|---|---|---|

| PRESENT VALUE ANALYSIS | YEAR | Total Cost | Total Cost Per Year | Discount Factor (7%) | Present Value |
|---|---|---|---|---|---|
| CAPITAL COST | 0 | $ 22,372,344 | $22,372,344 | 1.000 | $22,372,344 |
| PERIODIC COST | 1 | $77,460 | **$72,038** | 0.930 | $66,995 |
| PERIODIC COST | 2 | $72,038 | $66,995 | 0.930 | $0 |
| PERIODIC COST | 3 | $66,995 | $62,305 | 0.930 | $0 |
| PERIODIC COST | 4 | $62,305 | $57,944 | 0.930 | $0 |
| PERIODIC COST | 5 | $57,944 | $53,888 | 0.930 | $0 |
| PERIODIC COST | 6 | $53,888 | **$50,116** | 0.930 | $46,608 |
| PERIODIC COST | 7 | $50,116 | $46,608 | 0.930 | $0 |
| PERIODIC COST | 8 | $46,608 | $43,345 | 0.930 | $0 |
| PERIODIC COST | 9 | $43,345 | $40,311 | 0.930 | $0 |
| PERIODIC COST | 10 | $40,311 | $37,489 | 0.930 | $0 |
| PERIODIC COST | 11 | $37,489 | **$34,865** | 0.930 | $32,424 |
| PERIODIC COST | 12 | $34,865 | $32,424 | 0.930 | $0 |
| PERIODIC COST | 13 | $32,424 | $30,155 | 0.930 | $0 |
| PERIODIC COST | 14 | $30,155 | $28,044 | 0.930 | $0 |
| PERIODIC COST | 15 | $28,044 | $26,081 | 0.930 | $0 |
| PERIODIC COST | 16 | $26,081 | **$24,255** | 0.930 | $22,557 |
| PERIODIC COST | 17 | $24,255 | $22,557 | 0.930 | $0 |
| PERIODIC COST | 18 | $22,557 | $20,978 | 0.930 | $0 |
| PERIODIC COST | 19 | $20,978 | $19,510 | 0.930 | $0 |
| PERIODIC COST | 20 | $19,510 | $18,144 | 0.930 | $0 |
| PERIODIC COST | 21 | $18,144 | **$16,874** | 0.930 | $15,693 |
| PERIODIC COST | 22 | $16,874 | $15,693 | 0.930 | $0 |
| PERIODIC COST | 23 | $15,693 | $14,594 | 0.930 | $0 |
| PERIODIC COST | 24 | $14,594 | $13,573 | 0.930 | $0 |
| PERIODIC COST | 25 | $13,573 | $12,623 | 0.930 | $0 |
| PERIODIC COST | 26 | $12,623 | **$11,739** | 0.930 | $10,917 |
| PERIODIC COST | 27 | $11,739 | $10,917 | 0.930 | $0 |
| PERIODIC COST | 28 | $10,917 | $10,153 | 0.930 | $0 |
| PERIODIC COST | 29 | $10,153 | $9,442 | 0.930 | $0 |
| PERIODIC COST | 30 | $9,442 | **$8,781** | 0.930 | $8,167 |
| | | | | | **$203,362** |
| | | | | | $22,372,344 |
| **TOTAL PRESENT VALUE FOR ALTERNATE 3** | | | | | **$22,575,706** |

**TABLE G-2c**
**Detailed Cost Estimate - Alternative 4**
*United Heckathorn Superfund Site, Richmond, California*

| Item/Activity | | Quantity | Unit | Unit Cost | Cost | Comments |
|---|---|---|---|---|---|---|
| **1.0** | **WORK PLANNING, REPORTING, AND PROJECT MANAGEMENT** | | | | | |
| 1.01 | Work Plan (Agency submittal and /or Internal) | 1 | LS | $ 50,000 | $ 50,000 | |
| 1.02 | Permitting (Water Quality, USACE [404]) | 1 | LS | $ 70,000 | $ 70,000 | |
| 1.03 | Quality Management (Plan and Audit) | 1 | LS | $ 12,500 | $ 12,500 | |
| 1.04 | Health and Safety (Plan, Activity Hazard Analyses, Audit) | 1 | LS | $ 20,000 | $ 20,000 | |
| 1.05 | Project Chartering (Team Charter, Miscellaneous Meetings) | 1 | LS | $ 13,500 | $ 13,500 | |
| 1.06 | Procurement of Subcontractors (Prequalification, RFP Development, Bid Evaluation, Contracting, Close Outs) | 1 | LS | $ 40,000 | $ 40,000 | |
| 1.07 | Waste Management (Plan Development, Sampling, Characterization, Landfill Acceptance) | 1 | LS | $ 15,000 | $ 15,000 | |
| 1.08 | Data Management (Lab Contractor, Sample Tracking, Data Verification, Uploading, Tables) | 1 | LS | $ 15,000 | $ 15,000 | |
| 1.10 | Project Management | 1 | LS | $ 65,000 | $ 65,000 | 4 Months in Field ($12.5K/mo) & 2 Months Out ($7.5K/mo) |
| 1.11 | Contingency | 20% | | | $ 60,200 | |
| **Subtotal Planning, Reporting, Project Management** | | | | | **$ 361,200** | |
| **2.0** | **DESIGN** | | | | | |
| 2.01 | Predesign Data Collection | 1 | LS | $ 125,000 | $ 125,000 | |
| 2.02 | Modeling (Scour, Fate and Transport, Hydraulic, etc.,) | 1 | LS | $ 125,000 | $ 125,000 | |
| 2.03 | Regulatory Review - Permitting | 1 | LS | $ 50,000 | $ 50,000 | |
| 2.04 | Remedial Design (Includes Basis of Design, Intermediate, and Final) | 1 | LS | $ 450,000 | $ 450,000 | |
| 2.05 | Contingency | 20% | | | $ 150,000 | |
| **Subtotal Design** | | | | | **$ 900,000** | |
| **3.0** | **CONSTRUCTION** | | | | | |
| **3.1** | **Pre Start-up Sampling & Testing** | | | | **$ 70,500** | |
| | Pre-construction Bathymetric Survey and Survey | 10 | day | $ 6,850.00 | $68,500.00 | Based on 10 Days at $6850/Day - from Cost Estimator |
| | Waste Profile Analysis | 1 | LS | $ 2,000.00 | $2,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| **3.2** | **Mobilization** | | | | **$ 265,000** | |
| | Permits | 1 | LS | $ 35,000.00 | $35,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Pre-Construction Submittals | 1 | LS | $ 75,000.00 | $75,000.00 | Includes H&S, Specs, Drawings, Site plans, Labor, and PM |
| | Mechanical Dredge Mobilization | 1 | LS | $ 75,000.00 | $75,000.00 | Experience from Typical Contractor Bids |
| | Barge Mooring Mobilization | 1 | LS | $ 15,000.00 | $15,000.00 | Experience from Typical Contractor Bids |
| | Stabilization Mobilization | 1 | LS | $ 50,000.00 | $50,000.00 | Experience from Typical Contractor Bids |
| | Civil Construction Mobilization | 1 | LS | $ 15,000.00 | $15,000.00 | Experience from Typical Contractor Bids |
| **3.3** | **Pre-dredge Activities** | | | | **$ 552,786** | |
| | Office Trailers (2) | 4 | mo | $ 800.00 | $6,400.00 | Unit Cost / Lump sum Based on Project Team Experience, 2 Office Trailers |
| | Office Trailer Set Up | 1 | LS | $ 3,000.00 | $3,000.00 | Unit Cost / Lump sum Based on Project Team Experience, 2 Office Trailers |
| | Sanitation Facilities | 4 | mo | $ 3,000.00 | $12,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Trash | 4 | mo | $ 1,000.00 | $4,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Perimeter Chain Link Fencing | 1,000 | LF | $ 56.00 | $56,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Haul Road Construction | 11,200 | $ft^2$ | $ 1.84 | $20,608.00 | Unit Cost for Haul Road Construction Based on Project Team Experience |
| | Site Preparation Asphalt Pad Install for Stabilization (300 x 300) | 10,000 | $yd^3$ | $ 24.10 | $241,000.00 | Means 32 12 16 - Cost Estimator - Area Will Be Provided by Client (PRP) |
| | Install Sumps | 3 | ea | $ 5,000.00 | $15,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Site Preparation Asphalt Pad Install for WWT (100 x 100) | 1,111 | $yd^3$ | $ 24.10 | $26,777.78 | Means 32 12 16 - Cost Estimator - Area Will Be Provided by Client (PRP) |
| | Install Sumps | 2 | ea | $ 5,000.00 | $10,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Temporary Site Utilities (Phone & Electric) | 4 | mo | $ 2,000.00 | $8,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Electrical Connection Allowance | 1 | LS | $ 5,000.00 | $5,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Erosion and Sediment Controls Installation | 1 | LS | $ 60,000.00 | $60,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Barge Mooring Area Construction | 0 | LS | $ 200,000.00 | $0.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Construct Dredge Offloading Areas/River Access structures | 1 | LS | $ 50,000.00 | $50,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| | Post Decontamination Equipment Wipe Samples | 1 | LS | $ 10,000.00 | $10,000.00 | Unit Cost / Lump sum Based on Project Team Experience |

**TABLE G-2c**
**Detailed Cost Estimate - Alternative 4**
*United Heckathorn Superfund Site, Richmond, California*

| Item/Activity | Quantity | Unit | | Unit Cost | Cost | Comments |
|---|---|---|---|---|---|---|
| Pre-construction Sampling | 1 | LS | $ | 15,000.00 | $15,000.00 | Unit Cost / Lump sum Based on Project Team Experience |
| Establish Required Vertical Control Points & Tide Gauges | 1 | LS | $ | 10,000.00 | $10,000.00 | Allowance - Based on Project Team Experience |
| **3.4 Turbidity Curtains** | | | | | **$ 72,900** | |
| Turbidity Curtain | 10,000 | $ft^2$ | $ | 7.29 | $72,900.00 | Unit Cost of $7.29/$ft^2$ Based on Project Team Experience |
| **3.5 Monitoring Costs** | | | | | **$ 191,710** | |
| Water Quality Monitoring | 1 | LS | $ | 170,910.00 | $170,910.00 | See Table G-6 |
| Air Monitoring | 4 | mo | $ | 3,600.00 | $14,400.00 | Air Monitoring for VOCs and Particulates |
| Air Monitoring Sample Analysis | 4 | mo | $ | 1,600.00 | $6,400.00 | Air Monitoring for VOCs and Particulates |
| **3.6 Dredging: Sediment Removal and Disposal** | | | | | **$ 17,087,609** | |
| Mobilize Mechanical Dredge | 1 | LS | $ | 75,000.00 | $75,000.00 | Experience from Typical Contractor Bids |
| Mobilize Stabilization | 1 | LS | $ | 50,000.00 | $50,000.00 | See Table G-3c |
| Scows four (4) 30 ft x 100 ft | 12 | mo | $ | 4,500.00 | $54,000.00 | |
| Mechanical Dredging of Sediment - Tight Areas | 6,600 | $yd^3$ | $ | 22.86 | $150,884.80 | See Table G-3c |
| Mechanical Dredging of Sediment - Open Areas | 59,400 | $yd^3$ | $ | 16.73 | $993,792.63 | See Table G-3c |
| Reagent Mixing, Stabilization of West Dredging Sediments | 6,600 | $yd^3$ | $ | 18.45 | $121,756.92 | See Table G-3c |
| Reagent Mixing, Stabilization of East Dredging Sediments | 59,400 | $yd^3$ | $ | 18.45 | $1,095,812.28 | See Table G-3c |
| Loading, Transport and Disposal of West Dredging Sediments | 10,763 | ton | $ | 10.67 | $114,832.35 | |
| Loading, Transport and Disposal of East Dredging Sediments | 97,736 | ton | $ | 10.67 | $1,042,783.25 | |
| Off-loading & Placing Dredge Material on Mixing Pad | 66,000 | $yd^3$ | $ | 5.00 | $330,000.00 | Quote |
| Transport and disposal of Sediments - over 8,000 tons | 108,449 | ton | $ | 99.90 | $10,834,055.10 | Quote |
| Aqua Gate - Material | 231 | ton | $ | 495.00 | $114,345.00 | Based on Project Team Experience |
| Aqua Gate - Shipping | 11 | load | $ | 5,085.00 | $55,935.00 | Quote |
| Aqua Gate - Installation | 231 | ton | $ | 75.00 | $17,325.00 | Based on Project Team Experience |
| Dust and Odor Control | 45 | day | $ | 150.00 | $6,750.00 | Experience from Typical Contractor Bids - Cost Estimator |
| Bathymetry Surveys (Periodic) | 12 | day | $ | 3,000.00 | $36,000.00 | I Day per Week, Multibeam, 6,800 Verbal from Surveying Company |
| Confirmation Sampling | 1 | LS | $ | 100,000.00 | $100,000.00 | Based on Project Team Experience |
| Clean, Demolish, and Dispose of Asphalt Pad (300 x 300) | 2,333 | ton | $ | 30.00 | $70,000.00 | Experience from Typical Contractor Bids |
| 6" Residual Sand Cover - Material Costs | 1,004 | ton | $ | 22.00 | $22,096.43 | Based on Project Team Experience |
| 6" Residual Sand Cover - Equipment, Handling, and Spreading | 1 | day | $ | 4,000.00 | $5,739.33 | Based on Project Team Experience |
| Northern End Shoreline Area - Sheet Pile | 135 | LF | $ | 1,200.00 | $162,000.00 | Based on Project Team Experience |
| Northern End Shoreline Area - Rip Rap | 325 | ton | $ | 40.00 | $13,000.00 | Based on Project Team Experience |
| Northern End Shoreline Area - Geotextile | 4,368 | $ft^2$ | $ | 0.40 | $1,747.20 | Based on Project Team Experience |
| Northern End Piles Area - Piles Removal | 10 | ea | $ | 750.00 | $7,500.00 | Based on Project Team Experience |
| Northern Pile Area - Sheet Pile | 318 | LF | $ | 1,200.00 | $381,600.00 | Based on Project Team Experience |
| Northern Pile Area - Rip Rap | 400 | ton | $ | 40.00 | $16,000.00 | Based on Project Team Experience |
| Northern Pile Area - Geotextile | 5,461 | SF | $ | 0.40 | $2,184.40 | Based on Project Team Experience |
| Northern Pile Area - Piles Removal | 10 | ea | $ | 750.00 | $7,500.00 | Based on Project Team Experience |
| Southern Pile Area - Sheet Pile | 406 | LF | $ | 1,200.00 | $487,200.00 | Based on Project Team Experience |
| Southern Pile Area - Rip Rap | 760 | ton | $ | 40.00 | $30,400.00 | Based on Project Team Experience |
| Southern Pile Area - Geotextile | 5,461 | $ft^2$ | $ | 0.40 | $2,184.40 | Based on Project Team Experience |
| Southern Pile Area - Piles Removal | 10 | ea | $ | 750.00 | $7,500.00 | Based on Project Team Experience |
| Levin Pier Shoreline Area - Sheet Pile | 299 | LF | $ | 1,200.00 | $358,800.00 | Based on Project Team Experience |
| Levin Pier Shoreline Area - Rip Rap | 420 | ton | $ | 40.00 | $16,800.00 | Based on Project Team Experience |
| Levin Pier Shoreline Area - Geotextile | 5,461 | $ft^2$ | $ | 0.40 | $2,184.40 | Based on Project Team Experience |
| Levin Pier Shoreline Area - Piles Removal | 0 | ea | $ | 750.00 | $0.00 | Based on Project Team Experience |
| Removal of Residual Sediment from the City of Richmond Municipal Storm Drain System | 400 | LF | $ | 500.00 | $200,000.00 | |
| Transportation and Disposal Residual Sediment from the City of Richmond Municipal Storm Drain System | 1,000 | ton | $ | 99.90 | $99,900.00 | |

**TABLE G-2c**
**Detailed Cost Estimate - Alternative 4**
*United Heckathorn Superfund Site, Richmond, California*

| Item/Activity | Quantity | Unit | Unit Cost | Cost | Comments |
|---|---|---|---|---|---|
| **3.7 Dredging: Water Treatment** | **3,740,132** | **gal** | **$ 0.07** | **$ 364,587** | |
| Mobilization | 1 | LS | $ 35,000.00 | $50,000.00 | 10 Loads @ 1500, 4 Men 5 Days @ 80, Crane @ 1200 for 1 Day |
| Water Treatment Operations | 3,740,132 | gal | $ 0.07 | $261,809.23 | |
| Decontamination and Demobilization | 1 | LS | $ 45,000.00 | $45,000.00 | 10 Pieces @ 4500 |
| Clean, Demolish and Dispose of Asphalt Pad (100 x 100) | 259 | ton | $ 30.00 | $7,777.78 | Means 32 12 16, Based on Project Team Experience |
| **3.8 Post-dredging Activities** | | | | **$ 118,333** | |
| Post-construction Bathymetric Survey and Survey | 5 | day | $ 6,800.00 | $34,000.00 | 5 days @ $6800/Day |
| Haul Road removal and disposal | 311 | ton | $ 30.00 | $9,333.33 | Unit Cost and Quantities by Cost Estimator |
| Barge mooring removal | 1 | LS | $ 40,000.00 | $40,000.00 | Experience on Similar Projects |
| Miscellaneous Structure Removal | 1 | LS | $ 20,000.00 | $20,000.00 | Based on Project Team Experience |
| Post Construction Sampling | 1 | LS | $ 15,000.00 | $15,000.00 | Based on Project Team Experience |
| **3.9 Demobilization** | | | | **$ 150,000** | |
| Record Drawings | 1 | LS | $ 20,000.00 | $20,000.00 | Based on Project Team Experience |
| Subcontract Project Closeout | 1 | LS | $ 30,000.00 | $30,000.00 | Based on Project Team Experience |
| Demobilize Equipment | 1 | LS | $ 100,000.00 | $100,000.00 | Based on Project Team Experience |
| **Subtotal Mobilization, Construction, Operation, Maintenance, and Demobilization** | | | | **$ 18,873,425** | |
| **3.10 Construction Project Add-ons** | | | | | |
| Performance and Payment Bonds | 2% | | $ 18,873,425 | $ 377,468 | Experience on Similar Projects |
| Project Management and Overhead Costs | 5% | | $ 18,873,425 | $ 943,671 | EPA 2000, Page 5-12 |
| Remedial Design | 0% | | $ 18,873,425 | $ - | EPA 2000, Page 5-12 |
| Construction Management | 6% | | $ 18,873,425 | $ 1,132,405 | EPA 2000, Page 5-12 |
| Contingency | 0% | | $ 18,873,425 | $ - | Contingency Included in Sub Costs |
| **Subtotal Construction Project Add-ons** | | | | **$ 2,453,545** | |

| | | |
|---|---|---|
| **TOTAL CONSTRUCTION ROM COSTS (Current Costs)** | **$ 21,326,970** | Class 4 ROM with Accuracy of +50%/-30%. |
| **TOTAL PROJECT PLANNING AND MANAGEMENT COSTS** | **$ 361,200** | From Above |
| **TOTAL DESIGN COSTS** | **$ 900,000** | From Above |
| **Total CAPITAL COST** | **$ 22,588,170** | |
| **TOTAL O&M COST** | **$ 123,133** | |
| **TOTAL ALL ROM COSTS (Current Costs)** | **$ 22,711,303** | |
| **Upper ROM Range (+50%)** | **$ 21,326,970** | |
| **Lower ROM Range (-30%)** | **$ 21,326,970** | |

**TABLE G-2c**
**Detailed Cost Estimate - Alternative 4**
*United Heckathorn Superfund Site, Richmond, California*

| Item/Activity | Quantity | Unit | Unit Cost | Cost | Comments |
|---|---|---|---|---|---|
| **PRESENT VALUE ANALYSIS** | **YEAR** | **Total Cost** | **Total Cost Per Year** | **Discount Factor (7%)** | **Present Value** |
| CAPITAL COST | 0 | $ 22,588,170 | $22,588,170 | 1.000 | $22,588,170 |
| PERIODIC COST | 1 | $46,901 | **$43,618** | 0.930 | $40,565 |
| PERIODIC COST | 2 | $43,618 | $40,565 | 0.930 | $0 |
| PERIODIC COST | 3 | $40,565 | $37,725 | 0.930 | $0 |
| PERIODIC COST | 4 | $37,725 | $35,085 | 0.930 | $0 |
| PERIODIC COST | 5 | $35,085 | $32,629 | 0.930 | $0 |
| PERIODIC COST | 6 | $32,629 | **$30,345** | 0.930 | $28,221 |
| PERIODIC COST | 7 | $30,345 | $28,221 | 0.930 | $0 |
| PERIODIC COST | 8 | $28,221 | $26,245 | 0.930 | $0 |
| PERIODIC COST | 9 | $26,245 | $24,408 | 0.930 | $0 |
| PERIODIC COST | 10 | $24,408 | $22,699 | 0.930 | $0 |
| PERIODIC COST | 11 | $22,699 | **$21,110** | 0.930 | $19,633 |
| PERIODIC COST | 12 | $21,110 | $19,633 | 0.930 | $0 |
| PERIODIC COST | 13 | $19,633 | $18,258 | 0.930 | $0 |
| PERIODIC COST | 14 | $18,258 | $16,980 | 0.930 | $0 |
| PERIODIC COST | 15 | $16,980 | $15,792 | 0.930 | $0 |
| PERIODIC COST | 16 | $15,792 | **$14,686** | 0.930 | $13,658 |
| PERIODIC COST | 17 | $14,686 | $13,658 | 0.930 | $0 |
| PERIODIC COST | 18 | $13,658 | $12,702 | 0.930 | $0 |
| PERIODIC COST | 19 | $12,702 | $11,813 | 0.930 | $0 |
| PERIODIC COST | 20 | $11,813 | $10,986 | 0.930 | $0 |
| PERIODIC COST | 21 | $10,986 | **$10,217** | 0.930 | $9,502 |
| PERIODIC COST | 22 | $10,217 | $9,502 | 0.930 | $0 |
| PERIODIC COST | 23 | $9,502 | $8,837 | 0.930 | $0 |
| PERIODIC COST | 24 | $8,837 | $8,218 | 0.930 | $0 |
| PERIODIC COST | 25 | $8,218 | $7,643 | 0.930 | $0 |
| PERIODIC COST | 26 | $7,643 | **$7,108** | 0.930 | $6,610 |
| PERIODIC COST | 27 | $7,108 | $6,610 | 0.930 | $0 |
| PERIODIC COST | 28 | $6,610 | $6,148 | 0.930 | $0 |
| PERIODIC COST | 29 | $6,148 | $5,717 | 0.930 | $0 |
| PERIODIC COST | 30 | $5,717 | **$5,317** | 0.930 | $4,945 |
| | | | | | **$123,133** |
| | | | | | $22,588,170 |
| **TOTAL PRESENT VALUE FOR ALTERNATE 4** | | | | | **$22,711,303** |

**TABLE G-3a**

**Summary of Data Assumptions - Alternative 2**

*United Heckathorn Superfund Site, Richmond, California*

| **Dredging Volumes** | **Volume** | |
|---|---|---|
| Tight Area Dredging (10% of Dredging Volume) | 5,800 | $yd^3$ |
| Open Area Dredging (90% of Dredging Volume) | 52,200 | $yd^3$ |
| **Total Volume** | **58,000** | $yd^3$ |
| | | |
| **Dredging Estimated Production Rates** | | |
| Tight Area Dredging (10% of Dredging Volume) | 1,250 | $yd^3$/day |
| Open Area Dredging (90% of Dredging Volume) | 1,500 | $yd^3$/day |
| | | |
| **Dredging Days to Complete** | | |
| Tight Area Dredging (10% of Dredging Volume) | 5 | days |
| Open Area Dredging (90% of Dredging Volume) | 35 | days |
| **Total Days** | **39** | **days** |

| **Daily Dredging Costs** | | **Units** | **Unit Cost** | **Total** |
|---|---|---|---|---|
| Dredge and Personnel | 1 | ea | $20,000 | $20,000 |
| Scows | 4 | ea | $500 | $2,000 |
| Tug | 12 | hrs | $400 | $4,800 |
| Per diem | 6 | ea | $170 | $1,020 |
| Misc. | 1 | day | $1,000 | $1,000 |
| **Daily Cost** | | | | **$28,820** |

| **Daily Stabilization Costs** | | **Units** | **Unit Cost** | **Total** |
|---|---|---|---|---|
| Screening Plant | 1 | ea | $600 | $600 |
| Rapid Mix 400 | 3 | ea | $1,350 | $4,050 |
| Personnel | 4 | ea | $1,200 | $4,800 |
| Per diem | 4 | ea | $170 | $680 |
| Miscellaneous | 1 | day | $1,000 | $1,000 |
| **Daily Cost** | | | | **$11,130** |

| **Landside Water Control** | | | | |
|---|---|---|---|---|
| **Processing Pad Rainwater** | | | | |
| Estimated Surface Area to Control Water (600 ft x 600 ft) | 360,000 | $ft^2$ | | |
| Rainfall | 3 | in/mo | | |
| Pad Water Volume from Rainfall | 673,200 | gal/mo | 2,807 | ton/mo |
| Pad Water Volume from Rainfall | 22,116 | gal/day | 92 | ton/day |
| **Pad Water Volume from Rainfall** | **872,241** | **gal/job** | **3,637** | **ton/job** |
| | | | | |
| **Pressure Washer** | | | | |
| Pressure Washer (Assume 4 gpm Operating 6 HPD) | 1,440 | gal/day | 6 | ton/day |
| **Pressure Washer (Assume 4 gpm operating 6 HPD)** | **56,794** | **gal/job** | **237** | **ton/job** |
| | | | | |
| **Total Estimated Pad Water** | **929,034** | **gal/job** | **3,874.07** | **ton/job** |

**TABLE G-3a**

**Summary of Data Assumptions - Alternative 2**

*United Heckathorn Superfund Site, Richmond, California*

| | Unit | Tight Area (10%) | Open Area (90%) | Total |
|---|---|---|---|---|
| **Dredging Volume Estimate** | | | | |
| Dredge Volume | $yd^3$ | 5,800 | 52,200 | 58,000 |
| Estimated In Situ Density of Sediment | $ton/yd^3$ | 1.5 | 1.5 | |
| Mass of In Situ Sediment | ton | 9,600 | 78,300 | 87,000 |
| Solids Content In Situ | % | 50% | 50% | |
| Estimated Dry Solids in Sediment | ton | 4,350 | 39,150 | 43,500 |
| Solids after Mechanical Dredging (In Scows) | % | 45% | 45% | |
| Total Mass Delivered to Offload | ton | 9,667 | 87,000 | 96,667 |
| Percent Bucket Full of Sediment | % | 80% | 80% | |
| Total Est Free Water In Scows after Dredging | gal | 234,320 | 2,108,880 | 2,343,200 |
| % Free Water Removed at Upland Facility | % | 95% | 95% | |
| Free Water Incorporated in Sediment | gal | 11,716 | 105,444 | 117,160 |
| Mass Free Water Incorporated in Sediment | ton | 49 | 440 | 489 |
| **Water Treatment Estimate** | | 700 | 700 | |
| Volume Water Recovered From Scows | gal/job | 222,604 | 2,003,436 | 2,226,040 |
| Rainwater Estimate | gal/job | 102,617 | 769,624 | 872,241 |
| Pressure Wash Water | gal | 6,682 | 50,112 | 56,794 |
| Backwash Water from Water Treatment System | gal/job | 92,800 | 696,000 | 788,800 |
| Total Estimated Water to Treat | gal/job | 424,702 | 3,519,172 | 3,943,874 |
| | gal/day | | | 99,997 |
| | gpm | | | 67 |
| **Water Treatment** | | | | |
| Water Treatment Uptime | | 90% | 90% | |
| Hours/Day | | 24 | 24 | |
| Uptime/Day (WWT System) | | 22 | 22 | |
| Process Time | min | 6,013 | 45,101 | 51,114 |
| WWT System Capacity Required | gpm | 71 | 78 | 74 |
| **Stabilization** | | | | |
| Total Sediment Tons to Process | ton | 8,700 | 78,300 | 87,000 |
| Total Free Water Tons to Process | ton | 49 | 440 | 489 |
| Total Mass to Solidify | ton | 8,749 | 78,740 | 87,489 |
| **Stabilization Agents** | | | | |
| Portland Cement (8%) | ton | 700 | 6,299 | 6,999 |
| **Disposal Estimates** | | | | |
| Stabilized Sediment | ton | 9,449 | 85,039 | 94,488 |
| Class 1 Non-RCRA Waste Disposal | % | 100% | 100% | |
| RCRA Subtitle C Waste Disposal | % | 0% | 0% | |
| Class 1 Non-RCRA Waste Disposal (Debris) | % | 0.10% | 1.00% | |
| RCRA Subtitle D Waste Disposal | ton | 9,449 | 85,039 | 94,488 |
| RCRA Subtitle C Waste Disposal | ton | - | - | - |
| RCRA Subtitle D Waste Disposal (Debris) | ton | 9 | 850 | 860 |
| **Total Offsite Disposal** | | **9,458** | **85,889** | **95,347** |

**TABLE G-3b**

**Summary of Data Assumptions - Alternative 3**

*United Heckathorn Superfund Site, Richmond, California*

| **Dredging Volumes** | **Volume** | |
|---|---|---|
| Tight Area Dredging (10% of Dredging Volume) | 6,400 | $yd^3$ |
| Open Area Dredging (90% of Dredging Volume) | 57,600 | $yd^3$ |
| **Total Volume** | **64,000** | $yd^3$ |

| **Dredging Estimated Production Rates** | | |
|---|---|---|
| Tight Area Dredging (10% of Dredging Volume) | 1,250 | $yd^3$/day |
| Open Area Dredging (90% of Dredging Volume) | 1,500 | $yd^3$/day |

| **Dredging Days to Complete** | | |
|---|---|---|
| Tight Area Dredging (10% of Dredging Volume) | 5 | days |
| Open Area Dredging (90% of Dredging Volume) | 38 | days |
| **Total Days** | **44** | **days** |

| **Daily Dredging Costs** | | **Units** | **Unit Cost** | **Total** |
|---|---|---|---|---|
| Dredge and Personnel | 1 | ea | $20,000 | $20,000 |
| Scows | 4 | ea | $500 | $2,000 |
| Tug | 12 | hrs | $400 | $4,800 |
| Per diem | 6 | ea | $170 | $1,020 |
| Misc. | 1 | day | $1,000 | $1,000 |
| **Daily Cost** | | | | **$28,820** |

| **Daily Stabilization Costs** | | **Units** | **Unit Cost** | **Total** |
|---|---|---|---|---|
| Screening Plant | 1 | ea | $600 | $600 |
| Rapid Mix 400 | 3 | ea | $1,350 | $4,050 |
| Personnel | 4 | ea | $1,200 | $4,800 |
| Per diem | 4 | ea | $170 | $680 |
| Miscellaneous | 1 | day | $1,000 | $1,000 |
| **Daily Cost** | | | | **$11,130** |

| **Landside Water Control** | | | | |
|---|---|---|---|---|
| **Processing Pad Rainwater** | | | | |
| Estimated Surface Area to Control Water (600 ft x 600 ft) | 360,000 | $ft^2$ | | |
| Rainfall | 3 | in/mo | | |
| Pad Water Volume from Rainfall | 673,200 | gal/mo | 2,807 | ton/mo |
| Pad Water Volume from Rainfall | 22,116 | gal/day | 92 | ton/day |
| **Pad Water volume from rainfall** | **962,473** | **gal/job** | **4,014** | **ton/job** |
| | | | | |
| **Pressure Washer** | | | | |
| Pressure Washer (Assume 4 gpm Operating 6 HPD) | 1,440 | gal/day | 6 | ton/day |
| **Pressure Washer (Assume 4 gpm Operating 6 HPD)** | **62,669** | **gal/job** | **261** | **ton/job** |
| | | | | |
| **Total Est Pad Water** | **1,025,141** | **gal/job** | **4,274.84** | **ton/job** |

**TABLE G-3b**

**Summary of Data Assumptions - Alternative 3**

*United Heckathorn Superfund Site, Richmond, California*

| | Unit | Tight Area (10%) | Open Area (90%) | Total |
|---|---|---|---|---|
| **Dredging Volume Estimate** | | | | |
| Dredge Volume | $yd^3$ | 6,400 | 57,600 | 64,000 |
| Estimated In Situ Density of Sediment | $ton/yd^3$ | 1.5 | 1.5 | |
| Mass of In Situ Sediment | ton | 9,600 | 86,400 | 96,000 |
| Solids Content In Situ | % | 50% | 50% | |
| Estimated Dry Solids in Sediment | ton | 4,800 | 43,200 | 48,000 |
| Solids after Mechanical Dredging (In Scows) | % | 45% | 45% | |
| Total Mass Delivered to Offload | ton | 10,667 | 96,000 | 106,667 |
| Percent Bucket Full of Sediment | % | 80% | 80% | |
| Total Est Free Water In Scows after Dredging | gal | 258,560 | 2,327,040 | 2,585,600 |
| % Free Water Removed at Upland Facility | % | 95% | 95% | |
| Free Water Incorporated in Sediment | gal | 12,928 | 116,352 | 129,280 |
| Mass Free Water Incorporated in Sediment | ton | 54 | 485 | 539 |
| **Water Treatment Estimate** | | 700 | 700 | |
| Volume Water Recovered From Scows | gal/job | 245,632 | 2,210,688 | 2,456,320 |
| Rainwater Estimate | gal/job | 113,232 | 849,240 | 962,473 |
| Pressure Wash Water | gal | 7,373 | 55,296 | 62,669 |
| Backwash Water from Water Treatment System | gal/job | 102,400 | 768,000 | 870,400 |
| Total Estimated Water to Treat | gal/job | 468,637 | 3,883,224 | 4,351,861 |
| | gal/day | | | 99,997 |
| | gpm | | | 67 |
| **Water Treatment** | | | | |
| Water Treatment Uptime | | 90% | 90% | |
| Hours/Day | | 24 | 24 | |
| Uptime/Day (WWT System) | | 22 | 22 | |
| Process Time | min | 6,636 | 49,766 | 56,402 |
| WWT System Capacity Required | gpm | 71 | 78 | 74 |
| **Stabilization** | | | | |
| Total Sediment Tons to Process | ton | 9,600 | 86,400 | 96,000 |
| Total Free Water Tons to Process | ton | 54 | 485 | 539 |
| Total Mass to Solidify | ton | 9,654 | 86,885 | 96,539 |
| **Stabilization Agents** | | | | |
| Portland Cement (8%) | ton | 772 | 6,951 | 7,723 |
| **Disposal Estimates** | | | | |
| Stabilized Sediment | ton | 10,426 | 93,836 | 104,262 |
| Class 1 Non-RCRA Waste Disposal | % | 100% | 100% | |
| RCRA Subtitle C Waste Disposal | % | 0% | 0% | |
| Class 1 Non-RCRA Waste Disposal (Debris) | % | 0.10% | 1.00% | |
| RCRA Subtitle D Waste Disposal | ton | 10,426 | 93,836 | 104,262 |
| RCRA Subtitle C Waste Disposal | ton | - | - | - |
| RCRA Subtitle D Waste Disposal (Debris) | ton | 10 | 938 | 949 |
| **Total Offsite Disposal** | | **10,437** | **94,774** | **105,211** |

**TABLE G-3c**

**Summary of Data Assumptions - Alternative 4**

*United Heckathorn Superfund Site, Richmond, California*

| **Dredging Volumes** | **Volume** | |
|---|---|---|
| Tight Area Dredging (10% of Dredging Volume) | 6,600 | $yd^3$ |
| Open Area Dredging (90% of Dredging Volume) | 59,400 | $yd^3$ |
| **Total Volume** | **66,000** | $yd^3$ |

| **Dredging Estimated Production Rates** | | |
|---|---|---|
| Tight Area Dredging (10% of Dredging Volume) | 1,250 | $yd^3$/day |
| Open Area Dredging (90% of Dredging Volume) | 1,500 | $yd^3$/day |

| **Dredging Days to Complete** | | |
|---|---|---|
| Tight Area Dredging (10% of Dredging Volume) | 5 | days |
| Open Area Dredging (90% of Dredging Volume) | 40 | days |
| **Total Days** | **45** | **days** |

| **Daily Dredging Costs** | | **Units** | **Unit Cost** | **Total** |
|---|---|---|---|---|
| Dredge and Personnel | 1 | ea | $20,000 | $20,000 |
| Scows | 4 | ea | $500 | $2,000 |
| Tug | 12 | hrs | $400 | $4,800 |
| Per diem | 6 | ea | $170 | $1,020 |
| Misc. | 1 | day | $1,000 | $1,000 |
| **Daily Cost** | | | | **$28,820** |

| **Daily Stabilization Costs** | | **Units** | | |
|---|---|---|---|---|
| Screening Plant | 1 | ea | $600 | $600 |
| Rapid Mix 400 | 3 | ea | $1,350 | $4,050 |
| Personnel | 4 | ea | $1,200 | $4,800 |
| Per diem | 4 | ea | $170 | $680 |
| Miscellaneous | 1 | day | $1,000 | $1,000 |
| **Daily Cost** | | | | **$11,130** |

| **Landside Water Control** | | | **Unit Cost** | | **Total** |
|---|---|---|---|---|---|
| **Processing Pad Rainwater** | | | | | |
| Estimated Surface Area to Control Water (600 ft x 600 ft) | 360,000 | $ft^2$ | | | |
| Rainfall | 3 | in/mo | | | |
| Pad Water Volume from Rainfall | 673,200 | gal/mo | 2,807 | ton/mo | |
| Pad Water Volume from Rainfall | 22,116 | gal/day | 92 | ton/day | |
| **Pad Water Volume from Rainfall** | **992,550** | **gal/job** | **4,139** | **ton/job** | |
| **Pressure Washer** | | | | | |
| Pressure Washer (Assume 4 gpm Operating 6 HPD) | 1,440 | gal/day | 6 | ton/day | |
| **Pressure Washer (Assume 4 gpm Operating 6 HPD)** | **64,627** | **gal/job** | **269** | **ton/job** | |
| **Total Est Pad Water** | **1,057,177** | **gal/job** | **4,408.43** | **ton/job** | |

**TABLE G-3c**

**Summary of Data Assumptions - Alternative 4**

*United Heckathorn Superfund Site, Richmond, California*

| | Unit | Tight Area (10%) | Open Area (90%) | Total |
|---|---|---|---|---|
| **Dredging Volume Estimate** | | | | |
| Dredge Volume | $yd^3$ | 6,600 | 59,400 | 66,000 |
| Estimated In Situ Density of Sediment | $ton/yd^3$ | 1.5 | 1.5 | |
| Mass of In Situ Sediment | ton | 9,600 | 89,100 | 99,000 |
| Solids Content In Situ | % | 50% | 50% | |
| Estimated Dry Solids in Sediment | ton | 4,950 | 44,550 | 49,500 |
| Solids after Mechanical Dredging (In Scows) | % | 45% | 45% | |
| Total Mass Delivered to Offload | ton | 11,000 | 99,000 | 110,000 |
| Percent Bucket Full of Sediment | % | 80% | 80% | |
| Total Est Free Water In Scows after Dredging | gal | 266,640 | 2,399,760 | 2,666,400 |
| % Free Water Removed at Upland Facility | % | 95% | 95% | |
| Free Water Incorporated in Sediment | gal | 13,332 | 119,988 | 133,320 |
| Mass Free Water Incorporated in Sediment | ton | 56 | 500 | 556 |
| **Water Treatment Estimate** | | 700 | 700 | |
| Volume Water Recovered From Scows | gal/job | 253,308 | 2,279,772 | 2,533,080 |
| Rainwater Estimate | gal/job | 116,771 | 875,779 | 992,550 |
| Pressure Wash Water | gal | 7,603 | 57,024 | 64,627 |
| Backwash Water from Water Treatment System | gal/job | 105,600 | 792,000 | 897,600 |
| Total Estimated Water to Treat | gal/job | 483,282 | 4,004,575 | 4,487,857 |
| | gal/day | | | 99,997 |
| | gpm | | | 67 |
| **Water Treatment** | | | | |
| Water Treatment Uptime | | 90% | 90% | |
| Hours/Day | | 24 | 24 | |
| Uptime/Day (WWT System) | | 22 | 22 | |
| Process Time | min | 6,843 | 51,322 | 58,164 |
| WWT System Capacity Required | gpm | 71 | 78 | 74 |
| **Stabilization** | | | | |
| Total Sediment Tons to Process | ton | 9,900 | 89,100 | 99,000 |
| Total Free Water Tons to Process | ton | 56 | 500 | 556 |
| Total Mass to Solidify | ton | 9,956 | 89,600 | 99,556 |
| **Stabilization Agents** | | | | |
| Portland Cement (8%) | ton | 796 | 7,168 | 7,964 |
| **Disposal Estimates** | | | | |
| Stabilized Sediment | ton | 10,752 | 96,768 | 107,520 |
| Class 1 Non-RCRA Waste Disposal | % | 100% | 100% | |
| RCRA Subtitle C Waste Disposal | % | 0% | 0% | |
| Class 1 Non-RCRA Waste Disposal (Debris) | % | 0.10% | 1.00% | |
| RCRA Subtitle D Waste Disposal | ton | 10,752 | 96,768 | 107,520 |
| RCRA Subtitle C Waste Disposal | ton | - | - | - |
| RCRA Subtitle D Waste Disposal (Debris) | ton | 11 | 968 | 978 |
| **Total Offsite Disposal** | | **10,763** | **97,736** | **108,499** |

**TABLE G-4a**
**Dredging Assumptions - Alternative 2**
*United Heckathorn Superfund Site, Richmond, California*

| Description | No of Units | Unit | Cost |
|---|---|---|---|
| Task 1 - Dredge Tight Areas | 5,800 | $yd^3$ | $132,596 |
| Task 2 - Dredge Open Areas | 52,200 | $yd^3$ | $993,793 |
| Task 3 - Turbidity Controls | 39 | day | $167,542 |
| Task 4 - Supply Portland Cement Reagent | 6,999 | ton | $1,154,849 |
| Task 5 - Mix Reagents; Stockpile Sediment on Pad | 58,000 | $yd^3$ | $1,166,570 |
| Task 6 - Load Class 1 Non-RCRA Stabilized Materials into Rail; Transport and Dispose at Landfill (Utah) [Tight Areas] | 9,449 | ton | $100,812 |
| Task 7 - Load Class 1 Non-RCRA Stabilized Materials into Rail; Transport and Dispose at Landfill (Utah) [Open Areas] | 85,889 | ton | $636,015 |
| Task 8 - Water Treatment | 3,943,874 | gal | $1,921,590 |
| Task 9 - Debris Removal and RCRA Subtitle D Disposal | 860 | ton | $93,129 |
| Task 10 - Mechanical Dredge Standby Time | 24 | hrs | $27,015 |
| **8th Street Slip Sheet Piling Reinforcement** | 0 | **LF** | **$ -** |
| | | **TOTAL** | **$6,393,910** |

**Task 1 - Dredge Tight Areas** **5 day** **5,800 $yd^3$** **1,250 $yd^3$/day**

| | Description | Resource Description | No of Units | Unit Rate | Units | Additional Units | Unit Description | Raw Cost | Subcontractor Markup | Subcontractor Markup Amount | Total Cost | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Dredging PM | Dredge Labor | 6 | $ 65.40 | $/hr | 5 | day | $ 1,820.74 | 25.0% | $ 455.18 | $ 2,275.92 | 20% | $ 455.18 | $ 2,731.10 |
| SUB: Dredger | Dredge Operator (ST) | Dredge Labor | 16 | $ 74.83 | $/hr | 5 | day | $ 5,555.27 | 25.0% | $ 1,388.82 | $ 6,944.08 | 20% | $ 1,388.82 | $ 8,332.90 |
| SUB: Dredger | Dredge Operator (OT) | Dredge Labor | 8 | $ 96.92 | $/hr | 5 | day | $ 3,597.57 | 25.0% | $ 899.39 | $ 4,496.97 | 20% | $ 899.39 | $ 5,396.36 |
| SUB: Dredger | Dredge Labor (ST) | Dredge Labor | 32 | $ 30.33 | $/hr | 5 | day | $ 4,504.10 | 25.0% | $ 1,126.02 | $ 5,630.12 | 20% | $ 1,126.02 | $ 6,756.14 |
| SUB: Dredger | Dredge Labor (OT) | Dredge Labor | 16 | $ 42.28 | $/hr | 5 | day | $ 3,138.54 | 25.0% | $ 784.64 | $ 3,923.18 | 20% | $ 784.64 | $ 4,707.82 |
| SUB: Dredger | Safety Supplies | | 9 | $ 25.00 | $/day | 5 | day | $ 1,044.00 | 10.0% | $ 104.40 | $ 1,148.40 | 20% | $ 229.68 | $ 1,378.08 |
| SUB: Dredger | Hotel | | 4 | $ 100.00 | $/day | 5 | day | $ 1,856.00 | 10.0% | $ 185.60 | $ 2,041.60 | 20% | $ 408.32 | $ 2,449.92 |
| SUB: Dredger | Per diem | | 4 | $ 50.00 | $/day | 5 | day | $ 928.00 | 10.0% | $ 92.80 | $ 1,020.80 | 20% | $ 204.16 | $ 1,224.96 |
| SUB: Dredger | Truck | | 2 | $ 75.00 | $/day | 5 | day | $ 696.00 | 25.0% | $ 174.00 | $ 870.00 | 20% | $ 174.00 | $ 1,044.00 |
| SUB: Dredger | Dredge Rental | 40 x 80 Flat Deck Spud Barge with CAT 345 & 4 $yd^3$ Environmental Bucket and Support Equipment | 1 | $ 10,000.00 | $/day | 5 | day | $ 46,400.00 | 25.0% | $ 11,600.00 | $ 58,000.00 | 20% | $ 11,600.00 | $ 69,600.00 |
| SUB: Dredger | Tender Tug | | 1 | $ 550.00 | $/hr | 5 | day | $ 2,552.00 | 25.0% | $ 638.00 | $ 3,190.00 | 20% | $ 638.00 | $ 3,828.00 |
| SUB: Dredger | Tow Tug | | 3 | $ 550.00 | $/hr | 5 | day | $ 7,656.00 | 25.0% | $ 1,914.00 | $ 9,570.00 | 20% | $ 1,914.00 | $ 11,484.00 |
| SUB: Dredger | Small Tool and Equipment | Skiff | 1 | $ 250.00 | $/day | 5 | day | $ 1,160.00 | 25.0% | $ 290.00 | $ 1,450.00 | 20% | $ 290.00 | $ 1,740.00 |
| SUB: Dredger | Workboat | | 1 | $ 100.00 | $/day | 5 | day | $ 464.00 | 25.0% | $ 116.00 | $ 580.00 | 20% | $ 116.00 | $ 696.00 |
| SUB: Dredger | FOGM | | 500 | $ 3.50 | $/gal | 5 | day | $ 8,120.00 | 10.0% | $ 812.00 | $ 8,932.00 | 20% | $ 1,786.40 | $ 10,718.40 |
| SUB: Dredger | Office Trailer Rentals | | 2 | $ 350.00 | $/mo | 0 | mo | $ 106.70 | 25.0% | $ 26.68 | $ 133.38 | 20% | $ 26.68 | $ 160.05 |
| SUB: Dredger | Office Trailer | | 1 | $ 50.00 | $/day | 5 | day | $ 232.00 | 25.0% | $ 58.00 | $ 290.00 | 20% | $ 58.00 | $ 348.00 |
| ***Subtotal*** | | | | | | | | **$ 89,830.92** | | **$ 20,665.53** | **$ 110,496.45** | | **$ 22,099.29** | **$ 132,595.74** |

**Task 2 - Dredge Open Areas** **35 days** **52,200 $yd^3$** **1,500 $yd^3$/day**

| | Description | Resource Description | No of Units | Unit Rate | Units | Additional Units | Unit Description | Raw Cost | Subcontractor Markup | Subcontractor Markup Amount | Total Cost | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Dredging PM | Dredge Labor | 6 | $ 65.40 | $/hr | 35 | day | $ 13,655.52 | 25.0% | $ 3,413.88 | $ 17,069.40 | 20% | $ 3,413.88 | $ 20,483.28 |
| SUB: Dredger | Dredge Operator (ST) | Dredge Labor | 16 | $ 74.83 | $/hr | 35 | day | $ 41,664.51 | 25.0% | $ 10,416.13 | $ 52,080.64 | 20% | $ 10,416.13 | $ 62,496.76 |
| SUB: Dredger | Dredge Operator (OT) | Dredge Labor | 8 | $ 96.92 | $/hr | 35 | day | $ 26,981.79 | 25.0% | $ 6,745.45 | $ 33,727.24 | 20% | $ 6,745.45 | $ 40,472.69 |
| SUB: Dredger | Dredge Labor (ST) | Dredge Labor | 32 | $ 30.33 | $/hr | 35 | day | $ 33,780.72 | 25.0% | $ 8,445.18 | $ 42,225.90 | 20% | $ 8,445.18 | $ 50,671.08 |
| SUB: Dredger | Dredge Labor (OT) | Dredge Labor | 16 | $ 42.28 | $/hr | 35 | day | $ 23,539.08 | 25.0% | $ 5,884.77 | $ 29,423.85 | 20% | $ 5,884.77 | $ 35,308.62 |
| SUB: Dredger | Safety Supplies | | 9 | $ 25.00 | $/day | 35 | day | $ 7,830.00 | 10.0% | $ 783.00 | $ 8,613.00 | 20% | $ 1,722.60 | $ 10,335.60 |
| SUB: Dredger | Hotel | | 4 | $ 100.00 | $/day | 35 | day | $ 13,920.00 | 10.0% | $ 1,392.00 | $ 15,312.00 | 20% | $ 3,062.40 | $ 18,374.40 |
| SUB: Dredger | Per diem | | 4 | $ 50.00 | $/day | 35 | day | $ 6,960.00 | 10.0% | $ 696.00 | $ 7,656.00 | 20% | $ 1,531.20 | $ 9,187.20 |
| SUB: Dredger | Truck | | 2 | $ 75.00 | $/day | 35 | day | $ 5,220.00 | 25.0% | $ 1,305.00 | $ 6,525.00 | 20% | $ 1,305.00 | $ 7,830.00 |

**TABLE G-4a**
**Dredging Assumptions - Alternative 2**
*United Heckathorn Superfund Site, Richmond, California*

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Dredge Rental | 40 x 80 Flat Deck Spud Barge with CAT 345 & 4 $yd^3$ Environmental Bucket and Support Equipment | 1 | $ 10,000.00 | $/day | 35 | day | $ 348,000.00 | 25.0% | $ 87,000.00 | $ 435,000.00 | 20% | $ 87,000.00 | $ 522,000.00 |
| SUB: Dredger | Tender Tug | | 1 | $ 550.00 | $/hr | 35 | day | $ 19,140.00 | 25.0% | $ 4,785.00 | $ 23,925.00 | 20% | $ 4,785.00 | $ 28,710.00 |
| SUB: Dredger | Tow Tug | | 3 | $ 550.00 | $/hr | 35 | day | $ 57,420.00 | 25.0% | $ 14,355.00 | $ 71,775.00 | 20% | $ 14,355.00 | $ 86,130.00 |
| SUB: Dredger | Small Tool and Equipment | Skiff | 1 | $ 250.00 | $/day | 35 | day | $ 8,700.00 | 25.0% | $ 2,175.00 | $ 10,875.00 | 20% | $ 2,175.00 | $ 13,050.00 |
| SUB: Dredger | Workboat | | 1 | $ 100.00 | $/day | 35 | day | $ 3,480.00 | 25.0% | $ 870.00 | $ 4,350.00 | 20% | $ 870.00 | $ 5,220.00 |
| SUB: Dredger | FOGM | | 500 | $ 3.50 | $/gal | 35 | day | $ 60,900.00 | 10.0% | $ 6,090.00 | $ 66,990.00 | 20% | $ 13,398.00 | $ 80,388.00 |
| SUB: Dredger | Office Trailer Rentals | | 2 | $ 350.00 | $/mo | 1 | mo | $ 350.00 | 25.0% | $ 87.50 | $ 437.50 | 20% | $ 87.50 | $ 525.00 |
| SUB: Dredger | Office Trailer | | 1 | $ 50.00 | $/day | 35 | day | $ 1,740.00 | 25.0% | $ 435.00 | $ 2,175.00 | 20% | $ 435.00 | $ 2,610.00 |
| ***Subtotal*** | | | | | | | | **$ 673,281.62** | | **$ 154,878.91** | **$ 828,160.53** | | **$ 165,632.11** | **$ 993,792.63** |

**Task 3 - Turbidity Controls** **39 days**

| | Description | Resource Description | No of Units | Unit Rate | Units | Additional Units | Unit Description | Raw Cost | Subcontractor Markup | Subcontractor Markup Amount | Total Cost | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Turbidity Curtains | 25-ft Depth, Supply, Install, Move with Dredge | 2400 | $ 28.50 | $/lf | 1 | na | $ 68,400.00 | 25.0% | $ 17,100.00 | $ 85,500.00 | 20% | $ 17,100.00 | $ 102,600.00 |
| SUB: Dredger | Dredge Operator (ST) | Dredge Labor | 4 | $ 74.83 | $/hr | 39 | day | $ 11,804.94 | 25.0% | $ 2,951.24 | $ 14,756.18 | 20% | $ 2,951.24 | $ 17,707.42 |
| SUB: Dredger | Dredge Labor (ST) | Dredge Labor | 4 | $ 30.33 | $/hr | 39 | day | $ 4,785.60 | 25.0% | $ 1,196.40 | $ 5,982.00 | 20% | $ 1,196.40 | $ 7,178.40 |
| SUB: Dredger | Hotel | | 1 | $ 100.00 | $/day | 39 | day | $ 3,944.00 | 10.0% | $ 394.40 | $ 4,338.40 | 20% | $ 867.68 | $ 5,206.08 |
| SUB: Dredger | Per diem | | 1 | $ 50.00 | $/day | 39 | day | $ 1,972.00 | 10.0% | $ 197.20 | $ 2,169.20 | 20% | $ 433.84 | $ 2,603.04 |
| SUB: Dredger | Truck | | 1 | $ 75.00 | $/day | 39 | day | $ 2,958.00 | 25.0% | $ 739.50 | $ 3,697.50 | 20% | $ 739.50 | $ 4,437.00 |
| SUB: Dredger | Equipment | Boat | 1 | $ 150.00 | $/day | 39 | day | $ 5,916.00 | 25.0% | $ 1,479.00 | $ 7,395.00 | 20% | $ 1,479.00 | $ 8,874.00 |
| SUB: Dredger | Disposal | Non-hazardous | 48 | $ 75.00 | $/ton | 1 | na | $ 3,600.00 | 25.0% | $ 900.00 | $ 4,500.00 | 20% | $ 900.00 | $ 5,400.00 |
| SUB: Dredger | FOGM | | 10 | $ 3.50 | $/gal | 39 | day | $ 1,380.40 | 10.0% | $ 138.04 | $ 1,518.44 | 20% | $ 303.69 | $ 1,822.13 |
| SUB: Dredger | Safety Supplies | | 9 | $ 25.00 | $/day | 39 | day | $ 8,874.00 | 10.0% | $ 887.40 | $ 9,761.40 | 20% | $ 1,952.28 | $ 11,713.68 |
| ***Subtotal*** | | | | | | | | **$ 113,634.95** | | **$ 25,983.18** | **$ 139,618.12** | | **$ 27,923.62** | **$ 167,541.75** |

**Task 4 - Supply Portland Cement Reagent**

| | Description | Resource Description | No of Units | Unit Rate | Units | Additional Units | Unit Description | Raw Cost | Subcontractor Markup | Subcontractor Markup Amount | Total Cost | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Purchase Portland Cement | | 6,999 | $ 125.00 | $/ton | 1 | na | $ 874,885.57 | 10.0% | $ 87,488.56 | $ 962,374.13 | 20% | $ 192,474.83 | $ 1,154,848.96 |
| ***Subtotal*** | | | | | | | | **$ 874,885.57** | **$ 0.10** | **$ 87,488.56** | **$ 962,374.13** | | **$ 192,474.83** | **$ 1,154,848.96** |

**Task 5 - Mix Reagents, Stockpile Sediment on Pad** **59 days** **6999 ton agent**

| | Resource | Resource Description | Quantity | Unit Rate | Units | Additional Units | Unit Description | Cost | Subcontractor Markup | Subcontractor Markup Amount | Total | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Treatment Contractor | Dredging PM | Landside Labor | 6 | $ 65.40 | $/hr | 59 | day | $ 23,324.26 | 25.0% | $ 5,831.06 | $ 29,155.32 | 20% | $ 5,831.06 | $ 34,986.38 |
| SUB: Treatment Contractor | Operator (ST) | Landside Labor | 16 | $ 74.83 | $/hr | 59 | day | $ 71,164.90 | 25.0% | $ 17,791.22 | $ 88,956.12 | 20% | $ 17,791.22 | $ 106,747.34 |
| SUB: Treatment Contractor | Operator (OT) | Landside Labor | 4 | $ 96.92 | $/hr | 59 | day | $ 23,043.07 | 25.0% | $ 5,760.77 | $ 28,803.84 | 20% | $ 5,760.77 | $ 34,564.60 |
| SUB: Treatment Contractor | Labor (ST) | Landside Labor | 16 | $ 30.33 | $/hr | 59 | day | $ 28,849.51 | 25.0% | $ 7,212.38 | $ 36,061.89 | 20% | $ 7,212.38 | $ 43,274.27 |
| SUB: Treatment Contractor | Labor (OT) | Landside Labor | 4 | $ 42.28 | $/hr | 59 | day | $ 10,051.46 | 25.0% | $ 2,512.86 | $ 12,564.32 | 20% | $ 2,512.86 | $ 15,077.19 |
| SUB: Treatment Contractor | Hotel | | 4 | $ 100.00 | $/day | 59 | day | $ 23,776.00 | 10.0% | $ 2,377.60 | $ 26,153.60 | 20% | $ 5,230.72 | $ 31,384.32 |
| SUB: Treatment Contractor | Per diem | | 4 | $ 50.00 | $/day | 59 | day | $ 11,888.00 | 10.0% | $ 1,188.80 | $ 13,076.80 | 20% | $ 2,615.36 | $ 15,692.16 |
| SUB: Treatment Contractor | Truck | | 2 | $ 75.00 | $/day | 59 | day | $ 8,916.00 | 25.0% | $ 2,229.00 | $ 11,145.00 | 20% | $ 2,229.00 | $ 13,374.00 |
| SUB: Treatment Contractor | CAT 345 Extended Stick Rental | | 1 | $ 1,250.00 | $/day | 59 | day | $ 74,300.00 | 25.0% | $ 18,575.00 | $ 92,875.00 | 20% | $ 18,575.00 | $ 111,450.00 |
| SUB: Treatment Contractor | Grinder and Screen | | 1 | $ 1,500.00 | $/day | 59 | day | $ 89,160.00 | 25.0% | $ 22,290.00 | $ 111,450.00 | 20% | $ 22,290.00 | $ 133,740.00 |
| SUB: Treatment Contractor | Cement/FlyAsh Metering and Pumill (Rapid Mix 400) | | 1 | $ 1,467.00 | $/day | 59 | day | $ 87,198.48 | 25.0% | $ 21,799.62 | $ 108,998.10 | 20% | $ 21,799.62 | $ 130,797.72 |
| SUB: Treatment Contractor | Wheel Loader (Cat IT62H) | | 1 | $ 269.00 | $/day | 59 | day | $ 15,989.36 | 25.0% | $ 3,997.34 | $ 19,986.70 | 20% | $ 3,997.34 | $ 23,984.04 |
| SUB: Treatment Contractor | Radial Stacking Conveyor | | 1 | $ 171.00 | $/day | 59 | day | $ 10,164.24 | 25.0% | $ 2,541.06 | $ 12,705.30 | 20% | $ 2,541.06 | $ 15,246.36 |
| SUB: Treatment Contractor | Miscellaneous Pumps, Hoses | | 1 | $ 150.00 | $/day | 59 | day | $ 8,916.00 | 25.0% | $ 2,229.00 | $ 11,145.00 | 20% | $ 2,229.00 | $ 13,374.00 |
| SUB: Treatment Contractor | 100-ton Pig Rental | | 1 | $ 350.00 | $/day | 59 | day | $ 20,804.00 | 25.0% | $ 5,201.00 | $ 26,005.00 | 20% | $ 5,201.00 | $ 31,206.00 |
| SUB: Treatment Contractor | Light Plant Rental | | 4 | $ 250.00 | $/day | 59 | day | $ 59,440.00 | 25.0% | $ 14,860.00 | $ 74,300.00 | 20% | $ 14,860.00 | $ 89,160.00 |

**TABLE G-4a**
**Dredging Assumptions - Alternative 2**
*United Heckathorn Superfund Site, Richmond, California*

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Treatment Contractor | Miscellaneous Expenses | | 1 | $ 250.00 | $/day | 59 | day | $ 14,860.00 | 25.0% | $ 3,715.00 | $ 18,575.00 | 20% | $ 3,715.00 | $ 22,290.00 |
| SUB: Treatment Contractor | Office Trailer Rentals | | 2 | $ 350.00 | $/mo | 2 | mo | $ 1,386.93 | 25.0% | $ 346.73 | $ 1,733.67 | 20% | $ 346.73 | $ 2,080.40 |
| SUB: Treatment Contractor | Office Trailer | | 1 | $ 17.00 | $/day | 59 | day | $ 1,010.48 | 25.0% | $ 252.62 | $ 1,263.10 | 20% | $ 252.62 | $ 1,515.72 |
| SUB: Treatment Contractor | Bobcat | | 1 | $ 75.00 | $/day | 59 | day | $ 4,458.00 | 25.0% | $ 1,114.50 | $ 5,572.50 | 20% | $ 1,114.50 | $ 6,687.00 |
| SUB: Treatment Contractor | Port-a-Potty | | 1 | $ 7.00 | $/day | 59 | day | $ 416.08 | 25.0% | $ 104.02 | $ 520.10 | 20% | $ 104.02 | $ 624.12 |
| SUB: Treatment Contractor | FOGM | | 300 | $ 3.25 | $/gal | 59 | day | $ 57,954.00 | 10.0% | $ 5,795.40 | $ 63,749.40 | 20% | $ 12,749.88 | $ 76,499.28 |
| SUB: Mobile Lab Supplier | Mob Mobile Laboratory | | 1 | $ 1,750.00 | $/trip | 1 | na | $ 1,750.00 | 15.0% | $ 262.50 | $ 2,012.50 | 20% | $ 402.50 | $ 2,415.00 |
| SUB: Mobile Lab Supplier | Mobile Laboratory | | 1 | $ 2,565.00 | $/day | 59 | day | $ 152,463.60 | 15.0% | $ 22,869.54 | $ 175,333.14 | 20% | $ 35,066.63 | $ 210,399.77 |
| ***Subtotal*** | | | | | | | | **$ 801,284.37** | | **$ 170,857.03** | **$ 972,141.40** | | **$ 194,428.28** | **$ 1,166,569.68** |

**Task 6 - Load Class 1 Non-RCRA Stabilized Materials into Rail, Transport and Dispose at Landfill (Utah) [Tight Areas]** — **9,449 tons** — **11 days** — **893 tons/day**

| | Resource | Resource Description | Quantity | Unit Rate | Units | Additional Units | Unit Description | Cost | Subcontractor Markup | Subcontractor Markup Amount | Total | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Treatment Contractor | Wheel Loader (Cat IT62H) | | 1 | $ 269.00 | $/day | 11 | day | $ 2,846.27 | 25.0% | $ 711.57 | $ 3,557.84 | 20% | $ 711.57 | $ 4,269.40 |
| SUB: Treatment Contractor | Dredging PM | | 2 | $ 65.40 | $/hr | 11 | day | $ 1,383.98 | 25.0% | $ 346.00 | $ 1,729.98 | 20% | $ 346.00 | $ 2,075.98 |
| SUB: Treatment Contractor | Loader Operator (ST) | Loader Operator | 8 | $ 74.83 | $/hr | 11 | day | $ 6,334.04 | 25.0% | $ 1,583.51 | $ 7,917.55 | 20% | $ 1,583.51 | $ 9,501.06 |
| SUB: Treatment Contractor | Loader Operator (OT) | Loader Operator | 4 | $ 96.92 | $/hr | 11 | day | $ 4,101.90 | 25.0% | $ 1,025.48 | $ 5,127.38 | 20% | $ 1,025.48 | $ 6,152.85 |
| SUB: Treatment Contractor | Laborer (ST) | Laborer | 24 | $ 30.33 | $/hr | 11 | day | $ 7,703.26 | 25.0% | $ 1,925.81 | $ 9,629.07 | 20% | $ 1,925.81 | $ 11,554.89 |
| SUB: Treatment Contractor | Laborer (OT) | Laborer | 12 | $ 42.28 | $/hr | 11 | day | $ 5,367.78 | 25.0% | $ 1,341.95 | $ 6,709.73 | 20% | $ 1,341.95 | $ 8,051.68 |
| SUB: Treatment Contractor | Hotel | | 4 | $ 100.00 | $/day | 11 | day | $ 4,232.37 | 10.0% | $ 423.24 | $ 4,655.61 | 20% | $ 931.12 | $ 5,586.73 |
| SUB: Treatment Contractor | Per diem | | 4 | $ 50.00 | $/day | 11 | day | $ 2,116.18 | 10.0% | $ 211.62 | $ 2,327.80 | 20% | $ 465.56 | $ 2,793.36 |
| SUB: Treatment Contractor | CAT 345 Rental | | 1 | $ 1,250.00 | $/day | 11 | day | $ 13,226.15 | 25.0% | $ 3,306.54 | $ 16,532.69 | 20% | $ 3,306.54 | $ 19,839.23 |
| SUB: Treatment Contractor | FOGM (Site Equipment) | | 120 | $ 3.50 | $/gal | 11 | day | $ 4,443.99 | 10.0% | $ 444.40 | $ 4,888.39 | 20% | $ 977.68 | $ 5,866.06 |
| SUB: Treatment Contractor | On Site Scales | Full-length Portable | 1 | $ 175.00 | $/day | 11 | day | $ 1,851.66 | 10.0% | $ 185.17 | $ 2,036.83 | 20% | $ 407.37 | $ 2,444.19 |
| SUB: Treatment Contractor | Sediment Transportation | Liner | 450 | $ 40.00 | $/load | 1 | na | $ 17,997.65 | 5.0% | $ 899.88 | $ 18,897.53 | 20% | $ 3,779.51 | $ 22,677.03 |
| ***Subtotal*** | | | | | | | | **$ 71,605.24** | | **$ 12,405.15** | **$ 84,010.39** | | **$ 16,802.08** | **$ 100,812.46** |

**Task 7 - Load Class 1 Non-RCRA Stabilized Materials into Rail, Transport and Dispose at Landfill (Utah) [Open Areas]** — **85,889 tons** — **34.8 days** — **2,468 tons/day**

| | Resource | Resource Description | Quantity | Unit Rate | Units | Additional Units | Unit Description | Cost | Subcontractor Markup | Subcontractor Markup Amount | Total | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Wheel Loader (Cat IT62H) | | 1 | $ 269.00 | $/day | 35 | day | $ 9,361.20 | 25.0% | $ 2,340.30 | $ 11,701.50 | 20% | $ 2,340.30 | $ 14,041.80 |
| SUB: Dredger | Dredging PM | | 2 | $ 65.40 | $/hr | 35 | day | $ 4,551.84 | 25.0% | $ 1,137.96 | $ 5,689.80 | 20% | $ 1,137.96 | $ 6,827.76 |
| SUB: Dredger | Dredge Operator (ST) | Dredge Labor | 8 | $ 74.83 | $/hr | 35 | day | $ 20,832.25 | 25.0% | $ 5,208.06 | $ 26,040.32 | 20% | $ 5,208.06 | $ 31,248.38 |
| SUB: Dredger | Dredge Operator (OT) | Dredge Labor | 4 | $ 96.92 | $/hr | 35 | day | $ 13,490.90 | 25.0% | $ 3,372.72 | $ 16,863.62 | 20% | $ 3,372.72 | $ 20,236.34 |
| SUB: Dredger | Dredge Labor (ST) | Dredge Labor | 24 | $ 30.33 | $/hr | 35 | day | $ 25,335.54 | 25.0% | $ 6,333.89 | $ 31,669.43 | 20% | $ 6,333.89 | $ 38,003.31 |
| SUB: Dredger | Dredge Labor (OT) | Dredge Labor | 12 | $ 42.28 | $/hr | 35 | day | $ 17,654.31 | 25.0% | $ 4,413.58 | $ 22,067.89 | 20% | $ 4,413.58 | $ 26,481.47 |
| SUB: Treatment Contractor | CAT 345 Rental | | 1 | $ 1,250.00 | $/day | 35 | day | $ 43,500.00 | 25.0% | $ 10,875.00 | $ 54,375.00 | 20% | $ 10,875.00 | $ 65,250.00 |
| SUB: Dredger | Hotel | | 4 | $ 100.00 | $/day | 35 | day | $ 13,920.00 | 10.0% | $ 1,392.00 | $ 15,312.00 | 20% | $ 3,062.40 | $ 18,374.40 |
| SUB: Dredger | Per diem | | 4 | $ 50.00 | $/day | 35 | day | $ 6,960.00 | 10.0% | $ 696.00 | $ 7,656.00 | 20% | $ 1,531.20 | $ 9,187.20 |
| SUB: Dredger | Truck | | 2 | $ 75.00 | $/day | 35 | day | $ 5,220.00 | 25.0% | $ 1,305.00 | $ 6,525.00 | 20% | $ 1,305.00 | $ 7,830.00 |
| SUB: Dredger | FOGM | | 60 | $ 3.50 | $/gal | 35 | day | $ 7,308.00 | 10.0% | $ 730.80 | $ 8,038.80 | 20% | $ 1,607.76 | $ 9,646.56 |
| SUB: Mobile Lab Supplier | Mobile Laboratory | | 1 | $ 2,565.00 | $/day | 35 | day | $ 89,262.00 | 15.0% | $ 13,389.30 | $ 102,651.30 | 20% | $ 20,530.26 | $ 123,181.56 |
| SUB: Treatment Contractor | Onsite Scales | Full Length Portable | 1 | $ 175.00 | $/day | 35 | day | $ 6,090.00 | 10.0% | $ 609.00 | $ 6,699.00 | 20% | $ 1,339.80 | $ 8,038.80 |
| SUB: Excavation Contractor | Sediment Transportation | Liner | 4090 | $ 50.00 | $/load | 1 | na | $ 204,498.25 | 5.0% | $ 10,224.91 | $ 214,723.17 | 20% | $ 42,944.63 | $ 257,667.80 |
| ***Subtotal*** | | | | | | | | **$ 458,623.10** | | **$ 59,688.22** | **$ 518,311.32** | | **$ 103,662.26** | **$ 636,015.38** |

**Task 8 - Water Treatment** — **83 days**

| | Resource | Resource Description | Quantity | Unit Rate | Units | Additional Units | Unit Description | Cost | Subcontractor Markup | Subcontractor Markup Amount | Total | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Water Treatment Sub | Dredging PM | | 4 | $ 65.40 | $/hr | 83 | day | $ 21,769.31 | 25.0% | $ 5,442.33 | $ 27,211.63 | 20% | $ 5,442.33 | $ 32,653.96 |
| SUB: Water Treatment Sub | WWT Operator (ST) | Dredge Labor | 32 | $ 74.83 | $/hr | 83 | day | $ 199,261.71 | 25.0% | $ 49,815.43 | $ 249,077.14 | 20% | $ 49,815.43 | $ 298,892.57 |
| SUB: Water Treatment Sub | WWT Operator (OT) | Dredge Labor | 16 | $ 96.92 | $/hr | 83 | day | $ 129,041.19 | 25.0% | $ 32,260.30 | $ 161,301.48 | 20% | $ 32,260.30 | $ 193,561.78 |
| SUB: Water Treatment Sub | WWT Labor (ST) | Dredge Labor | 32 | $ 30.33 | $/hr | 83 | day | $ 80,778.64 | 25.0% | $ 20,194.66 | $ 100,973.30 | 20% | $ 20,194.66 | $ 121,167.95 |
| SUB: Water Treatment Sub | WWT Labor (OT) | Dredge Labor | 16 | $ 42.28 | $/hr | 83 | day | $ 56,288.17 | 25.0% | $ 14,072.04 | $ 70,360.21 | 20% | $ 14,072.04 | $ 84,432.25 |
| SUB: Dredger | Hotel | | 8 | $ 100.00 | $/day | 83 | day | $ 66,572.80 | 10.0% | $ 6,657.28 | $ 73,230.08 | 20% | $ 14,646.02 | $ 87,876.10 |
| SUB: Dredger | Per diem | | 8 | $ 50.00 | $/day | 83 | day | $ 33,286.40 | 10.0% | $ 3,328.64 | $ 36,615.04 | 20% | $ 7,323.01 | $ 43,938.05 |
| SUB: Dredger | Truck | | 4 | $ 75.00 | $/day | 83 | day | $ 24,964.80 | 25.0% | $ 6,241.20 | $ 31,206.00 | 20% | $ 6,241.20 | $ 37,447.20 |
| SUB: Dredger | FOGM | | 120 | $ 3.50 | $/gal | 83 | day | $ 34,950.72 | 10.0% | $ 3,495.07 | $ 38,445.79 | 20% | $ 7,689.16 | $ 46,134.95 |

**TABLE G-4a**
**Dredging Assumptions - Alternative 2**
*United Heckathorn Superfund Site, Richmond, California*

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Safety Supplies | | 9 | $ 25.00 | $/day | 83 | day | $ 18,723.60 | 10.0% | $ 1,872.36 | $ 20,595.96 | 20% | $ 4,119.19 | $ 24,715.15 |
| SUB: Water Treatment Sub | Transfer Pump | Scows to System | 1 | $ 125.00 | $/day | 83 | day | $ 10,402.00 | 25.0% | $ 2,600.50 | $ 13,002.50 | 20% | $ 2,600.50 | $ 15,603.00 |
| SUB: Water Treatment Sub | Influent Frac Tank | | 2 | $ 45.00 | $/day | 83 | day | $ 7,489.44 | 25.0% | $ 1,872.36 | $ 9,361.80 | 20% | $ 1,872.36 | $ 11,234.16 |
| SUB: Water Treatment Sub | WWT Manifolds | | 2 | $ 6,000.00 | $/day | 35 | day | $ 417,600.00 | 25.0% | $ 104,400.00 | $ 522,000.00 | 20% | $ 104,400.00 | $ 626,400.00 |
| SUB: Water Treatment Sub | Pumps | | 1 | $ 150.00 | $/day | 83 | day | $ 12,482.40 | 25.0% | $ 3,120.60 | $ 15,603.00 | 20% | $ 3,120.60 | $ 18,723.60 |
| SUB: Water Treatment Sub | Sand Filters (2 units) | | 1 | $ 150.00 | $/day | 83 | day | $ 12,482.40 | 25.0% | $ 3,120.60 | $ 15,603.00 | 20% | $ 3,120.60 | $ 18,723.60 |
| SUB: Water Treatment Sub | GAC Filters (2 units) | | 1 | $ 250.00 | $/day | 83 | day | $ 20,804.00 | 25.0% | $ 5,201.00 | $ 26,005.00 | 20% | $ 5,201.00 | $ 31,206.00 |
| SUB: Water Treatment Sub | Bag Filter Pods | RFR 2 Bag Units | 2 | $ 75.00 | $/day | 83 | day | $ 12,482.40 | 25.0% | $ 3,120.60 | $ 15,603.00 | 20% | $ 3,120.60 | $ 18,723.60 |
| SUB: Water Treatment Sub | Sand | RFR 4 Pod Unit, 8 Tons per Charge | 16 | $ 50.00 | $/ton | 1 | na | $ 800.00 | 25.0% | $ 200.00 | $ 1,000.00 | 20% | $ 200.00 | $ 1,200.00 |
| SUB: Water Treatment Sub | GAC Filters (2 units) | 5000 lb per Vessel per Charge; Assume 2 Charges | 20,000 | $ 2.50 | $/lb | 1 | na | $ 50,000.00 | 25.0% | $ 12,500.00 | $ 62,500.00 | 20% | $ 12,500.00 | $ 75,000.00 |
| SUB: Water Treatment Sub | 10-micron Filter Bags, 4 per Day | | 4 | $ 5.50 | ea | 83 | na | $ 1,830.75 | 25.0% | $ 457.69 | $ 2,288.44 | 20% | $ 457.69 | $ 2,746.13 |
| SUB: Water Treatment Sub | Backwash Supply Tank | RFR 20,000 Frac Tank | 1 | $ 45.00 | $/day | 83 | day | $ 3,744.72 | 25.0% | $ 936.18 | $ 4,680.90 | 20% | $ 936.18 | $ 5,617.08 |
| SUB: Water Treatment Sub | Backwash Waste Tank | RFR 20,000 Frac Tank | 1 | $ 45.00 | $/day | 83 | day | $ 3,744.72 | 25.0% | $ 936.18 | $ 4,680.90 | 20% | $ 936.18 | $ 5,617.08 |
| SUB: Water Treatment Sub | Effluent Holding Tank | RFR 20,000 Frac Tank | 1 | $ 45.00 | $/day | 83 | day | $ 3,744.72 | 25.0% | $ 936.18 | $ 4,680.90 | 20% | $ 936.18 | $ 5,617.08 |
| SUB: Water Treatment Sub | Chemicals | | 1 | $ 75.00 | $/day | 83 | day | $ 6,241.20 | 10.0% | $ 624.12 | $ 6,865.32 | 20% | $ 1,373.06 | $ 8,238.38 |
| SUB: Water Treatment Sub | Vendor Start-up Assistance and Expenses | | 5 | $ 2,500.00 | $/day | 1 | na | $ 12,500.00 | 25.0% | $ 3,125.00 | $ 15,625.00 | 20% | $ 3,125.00 | $ 18,750.00 |
| SUB: Water Treatment Sub | Power/Electric | | 1 | $ 167.00 | $/day | 83 | day | $ 13,897.07 | 10.0% | $ 1,389.71 | $ 15,286.78 | 20% | $ 3,057.36 | $ 18,344.14 |
| SUB: Water Treatment Sub | Sand, GAC, TSS Disposal Allowance | | 1 | $ 50,000.00 | ea | 1 | na | $ 50,000.00 | 10.0% | $ 5,000.00 | $ 55,000.00 | 20% | $ 11,000.00 | $ 66,000.00 |
| SUB: Excavation Contractor | Water Treatment Residuals Transportation | | 26 | $ 10.00 | $/ton | 1 | na | $ 260.00 | 5.0% | $ 13.00 | $ 273.00 | 20% | $ 54.60 | $ 327.60 |
| SUB: Excavation Contractor | Water Treatment Residuals Transportation | Liner | 1.24 | $ 50.00 | $/load | 1 | na | $ 61.90 | 5.0% | $ 3.10 | $ 65.00 | 20% | $ 13.00 | $ 78.00 |
| SUB: Excavation Contractor | TSCA Disposal | Subtitle C Landfill | 26 | $ 80.00 | $/ton | 1 | na | $ 2,080.00 | 5.0% | $ 104.00 | $ 2,184.00 | 20% | $ 436.80 | $ 2,620.80 |
| ***Subtotal*** | | | | | | | | **$ 1,308,285.06** | | **$ 293,040.11** | **$ 1,601,325.17** | | **$ 320,265.03** | **$ 1,921,590.21** |

Assumes 24/7 operations
Includes 4 people per shift to offload water and run the system

**Task 9 - Debris Removal and RCRA Subtitle D Disposal** **860 tons** **20 tons/day** **43 days**

| | Resource | Resource Description | Quantity | Unit Rate | Units | Additional Units | Unit Description | Cost | Subcontractor Markup | Subcontractor Markup Amount | Total | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Wheel Loader (Cat IT62H) | | 1 | $ 269.00 | $/day | 43 | day | $ 11,567.00 | 25.0% | $ 2,891.75 | $ 14,458.75 | 20% | $ 2,891.75 | $ 17,350.50 |
| SUB: Dredger | Dredging PM | | 1 | $ 65.40 | $/hr | 43 | day | $ 2,812.20 | 25.0% | $ 703.05 | $ 3,515.25 | 20% | $ 703.05 | $ 4,218.30 |
| SUB: Dredger | Dredge Operator (ST) | Dredge Labor | 2 | $ 74.83 | $/hr | 43 | day | $ 6,435.25 | 25.0% | $ 1,608.81 | $ 8,044.06 | 20% | $ 1,608.81 | $ 9,652.88 |
| SUB: Dredger | Dredge Labor (ST) | Dredge Labor | 2 | $ 30.33 | $/hr | 43 | day | $ 2,608.78 | 25.0% | $ 652.20 | $ 3,260.98 | 20% | $ 652.20 | $ 3,913.18 |
| SUB: Dredger | Hotel | | 0.5 | $ 100.00 | $/day | 43 | day | $ 2,150.00 | 10.0% | $ 215.00 | $ 2,365.00 | 20% | $ 473.00 | $ 2,838.00 |
| SUB: Dredger | Per diem | | 0.5 | $ 50.00 | $/day | 43 | day | $ 1,075.00 | 10.0% | $ 107.50 | $ 1,182.50 | 20% | $ 236.50 | $ 1,419.00 |
| SUB: Dredger | Truck | | 1 | $ 75.00 | $/day | 43 | day | $ 3,225.00 | 25.0% | $ 806.25 | $ 4,031.25 | 20% | $ 806.25 | $ 4,837.50 |
| SUB: Excavation Contractor | Sediment Transportation | | 860 | $ 10.00 | $/ton | 1 | na | $ 8,598.38 | 5.0% | $ 429.92 | $ 9,028.29 | 20% | $ 1,805.66 | $ 10,833.95 |
| SUB: Excavation Contractor | Sediment Transportation | Liner | 43 | $ 40.00 | $/load | 1 | na | $ 1,719.68 | 5.0% | $ 85.98 | $ 1,805.66 | 20% | $ 361.13 | $ 2,166.79 |
| SUB: Excavation Contractor | Disposal | Subtitle D Landfill | 394 | $ 50.00 | $/ton | 1 | na | $ 19,706.74 | 5.0% | $ 985.34 | $ 20,692.08 | 20% | $ 4,138.42 | $ 24,830.50 |
| SUB: Dredger | FOGM | | 60 | $ 3.25 | $/gal | 43 | day | $ 8,385.00 | 10.0% | $ 838.50 | $ 9,223.50 | 20% | $ 1,844.70 | $ 11,068.20 |
| ***Subtotal*** | | | | | | | | **$ 68,283.03** | | **$ 9,324.30** | **$ 77,607.33** | | **$ 15,521.47** | **$ 93,128.79** |

**Task 10 Mechanical Dredge Standby Time** **24 hrs**

| | Resource | Resource Description | Quantity | Unit Rate | Units | Additional Units | Unit Description | Cost | Subcontractor Markup | Subcontractor Markup Amount | Total | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Dredging PM | | 8 | $ 65.40 | $/hr | 1.0 | day | $ 523.20 | 25.0% | $ 130.80 | $ 654.00 | 20% | $ 130.80 | $ 784.80 |
| SUB: Dredger | Dredge Operator (ST) | Dredge Labor | 16 | $ 74.83 | $/hr | 1.0 | day | $ 1,197.26 | 25.0% | $ 299.31 | $ 1,496.57 | 20% | $ 299.31 | $ 1,795.88 |
| SUB: Dredger | Dredge Operator (OT) | Dredge Labor | 8 | $ 96.92 | $/hr | 1.0 | day | $ 775.34 | 25.0% | $ 193.83 | $ 969.17 | 20% | $ 193.83 | $ 1,163.01 |
| SUB: Dredger | Dredge Labor (ST) | Dredge Labor | 32 | $ 30.33 | $/hr | 1.0 | day | $ 970.71 | 25.0% | $ 242.68 | $ 1,213.39 | 20% | $ 242.68 | $ 1,456.07 |
| SUB: Dredger | Dredge Labor (OT) | Dredge Labor | 16 | $ 42.28 | $/hr | 1.0 | day | $ 676.41 | 25.0% | $ 169.10 | $ 845.51 | 20% | $ 169.10 | $ 1,014.62 |
| SUB: Dredger | Hotel | | 6 | $ 100.00 | $/day | 1.0 | day | $ 600.00 | 10.0% | $ 60.00 | $ 660.00 | 20% | $ 132.00 | $ 792.00 |
| SUB: Dredger | Per diem | | 6 | $ 50.00 | $/day | 1.0 | day | $ 300.00 | 10.0% | $ 30.00 | $ 330.00 | 20% | $ 66.00 | $ 396.00 |
| SUB: Dredger | Truck | | 5 | $ 75.00 | $/day | 1.0 | day | $ 375.00 | 25.0% | $ 93.75 | $ 468.75 | 20% | $ 93.75 | $ 562.50 |

**TABLE G-4a**
**Dredging Assumptions - Alternative 2**
*United Heckathorn Superfund Site, Richmond, California*

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Dredge Rental | 40 x 80 Flat Deck Spud Barge with CAT 345 & 4 $yd^3$ Environmental Bucket and Support Equipment | 1 | $ 10,000.00 | $/day | 1.0 | day | $ 10,000.00 | 25.0% | $ 2,500.00 | $ 12,500.00 | 20% | $ 2,500.00 | $ 15,000.00 |
| SUB: Dredger | Tender Tug | | 1 | $ 550.00 | $/hr | 1.0 | day | $ 550.00 | 25.0% | $ 137.50 | $ 687.50 | 20% | $ 137.50 | $ 825.00 |
| SUB: Dredger | Scows | 30 ft x 60 ft, 700 $yd^3$ | 3 | $ 500.00 | $/day | 1.0 | day | $ 1,500.00 | 25.0% | $ 375.00 | $ 1,875.00 | 20% | $ 375.00 | $ 2,250.00 |
| SUB: Dredger | Tow Tug | | 1 | $ 550.00 | $/hr | 1.0 | day | $ 550.00 | 25.0% | $ 137.50 | $ 687.50 | 20% | $ 137.50 | $ 825.00 |
| SUB: Dredger | Equipment | Skiff | 1 | $ 100.00 | $/day | 1.0 | day | $ 100.00 | 25.0% | $ 25.00 | $ 125.00 | 20% | $ 25.00 | $ 150.00 |
| ***Subtotal*** | | | | | | | | **$ 18,117.92** | | **$ 4,394.48** | **$ 22,512.39** | | **$ 4,502.48** | **$ 27,014.87** |

| **Notes** | **Davis-Bacon Rates** | **Rate** | **Fringe** | **Taxes** | **Total** |
|---|---|---|---|---|---|
| Items do not include oversight effort | Dredge PM | $60.00 | -- | $5.40 | $65.40 |
| All cost based on estimates or RSMeans data | Operator (All) | $40.53 | $28.12 | $6.18 | $74.83 |
| All labor cost based on Davis-Bacon rates | Operator OT (All) | $60.80 | $28.12 | $8.00 | $96.92 |
| Scope details and assumptions provided elsewhere | Labor (All) | $21.91 | $5.92 | $2.50 | $30.33 |
| | Labor OT (All) | $32.87 | $5.92 | $3.49 | $42.28 |

U.S. Department of Labor. 2014. Davis Bacon Wage Determinations. http://www.wdol.gov/dba.aspx

**TABLE G-4b**
Dredging Assumptions - Alternative 3
*United Heckathorn Superfund Site, Richmond, California*

| Description | No of Units | Unit | Cost |
|---|---|---|---|
| Task 1 - Dredge Tight Areas | 6,400 | $yd^3$ | $146,313 |
| Task 2 - Dredge Open Areas | 57,600 | $yd^3$ | $993,793 |
| Task 3 - Turbidity Controls | 39 | day | $167,542 |
| Task 4 - Supply Portland Cement Reagent | 7,723 | ton | $1,154,849 |
| Task 5 - Mix Reagents; Stockpile Sediment on Pad | 64,000 | $yd^3$ | $1,217,569 |
| Task 6 - Load Class 1 Non-RCRA Stabilized Materials into Rail; Transport and Dispose at Landfill (Utah) [Tight Areas] | 10,426 | ton | $111,241 |
| Task 7 - Load Class 1 Non-RCRA Stabilized Materials into Rail; Transport and Dispose at Landfill (Utah) [Open Areas] | 93,836 | ton | $636,015 |
| Task 8 - Water Treatment | 4,351,861 | gal | $1,921,590 |
| Task 9 - Debris Removal and RCRA Subtitle D Disposal | 949 | ton | $99,618 |
| Task 10 - Mechanical Dredge Standby Time | 24 | hr | $27,015 |
| **8th Street Slip Sheet Piling Reinforcement** | 0 | **LF** | **$ -** |
| | | **TOTAL** | **$6,475,545** |

**Task 1 - Dredge Tight Areas** **5 days** **6,400 $yd^3$** **1,250 $yd^3$/day**

| | Description | Resource Description | No of Units | Unit Rate | Units | Additional Units | Unit Description | Raw Cost | Subcontractor Markup | Subcontractor Markup Amount | Total Cost | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Dredging PM | Dredge Labor | 6 | $ 65.40 | $/hr | 5 | day | $ 2,009.09 | 25.0% | $ 502.27 | $ 2,511.36 | 20% | $ 502.27 | $ 3,013.63 |
| SUB: Dredger | Dredge Operator (ST) | Dredge Labor | 16 | $ 74.83 | $/hr | 5 | day | $ 6,129.95 | 25.0% | $ 1,532.49 | $ 7,662.44 | 20% | $ 1,532.49 | $ 9,194.93 |
| SUB: Dredger | Dredge Operator (OT) | Dredge Labor | 8 | $ 96.92 | $/hr | 5 | day | $ 3,969.73 | 25.0% | $ 992.43 | $ 4,962.17 | 20% | $ 992.43 | $ 5,954.60 |
| SUB: Dredger | Dredge Labor (ST) | Dredge Labor | 32 | $ 30.33 | $/hr | 5 | day | $ 4,970.04 | 25.0% | $ 1,242.51 | $ 6,212.55 | 20% | $ 1,242.51 | $ 7,455.06 |
| SUB: Dredger | Dredge Labor (OT) | Dredge Labor | 16 | $ 42.28 | $/hr | 5 | day | $ 3,463.22 | 25.0% | $ 865.81 | $ 4,329.03 | 20% | $ 865.81 | $ 5,194.83 |
| SUB: Dredger | Safety Supplies | | 9 | $ 25.00 | $/day | 5 | day | $ 1,152.00 | 10.0% | $ 115.20 | $ 1,267.20 | 20% | $ 253.44 | $ 1,520.64 |
| SUB: Dredger | Hotel | | 4 | $ 100.00 | $/day | 5 | day | $ 2,048.00 | 10.0% | $ 204.80 | $ 2,252.80 | 20% | $ 450.56 | $ 2,703.36 |
| SUB: Dredger | Per diem | | 4 | $ 50.00 | $/day | 5 | day | $ 1,024.00 | 10.0% | $ 102.40 | $ 1,126.40 | 20% | $ 225.28 | $ 1,351.68 |
| SUB: Dredger | Truck | | 2 | $ 75.00 | $/day | 5 | day | $ 768.00 | 25.0% | $ 192.00 | $ 960.00 | 20% | $ 192.00 | $ 1,152.00 |
| SUB: Dredger | Dredge Rental | 40 x 80 Flat Deck Spud Barge with CAT 345 & 4 $yd^3$ Environmental Bucket and Support Equipment | 1 | $ 10,000.00 | $/day | 5 | day | $ 51,200.00 | 25.0% | $ 12,800.00 | $ 64,000.00 | 20% | $ 12,800.00 | $ 76,800.00 |
| SUB: Dredger | Tender Tug | | 1 | $ 550.00 | $/hr | 5 | day | $ 2,816.00 | 25.0% | $ 704.00 | $ 3,520.00 | 20% | $ 704.00 | $ 4,224.00 |
| SUB: Dredger | Tow Tug | | 3 | $ 550.00 | $/hr | 5 | day | $ 8,448.00 | 25.0% | $ 2,112.00 | $ 10,560.00 | 20% | $ 2,112.00 | $ 12,672.00 |
| SUB: Dredger | Small Tool and Equipment | Skiff | 1 | $ 250.00 | $/day | 5 | day | $ 1,280.00 | 25.0% | $ 320.00 | $ 1,600.00 | 20% | $ 320.00 | $ 1,920.00 |
| SUB: Dredger | Workboat | | 1 | $ 100.00 | $/day | 5 | day | $ 512.00 | 25.0% | $ 128.00 | $ 640.00 | 20% | $ 128.00 | $ 768.00 |
| SUB: Dredger | FOGM | | 500 | $ 3.50 | $/gal | 5 | day | $ 8,960.00 | 10.0% | $ 896.00 | $ 9,856.00 | 20% | $ 1,971.20 | $ 11,827.20 |
| SUB: Dredger | Office Trailer Rentals | | 2 | $ 350.00 | $/mo | 0 | mo | $ 117.74 | 25.0% | $ 29.43 | $ 147.17 | 20% | $ 29.43 | $ 176.61 |
| SUB: Dredger | Office Trailer | | 1 | $ 50.00 | $/day | 5 | day | $ 256.00 | 25.0% | $ 64.00 | $ 320.00 | 20% | $ 64.00 | $ 384.00 |
| ***Subtotal*** | | | | | | | | **$ 99,123.77** | | **$ 22,803.34** | **$ 121,927.11** | | **$ 24,385.42** | **$ 146,312.54** |

**Task 2 - Dredge Open Areas** **35 days** **52,200 $yd^3$** **1,500 $yd^3$/day**

| | Description | Resource Description | No of Units | Unit Rate | Units | Additional Units | Unit Description | Raw Cost | Subcontractor Markup | Subcontractor Markup Amount | Total Cost | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Dredging PM | Dredge Labor | 6 | $ 65.40 | $/hr | 35 | day | $ 13,655.52 | 25.0% | $ 3,413.88 | $ 17,069.40 | 20% | $ 3,413.88 | $ 20,483.28 |
| SUB: Dredger | Dredge Operator (ST) | Dredge Labor | 16 | $ 74.83 | $/hr | 35 | day | $ 41,664.51 | 25.0% | $ 10,416.13 | $ 52,080.64 | 20% | $ 10,416.13 | $ 62,496.76 |
| SUB: Dredger | Dredge Operator (OT) | Dredge Labor | 8 | $ 96.92 | $/hr | 35 | day | $ 26,981.79 | 25.0% | $ 6,745.45 | $ 33,727.24 | 20% | $ 6,745.45 | $ 40,472.69 |
| SUB: Dredger | Dredge Labor (ST) | Dredge Labor | 32 | $ 30.33 | $/hr | 35 | day | $ 33,780.72 | 25.0% | $ 8,445.18 | $ 42,225.90 | 20% | $ 8,445.18 | $ 50,671.08 |
| SUB: Dredger | Dredge Labor (OT) | Dredge Labor | 16 | $ 42.28 | $/hr | 35 | day | $ 23,539.08 | 25.0% | $ 5,884.77 | $ 29,423.85 | 20% | $ 5,884.77 | $ 35,308.62 |
| SUB: Dredger | Safety Supplies | | 9 | $ 25.00 | $/day | 35 | day | $ 7,830.00 | 10.0% | $ 783.00 | $ 8,613.00 | 20% | $ 1,722.60 | $ 10,335.60 |

**TABLE G-4b**
Dredging Assumptions - Alternative 3
*United Heckathorn Superfund Site, Richmond, California*

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Hotel | | 4 | $ 100.00 | $/day | 35 | day | $ 13,920.00 | 10.0% | $ 1,392.00 | $ 15,312.00 | 20% | $ 3,062.40 | $ 18,374.40 |
| SUB: Dredger | Per diem | | 4 | $ 50.00 | $/day | 35 | day | $ 6,960.00 | 10.0% | $ 696.00 | $ 7,656.00 | 20% | $ 1,531.20 | $ 9,187.20 |
| SUB: Dredger | Truck | | 2 | $ 75.00 | $/day | 35 | day | $ 5,220.00 | 25.0% | $ 1,305.00 | $ 6,525.00 | 20% | $ 1,305.00 | $ 7,830.00 |
| SUB: Dredger | Dredge Rental | 40 x 80 Flat Deck Spud Barge with CAT 345 & 4 $yd^3$ Environmental Bucket and Support Equipment | 1 | $ 10,000.00 | $/day | 35 | day | $ 348,000.00 | 25.0% | $ 87,000.00 | $ 435,000.00 | 20% | $ 87,000.00 | $ 522,000.00 |
| SUB: Dredger | Tender Tug | | 1 | $ 550.00 | $/hr | 35 | day | $ 19,140.00 | 25.0% | $ 4,785.00 | $ 23,925.00 | 20% | $ 4,785.00 | $ 28,710.00 |
| SUB: Dredger | Tow Tug | | 3 | $ 550.00 | $/hr | 35 | day | $ 57,420.00 | 25.0% | $ 14,355.00 | $ 71,775.00 | 20% | $ 14,355.00 | $ 86,130.00 |
| SUB: Dredger | Small Tool and Equipment | Skiff | 1 | $ 250.00 | $/day | 35 | day | $ 8,700.00 | 25.0% | $ 2,175.00 | $ 10,875.00 | 20% | $ 2,175.00 | $ 13,050.00 |
| SUB: Dredger | Workboat | | 1 | $ 100.00 | $/day | 35 | day | $ 3,480.00 | 25.0% | $ 870.00 | $ 4,350.00 | 20% | $ 870.00 | $ 5,220.00 |
| SUB: Dredger | FOGM | | 500 | $ 3.50 | $/gal | 35 | day | $ 60,900.00 | 10.0% | $ 6,090.00 | $ 66,990.00 | 20% | $ 13,398.00 | $ 80,388.00 |
| SUB: Dredger | Office Trailer Rentals | | 2 | $ 350.00 | $/mo | 1 | mo | $ 350.00 | 25.0% | $ 87.50 | $ 437.50 | 20% | $ 87.50 | $ 525.00 |
| SUB: Dredger | Office Trailer | | 1 | $ 50.00 | $/day | 35 | day | $ 1,740.00 | 25.0% | $ 435.00 | $ 2,175.00 | 20% | $ 435.00 | $ 2,610.00 |
| ***Subtotal*** | | | | | | | | **$ 673,281.62** | | **$ 154,878.91** | **$ 828,160.53** | | **$ 165,632.11** | **$ 993,792.63** |

**Task 3 - Turbidity Controls** **39 days**

| | Description | Resource Description | No of Units | Unit Rate | Units | Additional Units | Unit Description | Raw Cost | Subcontractor Markup | Subcontractor Markup Amt | Total Cost | Contingency Multiplier | Contingency Amt | Total w/Contin. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Turbidity Curtains | 25-ft Depth, Supply, Install, Move with Dredge | 2400 | $ 28.50 | $/lf | 1 | na | $ 68,400.00 | 25.0% | $ 17,100.00 | $ 85,500.00 | 20% | $ 17,100.00 | $ 102,600.00 |
| SUB: Dredger | Dredge Operator (ST) | Dredge Labor | 4 | $ 74.83 | $/hr | 39 | day | $ 11,804.94 | 25.0% | $ 2,951.24 | $ 14,756.18 | 20% | $ 2,951.24 | $ 17,707.42 |
| SUB: Dredger | Dredge Labor (ST) | Dredge Labor | 4 | $ 30.33 | $/hr | 39 | day | $ 4,785.60 | 25.0% | $ 1,196.40 | $ 5,982.00 | 20% | $ 1,196.40 | $ 7,178.40 |
| SUB: Dredger | Hotel | | 1 | $ 100.00 | $/day | 39 | day | $ 3,944.00 | 10.0% | $ 394.40 | $ 4,338.40 | 20% | $ 867.68 | $ 5,206.08 |
| SUB: Dredger | Per diem | | 1 | $ 50.00 | $/day | 39 | day | $ 1,972.00 | 10.0% | $ 197.20 | $ 2,169.20 | 20% | $ 433.84 | $ 2,603.04 |
| SUB: Dredger | Truck | | 1 | $ 75.00 | $/day | 39 | day | $ 2,958.00 | 25.0% | $ 739.50 | $ 3,697.50 | 20% | $ 739.50 | $ 4,437.00 |
| SUB: Dredger | Equipment | Boat | 1 | $ 150.00 | $/day | 39 | day | $ 5,916.00 | 25.0% | $ 1,479.00 | $ 7,395.00 | 20% | $ 1,479.00 | $ 8,874.00 |
| SUB: Dredger | Disposal | Non-hazardous | 48 | $ 75.00 | $/ton | 1 | na | $ 3,600.00 | 25.0% | $ 900.00 | $ 4,500.00 | 20% | $ 900.00 | $ 5,400.00 |
| SUB: Dredger | FOGM | | 10 | $ 3.50 | $/gal | 39 | day | $ 1,380.40 | 10.0% | $ 138.04 | $ 1,518.44 | 20% | $ 303.69 | $ 1,822.13 |
| SUB: Dredger | Safety Supplies | | 9 | $ 25.00 | $/day | 39 | day | $ 8,874.00 | 10.0% | $ 887.40 | $ 9,761.40 | 20% | $ 1,952.28 | $ 11,713.68 |
| ***Subtotal*** | | | | | | | | **$ 113,634.95** | | **$ 25,983.18** | **$ 139,618.12** | | **$ 27,923.62** | **$ 167,541.75** |

**Task 4 - Supply Portland Cement Reagent**

| | Description | Resource Description | No of Units | Unit Rate | Units | Additional Units | Unit Description | Raw Cost | Subcontractor Markup | Subcontractor Markup Amount | Total Cost | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Purchase Portland Cement | | 6,999 | $ 125.00 | $/ton | 1 | na | $ 874,885.57 | 10.0% | $ 87,488.56 | $ 962,374.13 | 20% | $ 192,474.83 | $ 1,154,848.96 |
| ***Subtotal*** | | | | | | | | **$ 874,885.57** | **$ 0.10** | **$ 87,488.56** | **$ 962,374.13** | | **$ 192,474.83** | **$ 1,154,848.96** |

**Task 5 - Mix Reagents; Stockpile Sediment on Pad** **59 days** **6999 ton agent**

| | Resource | Resource Description | Quantity | Unit Rate | Units | Additional Units | Unit Description | Cost | Subcontractor Markup | Subcontractor Markup Amount | Total | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Treatment Contractor | Dredging PM | Landside Labor | 6 | $ 65.40 | $/hr | 59 | day | $ 23,324.26 | 25.0% | $ 5,831.06 | $ 29,155.32 | 20% | $ 5,831.06 | $ 34,986.38 |
| SUB: Treatment Contractor | Operator (ST) | Landside Labor | 16 | $ 74.83 | $/hr | 59 | day | $ 71,164.90 | 25.0% | $ 17,791.22 | $ 88,956.12 | 20% | $ 17,791.22 | $ 106,747.34 |
| SUB: Treatment Contractor | Operator (OT) | Landside Labor | 4 | $ 96.92 | $/hr | 59 | day | $ 23,043.07 | 25.0% | $ 5,760.77 | $ 28,803.84 | 20% | $ 5,760.77 | $ 34,564.60 |
| SUB: Treatment Contractor | Labor (ST) | Landside Labor | 16 | $ 30.33 | $/hr | 59 | day | $ 28,849.51 | 25.0% | $ 7,212.38 | $ 36,061.89 | 20% | $ 7,212.38 | $ 43,274.27 |
| SUB: Treatment Contractor | Labor (OT) | Landside Labor | 4 | $ 42.28 | $/hr | 59 | day | $ 10,051.46 | 25.0% | $ 2,512.86 | $ 12,564.32 | 20% | $ 2,512.86 | $ 15,077.19 |
| SUB: Treatment Contractor | Hotel | | 4 | $ 100.00 | $/day | 59 | day | $ 23,776.00 | 10.0% | $ 2,377.60 | $ 26,153.60 | 20% | $ 5,230.72 | $ 31,384.32 |
| SUB: Treatment Contractor | Per diem | | 4 | $ 50.00 | $/day | 59 | day | $ 11,888.00 | 10.0% | $ 1,188.80 | $ 13,076.80 | 20% | $ 2,615.36 | $ 15,692.16 |
| SUB: Treatment Contractor | Truck | | 2 | $ 75.00 | $/day | 59 | day | $ 8,916.00 | 25.0% | $ 2,229.00 | $ 11,145.00 | 20% | $ 2,229.00 | $ 13,374.00 |
| SUB: Treatment Contractor | CAT 345 Extended Stick Rental | | 1 | $ 1,250.00 | $/day | 59 | day | $ 74,300.00 | 25.0% | $ 18,575.00 | $ 92,875.00 | 20% | $ 18,575.00 | $ 111,450.00 |
| SUB: Treatment Contractor | Grinder and Screen | | 1 | $ 1,500.00 | $/day | 59 | day | $ 89,160.00 | 25.0% | $ 22,290.00 | $ 111,450.00 | 20% | $ 22,290.00 | $ 133,740.00 |
| SUB: Treatment Contractor | Cement/FlyAsh Metering and Pumill (Rapid Mix 400) | | 1 | $ 1,467.00 | $/day | 59 | day | $ 87,198.48 | 25.0% | $ 21,799.62 | $ 108,998.10 | 20% | $ 21,799.62 | $ 130,797.72 |
| SUB: Treatment Contractor | Wheel Loader (Cat IT62H) | | 1 | $ 269.00 | $/day | 59 | day | $ 15,989.36 | 25.0% | $ 3,997.34 | $ 19,986.70 | 20% | $ 3,997.34 | $ 23,984.04 |
| SUB: Treatment Contractor | Radial Stacking Conveyor | | 1 | $ 171.00 | $/day | 59 | day | $ 10,164.24 | 25.0% | $ 2,541.06 | $ 12,705.30 | 20% | $ 2,541.06 | $ 15,246.36 |

**TABLE G-4b**
Dredging Assumptions - Alternative 3
*United Heckathorn Superfund Site, Richmond, California*

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Treatment Contractor | Miscellaneous Pumps, Hoses | | 1 | $ 150.00 | $/day | 59 | day | $ 8,916.00 | 25.0% | $ 2,229.00 | $ 11,145.00 | 20% | $ 2,229.00 | $ 13,374.00 |
| SUB: Treatment Contractor | 100 ton Pig Rental | | 1 | $ 350.00 | $/day | 59 | day | $ 20,804.00 | 25.0% | $ 5,201.00 | $ 26,005.00 | 20% | $ 5,201.00 | $ 31,206.00 |
| SUB: Treatment Contractor | Light Plant Rental | | 4 | $ 250.00 | $/day | 59 | day | $ 59,440.00 | 25.0% | $ 14,860.00 | $ 74,300.00 | 20% | $ 14,860.00 | $ 89,160.00 |
| SUB: Treatment Contractor | Miscellaneous Expenses | | 1 | $ 250.00 | $/day | 59 | day | $ 14,860.00 | 25.0% | $ 3,715.00 | $ 18,575.00 | 20% | $ 3,715.00 | $ 22,290.00 |
| SUB: Treatment Contractor | Office Trailer Rentals | | 2 | $ 350.00 | $/mo | 2 | mo | $ 1,386.93 | 25.0% | $ 346.73 | $ 1,733.67 | 20% | $ 346.73 | $ 2,080.40 |
| SUB: Treatment Contractor | Office Trailer | | 1 | $ 17.00 | $/day | 59 | day | $ 1,010.48 | 25.0% | $ 252.62 | $ 1,263.10 | 20% | $ 252.62 | $ 1,515.72 |
| SUB: Treatment Contractor | Bobcat | | 1 | $ 75.00 | $/day | 59 | day | $ 4,458.00 | 25.0% | $ 1,114.50 | $ 5,572.50 | 20% | $ 1,114.50 | $ 6,687.00 |
| SUB: Treatment Contractor | Port a Potty | | 1 | $ 7.00 | $/day | 59 | day | $ 416.08 | 25.0% | $ 104.02 | $ 520.10 | 20% | $ 104.02 | $ 624.12 |
| SUB: Treatment Contractor | FOGM | | 500 | $ 3.25 | $/gal | 59 | day | $ 96,590.00 | 10.0% | $ 9,659.00 | $ 106,249.00 | 20% | $ 21,249.80 | $ 127,498.80 |
| SUB: Mobile Lab Supplier | Mob Mobile Laboratory | | 1 | $ 1,750.00 | $/trip | 1 | na | $ 1,750.00 | 15.0% | $ 262.50 | $ 2,012.50 | 20% | $ 402.50 | $ 2,415.00 |
| SUB: Mobile Lab Supplier | Mobile Laboratory | | 1 | $ 2,565.00 | $/day | 59 | day | $ 152,463.60 | 15.0% | $ 22,869.54 | $ 175,333.14 | 20% | $ 35,066.63 | $ 210,399.77 |
| ***Subtotal*** | | | | | | | | **$ 839,920.37** | | **$ 174,720.63** | **$ 1,014,641.00** | | **$ 202,928.20** | **$ 1,217,569.20** |

**Task 6 - Load Class 1 Non-RCRA Stabilized Materials into Rail; Transport and Dispose at Landfill (Utah) [Tight Areas]** — **10,426 tons** — **12 days** — **893 tons/day**

| | Resource | Resource Description | Quantity | Unit Rate | Units | Additional Units | Unit Description | Cost | Subcontractor Markup | Subcontractor Markup Amount | Total | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Treatment Contractor | Wheel Loader (Cat IT62H) | | 1 | $ 269.00 | $/day | 12 | day | $ 3,140.71 | 25.0% | $ 785.18 | $ 3,925.89 | 20% | $ 785.18 | $ 4,711.06 |
| SUB: Treatment Contractor | Dredging PM | | 2 | $ 65.40 | $/hr | 12 | day | $ 1,527.16 | 25.0% | $ 381.79 | $ 1,908.94 | 20% | $ 381.79 | $ 2,290.73 |
| SUB: Treatment Contractor | Loader Operator (ST) | Loader Operator | 8 | $ 74.83 | $/hr | 12 | day | $ 6,989.28 | 25.0% | $ 1,747.32 | $ 8,736.60 | 20% | $ 1,747.32 | $ 10,483.92 |
| SUB: Treatment Contractor | Loader Operator (OT) | Loader Operator | 4 | $ 96.92 | $/hr | 12 | day | $ 4,526.23 | 25.0% | $ 1,131.56 | $ 5,657.79 | 20% | $ 1,131.56 | $ 6,789.35 |
| SUB: Treatment Contractor | Laborer (ST) | Laborer | 24 | $ 30.33 | $/hr | 12 | day | $ 8,500.15 | 25.0% | $ 2,125.04 | $ 10,625.18 | 20% | $ 2,125.04 | $ 12,750.22 |
| SUB: Treatment Contractor | Laborer (OT) | Laborer | 12 | $ 42.28 | $/hr | 12 | day | $ 5,923.07 | 25.0% | $ 1,480.77 | $ 7,403.84 | 20% | $ 1,480.77 | $ 8,884.61 |
| SUB: Treatment Contractor | Hotel | | 4 | $ 100.00 | $/day | 12 | day | $ 4,670.20 | 10.0% | $ 467.02 | $ 5,137.22 | 20% | $ 1,027.44 | $ 6,164.66 |
| SUB: Treatment Contractor | Per diem | | 4 | $ 50.00 | $/day | 12 | day | $ 2,335.10 | 10.0% | $ 233.51 | $ 2,568.61 | 20% | $ 513.72 | $ 3,082.33 |
| SUB: Treatment Contractor | CAT 345 Rental | | 1 | $ 1,250.00 | $/day | 12 | day | $ 14,594.38 | 25.0% | $ 3,648.59 | $ 18,242.97 | 20% | $ 3,648.59 | $ 21,891.56 |
| SUB: Treatment Contractor | FOGM (Site Equipment) | | 120 | $ 3.50 | $/gal | 12 | day | $ 4,903.71 | 10.0% | $ 490.37 | $ 5,394.08 | 20% | $ 1,078.82 | $ 6,472.90 |
| SUB: Treatment Contractor | On Site Scales | Full Length Portable | 1 | $ 175.00 | $/day | 12 | day | $ 2,043.21 | 10.0% | $ 204.32 | $ 2,247.53 | 20% | $ 449.51 | $ 2,697.04 |
| SUB: Treatment Contractor | Sediment Transportation | Liner | 496 | $ 40.00 | $/load | 1 | na | $ 19,859.47 | 5.0% | $ 992.97 | $ 20,852.45 | 20% | $ 4,170.49 | $ 25,022.93 |
| ***Subtotal*** | | | | | | | | **$ 79,012.67** | | **$ 13,688.44** | **$ 92,701.11** | | **$ 18,540.22** | **$ 111,241.34** |

**Task 7 - Load Class 1 Non-RCRA Stabilized Materials into Rail; Transport and Dispose at Landfill (Utah) [Open Areas]** — **85,889 tons** — **34.8 days** — **2,468 tons/day**

| | Resource | Resource Description | Quantity | Unit Rate | Units | Additional Units | Unit Description | Cost | Subcontractor Markup | Subcontractor Markup Amount | Total | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Wheel Loader (Cat IT62H) | | 1 | $ 269.00 | $/day | 35 | day | $ 9,361.20 | 25.0% | $ 2,340.30 | $ 11,701.50 | 20% | $ 2,340.30 | $ 14,041.80 |
| SUB: Dredger | Dredging PM | | 2 | $ 65.40 | $/hr | 35 | day | $ 4,551.84 | 25.0% | $ 1,137.96 | $ 5,689.80 | 20% | $ 1,137.96 | $ 6,827.76 |
| SUB: Dredger | Dredge Operator (ST) | Dredge Labor | 8 | $ 74.83 | $/hr | 35 | day | $ 20,832.25 | 25.0% | $ 5,208.06 | $ 26,040.32 | 20% | $ 5,208.06 | $ 31,248.38 |
| SUB: Dredger | Dredge Operator (OT) | Dredge Labor | 4 | $ 96.92 | $/hr | 35 | day | $ 13,490.90 | 25.0% | $ 3,372.72 | $ 16,863.62 | 20% | $ 3,372.72 | $ 20,236.34 |
| SUB: Dredger | Dredge Labor (ST) | Dredge Labor | 24 | $ 30.33 | $/hr | 35 | day | $ 25,335.54 | 25.0% | $ 6,333.89 | $ 31,669.43 | 20% | $ 6,333.89 | $ 38,003.31 |
| SUB: Dredger | Dredge Labor (OT) | Dredge Labor | 12 | $ 42.28 | $/hr | 35 | day | $ 17,654.31 | 25.0% | $ 4,413.58 | $ 22,067.89 | 20% | $ 4,413.58 | $ 26,481.47 |
| SUB: Treatment Contractor | CAT 345 Rental | | 1 | $ 1,250.00 | $/day | 35 | day | $ 43,500.00 | 25.0% | $ 10,875.00 | $ 54,375.00 | 20% | $ 10,875.00 | $ 65,250.00 |
| SUB: Dredger | Hotel | | 4 | $ 100.00 | $/day | 35 | day | $ 13,920.00 | 10.0% | $ 1,392.00 | $ 15,312.00 | 20% | $ 3,062.40 | $ 18,374.40 |
| SUB: Dredger | Per diem | | 4 | $ 50.00 | $/day | 35 | day | $ 6,960.00 | 10.0% | $ 696.00 | $ 7,656.00 | 20% | $ 1,531.20 | $ 9,187.20 |
| SUB: Dredger | Truck | | 2 | $ 75.00 | $/day | 35 | day | $ 5,220.00 | 25.0% | $ 1,305.00 | $ 6,525.00 | 20% | $ 1,305.00 | $ 7,830.00 |
| SUB: Dredger | FOGM | | 60 | $ 3.50 | $/gal | 35 | day | $ 7,308.00 | 10.0% | $ 730.80 | $ 8,038.80 | 20% | $ 1,607.76 | $ 9,646.56 |
| SUB: Mobile Lab Supplier | Mobile Laboratory | | 1 | $ 2,565.00 | $/day | 35 | day | $ 89,262.00 | 15.0% | $ 13,389.30 | $ 102,651.30 | 20% | $ 20,530.26 | $ 123,181.56 |
| SUB: Treatment Contractor | Onsite Scales | Full Length Portable | 1 | $ 175.00 | $/day | 35 | day | $ 6,090.00 | 10.0% | $ 609.00 | $ 6,699.00 | 20% | $ 1,339.80 | $ 8,038.80 |
| SUB: Excavation Contractor | Sediment Transportation | Liner | 4090 | $ 50.00 | $/load | 1 | na | $ 204,498.25 | 5.0% | $ 10,224.91 | $ 214,723.17 | 20% | $ 42,944.63 | $ 257,667.80 |
| ***Subtotal*** | | | | | | | | **$ 458,623.10** | | **$ 59,688.22** | **$ 518,311.32** | | **$ 103,662.26** | **$ 636,015.38** |

**Task 8 - Water Treatment** — **83 days**

| | Resource | Resource Description | Quantity | Unit Rate | Units | Additional Units | Unit Description | Cost | Subcontractor Markup | Subcontractor Markup Amount | Total | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Water Treatment Sub | Dredging PM | | 4 | $ 65.40 | $/hr | 83 | day | $ 21,769.31 | 25.0% | $ 5,442.33 | $ 27,211.63 | 20% | $ 5,442.33 | $ 32,653.96 |
| SUB: Water Treatment Sub | WWT Operator (ST) | Dredge Labor | 32 | $ 74.83 | $/hr | 83 | day | $ 199,261.71 | 25.0% | $ 49,815.43 | $ 249,077.14 | 20% | $ 49,815.43 | $ 298,892.57 |
| SUB: Water Treatment Sub | WWT Operator (OT) | Dredge Labor | 16 | $ 96.92 | $/hr | 83 | day | $ 129,041.19 | 25.0% | $ 32,260.30 | $ 161,301.48 | 20% | $ 32,260.30 | $ 193,561.78 |
| SUB: Water Treatment Sub | WWT Labor (ST) | Dredge Labor | 32 | $ 30.33 | $/hr | 83 | day | $ 80,778.64 | 25.0% | $ 20,194.66 | $ 100,973.30 | 20% | $ 20,194.66 | $ 121,167.95 |
| SUB: Water Treatment Sub | WWT Labor (OT) | Dredge Labor | 16 | $ 42.28 | $/hr | 83 | day | $ 56,288.17 | 25.0% | $ 14,072.04 | $ 70,360.21 | 20% | $ 14,072.04 | $ 84,432.25 |

**TABLE G-4b**
Dredging Assumptions - Alternative 3
*United Heckathorn Superfund Site, Richmond, California*

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Hotel | | 8 | $ 100.00 | $/day | 83 | day | $ 66,572.80 | 10.0% | $ 6,657.28 | $ 73,230.08 | 20% | $ 14,646.02 | $ 87,876.10 |
| SUB: Dredger | Per diem | | 8 | $ 50.00 | $/day | 83 | day | $ 33,286.40 | 10.0% | $ 3,328.64 | $ 36,615.04 | 20% | $ 7,323.01 | $ 43,938.05 |
| SUB: Dredger | Truck | | 4 | $ 75.00 | $/day | 83 | day | $ 24,964.80 | 25.0% | $ 6,241.20 | $ 31,206.00 | 20% | $ 6,241.20 | $ 37,447.20 |
| SUB: Dredger | FOGM | | 120 | $ 3.50 | $/gal | 83 | day | $ 34,950.72 | 10.0% | $ 3,495.07 | $ 38,445.79 | 20% | $ 7,689.16 | $ 46,134.95 |
| SUB: Dredger | Safety Supplies | | 9 | $ 25.00 | $/day | 83 | day | $ 18,723.60 | 10.0% | $ 1,872.36 | $ 20,595.96 | 20% | $ 4,119.19 | $ 24,715.15 |
| SUB: Water Treatment Sub | Transfer Pump | Scows to System | 1 | $ 125.00 | $/day | 83 | day | $ 10,402.00 | 25.0% | $ 2,600.50 | $ 13,002.50 | 20% | $ 2,600.50 | $ 15,603.00 |
| SUB: Water Treatment Sub | Influent Frac Tank | | 2 | $ 45.00 | $/day | 83 | day | $ 7,489.44 | 25.0% | $ 1,872.36 | $ 9,361.80 | 20% | $ 1,872.36 | $ 11,234.16 |
| SUB: Water Treatment Sub | WWT Manifolds | | 2 | $ 6,000.00 | $/day | 35 | day | $ 417,600.00 | 25.0% | $ 104,400.00 | $ 522,000.00 | 20% | $ 104,400.00 | $ 626,400.00 |
| SUB: Water Treatment Sub | Pumps | | 1 | $ 150.00 | $/day | 83 | day | $ 12,482.40 | 25.0% | $ 3,120.60 | $ 15,603.00 | 20% | $ 3,120.60 | $ 18,723.60 |
| SUB: Water Treatment Sub | Sand Filters (2 units) | | 1 | $ 150.00 | $/day | 83 | day | $ 12,482.40 | 25.0% | $ 3,120.60 | $ 15,603.00 | 20% | $ 3,120.60 | $ 18,723.60 |
| SUB: Water Treatment Sub | GAC Filters (2 units) | | 1 | $ 250.00 | $/day | 83 | day | $ 20,804.00 | 25.0% | $ 5,201.00 | $ 26,005.00 | 20% | $ 5,201.00 | $ 31,206.00 |
| SUB: Water Treatment Sub | Bag Filter Pods | RFR 2 Bag Units | 2 | $ 75.00 | $/day | 83 | day | $ 12,482.40 | 25.0% | $ 3,120.60 | $ 15,603.00 | 20% | $ 3,120.60 | $ 18,723.60 |
| SUB: Water Treatment Sub | Sand | RFR 4 Pod Unit, 8 Tons per Charge | 16 | $ 50.00 | $/ton | 1 | na | $ 800.00 | 25.0% | $ 200.00 | $ 1,000.00 | 20% | $ 200.00 | $ 1,200.00 |
| SUB: Water Treatment Sub | GAC Filters (2 units) | 5000 lb per Vessel per Charge; Assume 2 Charges | 20,000 | $ 2.50 | $/lb | 1 | na | $ 50,000.00 | 25.0% | $ 12,500.00 | $ 62,500.00 | 20% | $ 12,500.00 | $ 75,000.00 |
| SUB: Water Treatment Sub | 10-micron Filter Bags, 4 per Day | | 4 | $ 5.50 | ea | 83 | na | $ 1,830.75 | 25.0% | $ 457.69 | $ 2,288.44 | 20% | $ 457.69 | $ 2,746.13 |
| SUB: Water Treatment Sub | Backwash Supply Tank | RFR 20,000 Frac Tank | 1 | $ 45.00 | $/day | 83 | day | $ 3,744.72 | 25.0% | $ 936.18 | $ 4,680.90 | 20% | $ 936.18 | $ 5,617.08 |
| SUB: Water Treatment Sub | Backwash Waste Tank | RFR 20,000 Frac Tank | 1 | $ 45.00 | $/day | 83 | day | $ 3,744.72 | 25.0% | $ 936.18 | $ 4,680.90 | 20% | $ 936.18 | $ 5,617.08 |
| SUB: Water Treatment Sub | Effluent Holding Tank | RFR 20,000 Frac Tank | 1 | $ 45.00 | $/day | 83 | day | $ 3,744.72 | 25.0% | $ 936.18 | $ 4,680.90 | 20% | $ 936.18 | $ 5,617.08 |
| SUB: Water Treatment Sub | Chemicals | | 1 | $ 75.00 | $/day | 83 | day | $ 6,241.20 | 10.0% | $ 624.12 | $ 6,865.32 | 20% | $ 1,373.06 | $ 8,238.38 |
| SUB: Water Treatment Sub | Vendor Start-up Assistance and Expenses | | 5 | $ 2,500.00 | $/day | 1 | na | $ 12,500.00 | 25.0% | $ 3,125.00 | $ 15,625.00 | 20% | $ 3,125.00 | $ 18,750.00 |
| SUB: Water Treatment Sub | Power/Electric | | 1 | $ 167.00 | $/day | 83 | day | $ 13,897.07 | 10.0% | $ 1,389.71 | $ 15,286.78 | 20% | $ 3,057.36 | $ 18,344.14 |
| SUB: Water Treatment Sub | Sand, GAC, TSS Disposal Allowance | | 1 | $ 50,000.00 | ea | 1 | na | $ 50,000.00 | 10.0% | $ 5,000.00 | $ 55,000.00 | 20% | $ 11,000.00 | $ 66,000.00 |
| SUB: Excavation Contractor | Water Treatment Residuals Transportation | | 26 | $ 10.00 | $/ton | 1 | na | $ 260.00 | 5.0% | $ 13.00 | $ 273.00 | 20% | $ 54.60 | $ 327.60 |
| SUB: Excavation Contractor | Water Treatment Residuals Transportation | Liner | 1.24 | $ 50.00 | $/load | 1 | na | $ 61.90 | 5.0% | $ 3.10 | $ 65.00 | 20% | $ 13.00 | $ 78.00 |
| SUB: Excavation Contractor | TSCA Disposal | Subtitle C Landfill | 26 | $ 80.00 | $/ton | 1 | na | $ 2,080.00 | 5.0% | $ 104.00 | $ 2,184.00 | 20% | $ 436.80 | $ 2,620.80 |
| ***Subtotal*** | | | | | | | | **$ 1,308,285.06** | | **$ 293,040.11** | **$ 1,601,325.17** | | **$ 320,265.03** | **$ 1,921,590.21** |

Assumes 24/7 operations
Includes 4 people per shift to offload water and run the system

**Task 9 - Debris Removal and RCRA Subtitle D Disposal** **949 tons** **20 tons/day** **47 days**

| | Resource | Resource Description | Quantity | Unit Rate | Units | Additional Units | Unit Description | Cost | Subcontractor Markup | Subcontractor Markup Amount | Total | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Wheel Loader (Cat IT62H) | | 1 | $ 269.00 | $/day | 47 | day | $ 12,643.00 | 25.0% | $ 3,160.75 | $ 15,803.75 | 20% | $ 3,160.75 | $ 18,964.50 |
| SUB: Dredger | Dredging PM | | 1 | $ 65.40 | $/hr | 47 | day | $ 3,073.80 | 25.0% | $ 768.45 | $ 3,842.25 | 20% | $ 768.45 | $ 4,610.70 |
| SUB: Dredger | Dredge Operator (ST) | Dredge Labor | 2 | $ 74.83 | $/hr | 47 | day | $ 7,033.88 | 25.0% | $ 1,758.47 | $ 8,792.35 | 20% | $ 1,758.47 | $ 10,550.82 |
| SUB: Dredger | Dredge Labor (ST) | Dredge Labor | 2 | $ 30.33 | $/hr | 47 | day | $ 2,851.46 | 25.0% | $ 712.87 | $ 3,564.33 | 20% | $ 712.87 | $ 4,277.19 |
| SUB: Dredger | Hotel | | 0.5 | $ 100.00 | $/day | 47 | day | $ 2,350.00 | 10.0% | $ 235.00 | $ 2,585.00 | 20% | $ 517.00 | $ 3,102.00 |
| SUB: Dredger | Per diem | | 0.5 | $ 50.00 | $/day | 47 | day | $ 1,175.00 | 10.0% | $ 117.50 | $ 1,292.50 | 20% | $ 258.50 | $ 1,551.00 |
| SUB: Dredger | Truck | | 1 | $ 75.00 | $/day | 47 | day | $ 3,525.00 | 25.0% | $ 881.25 | $ 4,406.25 | 20% | $ 881.25 | $ 5,287.50 |
| SUB: Excavation Contractor | Sediment Transportation | | 949 | $ 10.00 | $/ton | 1 | na | $ 9,487.86 | 5.0% | $ 474.39 | $ 9,962.26 | 20% | $ 1,992.45 | $ 11,954.71 |
| SUB: Excavation Contractor | Sediment Transportation | Liner | 47 | $ 40.00 | $/load | 1 | na | $ 1,897.57 | 5.0% | $ 94.88 | $ 1,992.45 | 20% | $ 398.49 | $ 2,390.94 |
| SUB: Excavation Contractor | Disposal | Subtitle D Landfill | 394 | $ 50.00 | $/ton | 1 | na | $ 19,706.74 | 5.0% | $ 985.34 | $ 20,692.08 | 20% | $ 4,138.42 | $ 24,830.50 |
| SUB: Dredger | FOGM | | 60 | $ 3.25 | $/gal | 47 | day | $ 9,165.00 | 10.0% | $ 916.50 | $ 10,081.50 | 20% | $ 2,016.30 | $ 12,097.80 |
| ***Subtotal*** | | | | | | | | **$ 72,909.32** | | **$ 10,105.39** | **$ 83,014.71** | | **$ 16,602.94** | **$ 99,617.66** |

**Task 10 Mechanical Dredge Standby Time** **24 hrs**

| | Resource | Resource Description | Quantity | Unit Rate | Units | Additional Units | Unit Description | Cost | Subcontractor Markup | Subcontractor Markup Amount | Total | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Dredging PM | | 8 | $ 65.40 | $/hr | 1.0 | day | $ 523.20 | 25.0% | $ 130.80 | $ 654.00 | 20% | $ 130.80 | $ 784.80 |
| SUB: Dredger | Dredge Operator (ST) | Dredge Labor | 16 | $ 74.83 | $/hr | 1.0 | day | $ 1,197.26 | 25.0% | $ 299.31 | $ 1,496.57 | 20% | $ 299.31 | $ 1,795.88 |
| SUB: Dredger | Dredge Operator (OT) | Dredge Labor | 8 | $ 96.92 | $/hr | 1.0 | day | $ 775.34 | 25.0% | $ 193.83 | $ 969.17 | 20% | $ 193.83 | $ 1,163.01 |

**TABLE G-4b**
Dredging Assumptions - Alternative 3
*United Heckathorn Superfund Site, Richmond, California*

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Dredge Labor (ST) | Dredge Labor | 32 | $ 30.33 | $/hr | 1.0 | day | $ 970.71 | 25.0% | $ 242.68 | $ 1,213.39 | 20% | $ 242.68 | $ 1,456.07 |
| SUB: Dredger | Dredge Labor (OT) | Dredge Labor | 16 | $ 42.28 | $/hr | 1.0 | day | $ 676.41 | 25.0% | $ 169.10 | $ 845.51 | 20% | $ 169.10 | $ 1,014.62 |
| SUB: Dredger | Hotel | | 6 | $ 100.00 | $/day | 1.0 | day | $ 600.00 | 10.0% | $ 60.00 | $ 660.00 | 20% | $ 132.00 | $ 792.00 |
| SUB: Dredger | Per diem | | 6 | $ 50.00 | $/day | 1.0 | day | $ 300.00 | 10.0% | $ 30.00 | $ 330.00 | 20% | $ 66.00 | $ 396.00 |
| SUB: Dredger | Truck | | 5 | $ 75.00 | $/day | 1.0 | day | $ 375.00 | 25.0% | $ 93.75 | $ 468.75 | 20% | $ 93.75 | $ 562.50 |
| SUB: Dredger | Dredge Rental | 40 x 80 Flat Deck Spud Barge with CAT 345 & 4 $yd^3$ Environmental Bucket and Support Equipment | 1 | $ 10,000.00 | $/day | 1.0 | day | $ 10,000.00 | 25.0% | $ 2,500.00 | $ 12,500.00 | 20% | $ 2,500.00 | $ 15,000.00 |
| SUB: Dredger | Tender Tug | | 1 | $ 550.00 | $/hr | 1.0 | day | $ 550.00 | 25.0% | $ 137.50 | $ 687.50 | 20% | $ 137.50 | $ 825.00 |
| SUB: Dredger | Scows | 30 ft x 60 ft, 700 $yd^3$ | 3 | $ 500.00 | $/day | 1.0 | day | $ 1,500.00 | 25.0% | $ 375.00 | $ 1,875.00 | 20% | $ 375.00 | $ 2,250.00 |
| SUB: Dredger | Tow Tug | | 1 | $ 550.00 | $/hr | 1.0 | day | $ 550.00 | 25.0% | $ 137.50 | $ 687.50 | 20% | $ 137.50 | $ 825.00 |
| SUB: Dredger | Equipment | Skiff | 1 | $ 100.00 | $/day | 1.0 | day | $ 100.00 | 25.0% | $ 25.00 | $ 125.00 | 20% | $ 25.00 | $ 150.00 |
| ***Subtotal*** | | | | | | | | **$ 18,117.92** | | **$ 4,394.48** | **$ 22,512.39** | | **$ 4,502.48** | **$ 27,014.87** |

| **Notes:** | **Davis-Bacon Rates** | **Rate** | **Fringe** | **Taxes** | **Total** |
|---|---|---|---|---|---|
| Items do not include oversight effort | Dredge PM | $60.00 | -- | $5.40 | $65.40 |
| All cost based on estimates or RSMeans data | Operator (All) | $40.53 | $28.12 | $6.18 | $74.83 |
| All labor cost based on Davis-Bacon rates | Operator OT (All) | $60.80 | $28.12 | $8.00 | $96.92 |
| Scope details and assumptions provided elsewhere | Labor (All) | $21.91 | $5.92 | $2.50 | $30.33 |
| | Labor OT (All) | $32.87 | $5.92 | $3.49 | $42.28 |

U.S. Department of Labor. 2014. Davis Bacon Wage Determinations. http://www.wdol.gov/dba.aspx

**TABLE G-4c**
**Dredging Assumptions - Alternative 4**
*United Heckathorn Superfund Site, Richmond, California*

| Description | No of Units | Unit | Cost |
|---|---|---|---|
| Task 1 - Dredge Tight Areas | 6,600 | $yd^3$ | $150,885 |
| Task 2 - Dredge Open Areas | 59,400 | $yd^3$ | $993,793 |
| Task 3 - Turbidity Controls | 45 | day | $167,542 |
| Task 4 - Supply Portland Cement Reagent | 7,964 | ton | $1,154,849 |
| Task 5 - Mix Reagents; Stockpile Sediment on Pad | 66,000 | $yd^3$ | $1,217,569 |
| Task 6 - Load Class 1 Non-RCRA Stabilized Materials into Rail; Transport and Dispose at Landfill (Utah) [Tight Areas] | 10,752 | ton | $114,718 |
| Task 7 - Load Class 1 Non-RCRA Stabilized Materials into Rail; Transport and Dispose at Landfill (Utah) [Open Areas] | 96,768 | ton | $636,015 |
| Task 8 - Water Treatment | 3,740,132 | gal | $1,921,590 |
| Task 9 - Debris Removal and RCRA Subtitle D Disposal | 978 | ton | $102,638 |
| Task 10 - Mechanical Dredge Standby Time | 24 | hrs | $27,015 |
| **8th Street Slip Sheet Piling Reinforcement** | 0 | **LF** | **$ -** |
| | | **TOTAL** | **$6,486,613** |

**Task 1 - Dredge Tight Areas** **5 days** **6,600 $yd^3$** **1,250 $yd^3$/day**

| | Description | Resource Description | No of Units | Unit Rate | Units | Additional Units | Unit Description | Raw Cost | Subcontractor Markup | Subcontractor Markup Amount | Total Cost | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Dredging PM | Dredge Labor | 6 | $ 65.40 | $/hr | 5 | day | $ 2,071.87 | 25.0% | $ 517.97 | $ 2,589.84 | 20% | $ 517.97 | $ 3,107.81 |
| SUB: Dredger | Dredge Operator (ST) | Dredge Labor | 16 | $ 74.83 | $/hr | 5 | day | $ 6,321.51 | 25.0% | $ 1,580.38 | $ 7,901.89 | 20% | $ 1,580.38 | $ 9,482.27 |
| SUB: Dredger | Dredge Operator (OT) | Dredge Labor | 8 | $ 96.92 | $/hr | 5 | day | $ 4,093.79 | 25.0% | $ 1,023.45 | $ 5,117.24 | 20% | $ 1,023.45 | $ 6,140.68 |
| SUB: Dredger | Dredge Labor (ST) | Dredge Labor | 32 | $ 30.33 | $/hr | 5 | day | $ 5,125.35 | 25.0% | $ 1,281.34 | $ 6,406.69 | 20% | $ 1,281.34 | $ 7,688.03 |
| SUB: Dredger | Dredge Labor (OT) | Dredge Labor | 16 | $ 42.28 | $/hr | 5 | day | $ 3,571.45 | 25.0% | $ 892.86 | $ 4,464.31 | 20% | $ 892.86 | $ 5,357.17 |
| SUB: Dredger | Safety Supplies | | 9 | $ 25.00 | $/day | 5 | day | $ 1,188.00 | 10.0% | $ 118.80 | $ 1,306.80 | 20% | $ 261.36 | $ 1,568.16 |
| SUB: Dredger | Hotel | | 4 | $ 100.00 | $/day | 5 | day | $ 2,112.00 | 10.0% | $ 211.20 | $ 2,323.20 | 20% | $ 464.64 | $ 2,787.84 |
| SUB: Dredger | Per diem | | 4 | $ 50.00 | $/day | 5 | day | $ 1,056.00 | 10.0% | $ 105.60 | $ 1,161.60 | 20% | $ 232.32 | $ 1,393.92 |
| SUB: Dredger | Truck | | 2 | $ 75.00 | $/day | 5 | day | $ 792.00 | 25.0% | $ 198.00 | $ 990.00 | 20% | $ 198.00 | $ 1,188.00 |
| SUB: Dredger | Dredge Rental | 40 x 80 Flat Deck Spud Barge with CAT 345& 4 $yd^3$ Environmental Bucket and Support Equipment | 1 | $ 10,000.00 | $/day | 5 | day | $ 52,800.00 | 25.0% | $ 13,200.00 | $ 66,000.00 | 20% | $ 13,200.00 | $ 79,200.00 |
| SUB: Dredger | Tender Tug | | 1 | $ 550.00 | $/hr | 5 | day | $ 2,904.00 | 25.0% | $ 726.00 | $ 3,630.00 | 20% | $ 726.00 | $ 4,356.00 |
| SUB: Dredger | Tow Tug | | 3 | $ 550.00 | $/hr | 5 | day | $ 8,712.00 | 25.0% | $ 2,178.00 | $ 10,890.00 | 20% | $ 2,178.00 | $ 13,068.00 |
| SUB: Dredger | Small Tool and Equipment | Skiff | 1 | $ 250.00 | $/day | 5 | day | $ 1,320.00 | 25.0% | $ 330.00 | $ 1,650.00 | 20% | $ 330.00 | $ 1,980.00 |
| SUB: Dredger | Workboat | | 1 | $ 100.00 | $/day | 5 | day | $ 528.00 | 25.0% | $ 132.00 | $ 660.00 | 20% | $ 132.00 | $ 792.00 |
| SUB: Dredger | FOGM | | 500 | $ 3.50 | $/gal | 5 | day | $ 9,240.00 | 10.0% | $ 924.00 | $ 10,164.00 | 20% | $ 2,032.80 | $ 12,196.80 |
| SUB: Dredger | Office Trailer Rentals | | 2 | $ 350.00 | $/mo | 0 | mo | $ 121.42 | 25.0% | $ 30.35 | $ 151.77 | 20% | $ 30.35 | $ 182.13 |
| SUB: Dredger | Office Trailer | | 1 | $ 50.00 | $/day | 5 | day | $ 264.00 | 25.0% | $ 66.00 | $ 330.00 | 20% | $ 66.00 | $ 396.00 |
| ***Subtotal*** | | | | | | | | **$ 102,221.39** | | **$ 23,515.95** | **$ 125,737.34** | | **$ 25,147.47** | **$ 150,884.80** |

**Task 2 - Dredge Open Areas** **35 days** **52,200 $yd^3$** **1,500 $yd^3$/day**

| | Description | Resource Description | No of Units | Unit Rate | Units | Additional Units | Unit Description | Raw Cost | Subcontractor Markup | Subcontractor Markup Amount | Total Cost | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Dredging PM | Dredge Labor | 6 | $ 65.40 | $/hr | 35 | day | $ 13,655.52 | 25.0% | $ 3,413.88 | $ 17,069.40 | 20% | $ 3,413.88 | $ 20,483.28 |
| SUB: Dredger | Dredge Operator (ST) | Dredge Labor | 16 | $ 74.83 | $/hr | 35 | day | $ 41,664.51 | 25.0% | $ 10,416.13 | $ 52,080.64 | 20% | $ 10,416.13 | $ 62,496.76 |
| SUB: Dredger | Dredge Operator (OT) | Dredge Labor | 8 | $ 96.92 | $/hr | 35 | day | $ 26,981.79 | 25.0% | $ 6,745.45 | $ 33,727.24 | 20% | $ 6,745.45 | $ 40,472.69 |
| SUB: Dredger | Dredge Labor (ST) | Dredge Labor | 32 | $ 30.33 | $/hr | 35 | day | $ 33,780.72 | 25.0% | $ 8,445.18 | $ 42,225.90 | 20% | $ 8,445.18 | $ 50,671.08 |
| SUB: Dredger | Dredge Labor (OT) | Dredge Labor | 16 | $ 42.28 | $/hr | 35 | day | $ 23,539.08 | 25.0% | $ 5,884.77 | $ 29,423.85 | 20% | $ 5,884.77 | $ 35,308.62 |
| SUB: Dredger | Safety Supplies | | 9 | $ 25.00 | $/day | 35 | day | $ 7,830.00 | 10.0% | $ 783.00 | $ 8,613.00 | 20% | $ 1,722.60 | $ 10,335.60 |
| SUB: Dredger | Hotel | | 4 | $ 100.00 | $/day | 35 | day | $ 13,920.00 | 10.0% | $ 1,392.00 | $ 15,312.00 | 20% | $ 3,062.40 | $ 18,374.40 |

**TABLE G-4c**
**Dredging Assumptions - Alternative 4**
*United Heckathorn Superfund Site, Richmond, California*

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Per diem | | 4 | $ 50.00 | $/day | 35 | day | $ 6,960.00 | 10.0% | $ 696.00 | $ 7,656.00 | 20% | $ 1,531.20 | $ 9,187.20 |
| SUB: Dredger | Truck | | 2 | $ 75.00 | $/day | 35 | day | $ 5,220.00 | 25.0% | $ 1,305.00 | $ 6,525.00 | 20% | $ 1,305.00 | $ 7,830.00 |
| SUB: Dredger | Dredge Rental | 40 x 80 Flat Deck Spud Barge with CAT 345 & 4 $yd^3$ Environmental Bucket and Support Equipment | 1 | $ 10,000.00 | $/day | 35 | day | $ 348,000.00 | 25.0% | $ 87,000.00 | $ 435,000.00 | 20% | $ 87,000.00 | $ 522,000.00 |
| SUB: Dredger | Tender Tug | | 1 | $ 550.00 | $/hr | 35 | day | $ 19,140.00 | 25.0% | $ 4,785.00 | $ 23,925.00 | 20% | $ 4,785.00 | $ 28,710.00 |
| SUB: Dredger | Tow Tug | | 3 | $ 550.00 | $/hr | 35 | day | $ 57,420.00 | 25.0% | $ 14,355.00 | $ 71,775.00 | 20% | $ 14,355.00 | $ 86,130.00 |
| SUB: Dredger | Small Tool and Equipment | Skiff | 1 | $ 250.00 | $/day | 35 | day | $ 8,700.00 | 25.0% | $ 2,175.00 | $ 10,875.00 | 20% | $ 2,175.00 | $ 13,050.00 |
| SUB: Dredger | Workboat | | 1 | $ 100.00 | $/day | 35 | day | $ 3,480.00 | 25.0% | $ 870.00 | $ 4,350.00 | 20% | $ 870.00 | $ 5,220.00 |
| SUB: Dredger | FOGM | | 500 | $ 3.50 | $/gal | 35 | day | $ 60,900.00 | 10.0% | $ 6,090.00 | $ 66,990.00 | 20% | $ 13,398.00 | $ 80,388.00 |
| SUB: Dredger | Office Trailer Rentals | | 2 | $ 350.00 | $/mo | 1 | mo | $ 350.00 | 25.0% | $ 87.50 | $ 437.50 | 20% | $ 87.50 | $ 525.00 |
| SUB: Dredger | Office Trailer | | 1 | $ 50.00 | $/day | 35 | day | $ 1,740.00 | 25.0% | $ 435.00 | $ 2,175.00 | 20% | $ 435.00 | $ 2,610.00 |
| ***Subtotal*** | | | | | | | | **$ 673,281.62** | | **$ 154,878.91** | **$ 828,160.53** | | **$ 165,632.11** | **$ 993,792.63** |

**Task 3 - Turbidity Controls** **39 days**

| | Description | Resource Description | No of Units | Unit Rate | Units | Additional Units | Unit Description | Raw Cost | Subcontractor Markup | Subcontractor Markup Amount | Total Cost | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Turbidity Curtains | 25-ft Depth, Supply, Install, Move with Dredge | 2400 | $ 28.50 | $/lf | 1 | na | $ 68,400.00 | 25.0% | $ 17,100.00 | $ 85,500.00 | 20% | $ 17,100.00 | $ 102,600.00 |
| SUB: Dredger | Dredge Operator (ST) | Dredge Labor | 4 | $ 74.83 | $/hr | 39 | day | $ 11,804.94 | 25.0% | $ 2,951.24 | $ 14,756.18 | 20% | $ 2,951.24 | $ 17,707.42 |
| SUB: Dredger | Dredge Labor (ST) | Dredge Labor | 4 | $ 30.33 | $/hr | 39 | day | $ 4,785.60 | 25.0% | $ 1,196.40 | $ 5,982.00 | 20% | $ 1,196.40 | $ 7,178.40 |
| SUB: Dredger | Hotel | | 1 | $ 100.00 | $/day | 39 | day | $ 3,944.00 | 10.0% | $ 394.40 | $ 4,338.40 | 20% | $ 867.68 | $ 5,206.08 |
| SUB: Dredger | Per diem | | 1 | $ 50.00 | $/day | 39 | day | $ 1,972.00 | 10.0% | $ 197.20 | $ 2,169.20 | 20% | $ 433.84 | $ 2,603.04 |
| SUB: Dredger | Truck | | 1 | $ 75.00 | $/day | 39 | day | $ 2,958.00 | 25.0% | $ 739.50 | $ 3,697.50 | 20% | $ 739.50 | $ 4,437.00 |
| SUB: Dredger | Equipment | Boat | 1 | $ 150.00 | $/day | 39 | day | $ 5,916.00 | 25.0% | $ 1,479.00 | $ 7,395.00 | 20% | $ 1,479.00 | $ 8,874.00 |
| SUB: Dredger | Disposal | Non-hazardous | 48 | $ 75.00 | $/ton | 1 | na | $ 3,600.00 | 25.0% | $ 900.00 | $ 4,500.00 | 20% | $ 900.00 | $ 5,400.00 |
| SUB: Dredger | FOGM | | 10 | $ 3.50 | $/gal | 39 | day | $ 1,380.40 | 10.0% | $ 138.04 | $ 1,518.44 | 20% | $ 303.69 | $ 1,822.13 |
| SUB: Dredger | Safety Supplies | | 9 | $ 25.00 | $/day | 39 | day | $ 8,874.00 | 10.0% | $ 887.40 | $ 9,761.40 | 20% | $ 1,952.28 | $ 11,713.68 |
| ***Subtotal*** | | | | | | | | **$ 113,634.95** | | **$ 25,983.18** | **$ 139,618.12** | | **$ 27,923.62** | **$ 167,541.75** |

**Task 4 - Supply Portland Cement Reagent**

| | Description | Resource Description | No of Units | Unit Rate | Units | Additional Units | Unit Description | Raw Cost | Subcontractor Markup | Subcontractor Markup Amount | Total Cost | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Purchase Portland Cement | | 6,999 | $ 125.00 | $/ton | 1 | na | $ 874,885.57 | 10.0% | $ 87,488.56 | $ 962,374.13 | 20% | $ 192,474.83 | $ 1,154,848.96 |
| ***Subtotal*** | | | | | | | | **$ 874,885.57** | **$ 0.10** | **$ 87,488.56** | **$ 962,374.13** | | **$ 192,474.83** | **$ 1,154,848.96** |

**Task 5 - Mix Reagents; Stockpile Sediment on Pad** **59 days** **6999 ton agent**

| | Resource | Resource Description | Quantity | Unit Rate | Units | Additional Units | Unit Description | Cost | Subcontractor Markup | Subcontractor Markup Amount | Total | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Treatment Contractor | Dredging PM | Landside Labor | 6 | $ 65.40 | $/hr | 59 | day | $ 23,324.26 | 25.0% | $ 5,831.06 | $ 29,155.32 | 20% | $ 5,831.06 | $ 34,986.38 |
| SUB: Treatment Contractor | Operator (ST) | Landside Labor | 16 | $ 74.83 | $/hr | 59 | day | $ 71,164.90 | 25.0% | $ 17,791.22 | $ 88,956.12 | 20% | $ 17,791.22 | $ 106,747.34 |
| SUB: Treatment Contractor | Operator (OT) | Landside Labor | 4 | $ 96.92 | $/hr | 59 | day | $ 23,043.07 | 25.0% | $ 5,760.77 | $ 28,803.84 | 20% | $ 5,760.77 | $ 34,564.60 |
| SUB: Treatment Contractor | Labor (ST) | Landside Labor | 16 | $ 30.33 | $/hr | 59 | day | $ 28,849.51 | 25.0% | $ 7,212.38 | $ 36,061.89 | 20% | $ 7,212.38 | $ 43,274.27 |
| SUB: Treatment Contractor | Labor (OT) | Landside Labor | 4 | $ 42.28 | $/hr | 59 | day | $ 10,051.46 | 25.0% | $ 2,512.86 | $ 12,564.32 | 20% | $ 2,512.86 | $ 15,077.19 |
| SUB: Treatment Contractor | Hotel | | 4 | $ 100.00 | $/day | 59 | day | $ 23,776.00 | 10.0% | $ 2,377.60 | $ 26,153.60 | 20% | $ 5,230.72 | $ 31,384.32 |
| SUB: Treatment Contractor | Per diem | | 4 | $ 50.00 | $/day | 59 | day | $ 11,888.00 | 10.0% | $ 1,188.80 | $ 13,076.80 | 20% | $ 2,615.36 | $ 15,692.16 |
| SUB: Treatment Contractor | Truck | | 2 | $ 75.00 | $/day | 59 | day | $ 8,916.00 | 25.0% | $ 2,229.00 | $ 11,145.00 | 20% | $ 2,229.00 | $ 13,374.00 |
| SUB: Treatment Contractor | CAT 345 Extended Stick Rental | | 1 | $ 1,250.00 | $/day | 59 | day | $ 74,300.00 | 25.0% | $ 18,575.00 | $ 92,875.00 | 20% | $ 18,575.00 | $ 111,450.00 |
| SUB: Treatment Contractor | Grinder and Screen | | 1 | $ 1,500.00 | $/day | 59 | day | $ 89,160.00 | 25.0% | $ 22,290.00 | $ 111,450.00 | 20% | $ 22,290.00 | $ 133,740.00 |
| SUB: Treatment Contractor | Cement/FlyAsh Metering and Pumill (Rapid Mix 400) | | 1 | $ 1,467.00 | $/day | 59 | day | $ 87,198.48 | 25.0% | $ 21,799.62 | $ 108,998.10 | 20% | $ 21,799.62 | $ 130,797.72 |
| SUB: Treatment Contractor | Wheel Loader (Cat IT62H) | | 1 | $ 269.00 | $/day | 59 | day | $ 15,989.36 | 25.0% | $ 3,997.34 | $ 19,986.70 | 20% | $ 3,997.34 | $ 23,984.04 |
| SUB: Treatment Contractor | Radial Stacking Conveyor | | 1 | $ 171.00 | $/day | 59 | day | $ 10,164.24 | 25.0% | $ 2,541.06 | $ 12,705.30 | 20% | $ 2,541.06 | $ 15,246.36 |
| SUB: Treatment Contractor | Misc. Pumps, Hoses | | 1 | $ 150.00 | $/day | 59 | day | $ 8,916.00 | 25.0% | $ 2,229.00 | $ 11,145.00 | 20% | $ 2,229.00 | $ 13,374.00 |
| SUB: Treatment Contractor | 100 ton Pig Rental | | 1 | $ 350.00 | $/day | 59 | day | $ 20,804.00 | 25.0% | $ 5,201.00 | $ 26,005.00 | 20% | $ 5,201.00 | $ 31,206.00 |
| SUB: Treatment Contractor | Light Plant Rental | | 4 | $ 250.00 | $/day | 59 | day | $ 59,440.00 | 25.0% | $ 14,860.00 | $ 74,300.00 | 20% | $ 14,860.00 | $ 89,160.00 |

**TABLE G-4c**
**Dredging Assumptions - Alternative 4**
*United Heckathorn Superfund Site, Richmond, California*

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Treatment Contractor | Misc. Expenses | | 1 | $ 250.00 | $/day | 59 | day | $ 14,860.00 | 25.0% | $ 3,715.00 | $ 18,575.00 | 20% | $ 3,715.00 | $ 22,290.00 |
| SUB: Treatment Contractor | Office Trailer Rentals | | 2 | $ 350.00 | $/mo | 2 | mo | $ 1,386.93 | 25.0% | $ 346.73 | $ 1,733.67 | 20% | $ 346.73 | $ 2,080.40 |
| SUB: Treatment Contractor | Office Trailer | | 1 | $ 17.00 | $/day | 59 | day | $ 1,010.48 | 25.0% | $ 252.62 | $ 1,263.10 | 20% | $ 252.62 | $ 1,515.72 |
| SUB: Treatment Contractor | Bobcat | | 1 | $ 75.00 | $/day | 59 | day | $ 4,458.00 | 25.0% | $ 1,114.50 | $ 5,572.50 | 20% | $ 1,114.50 | $ 6,687.00 |
| SUB: Treatment Contractor | Port a Potty | | 1 | $ 7.00 | $/day | 59 | day | $ 416.08 | 25.0% | $ 104.02 | $ 520.10 | 20% | $ 104.02 | $ 624.12 |
| SUB: Treatment Contractor | FOGM | | 500 | $ 3.25 | $/gal | 59 | day | $ 96,590.00 | 10.0% | $ 9,659.00 | $ 106,249.00 | 20% | $ 21,249.80 | $ 127,498.80 |
| SUB: Mobile Lab Supplier | Mob Mobile Laboratory | | 1 | $ 1,750.00 | $/trip | 1 | na | $ 1,750.00 | 15.0% | $ 262.50 | $ 2,012.50 | 20% | $ 402.50 | $ 2,415.00 |
| SUB: Mobile Lab Supplier | Mobile Laboratory | | 1 | $ 2,565.00 | $/day | 59 | day | $ 152,463.60 | 15.0% | $ 22,869.54 | $ 175,333.14 | 20% | $ 35,066.63 | $ 210,399.77 |
| ***Subtotal*** | | | | | | | | **$ 839,920.37** | | **$ 174,720.63** | **$ 1,014,641.00** | | **$ 202,928.20** | **$ 1,217,569.20** |

**Task 6 - Load Class 1 Non-RCRA Stabilized Materials into Rail; Transport and Dispose at Landfill (Utah) [Tight Areas]** — **10,752 tons** — **12 days** — **893 tons/day**

| | Resource | Resource Description | Quantity | Unit Rate | Units | Additional Units | Unit Description | Cost | Subcontractor Markup | Subcontractor Markup Amount | Total | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Treatment Contractor | Wheel Loader (Cat IT62H) | | 1 | $ 269.00 | $/day | 12 | day | $ 3,238.86 | 25.0% | $ 809.71 | $ 4,048.57 | 20% | $ 809.71 | $ 4,858.29 |
| SUB: Treatment Contractor | Dredging PM | | 2 | $ 65.40 | $/hr | 12 | day | $ 1,574.88 | 25.0% | $ 393.72 | $ 1,968.60 | 20% | $ 393.72 | $ 2,362.32 |
| SUB: Treatment Contractor | Loader Operator (ST) | Loader Operator | 8 | $ 74.83 | $/hr | 12 | day | $ 7,207.70 | 25.0% | $ 1,801.92 | $ 9,009.62 | 20% | $ 1,801.92 | $ 10,811.55 |
| SUB: Treatment Contractor | Loader Operator (OT) | Loader Operator | 4 | $ 96.92 | $/hr | 12 | day | $ 4,667.68 | 25.0% | $ 1,166.92 | $ 5,834.60 | 20% | $ 1,166.92 | $ 7,001.52 |
| SUB: Treatment Contractor | Laborer (ST) | Laborer | 24 | $ 30.33 | $/hr | 12 | day | $ 8,765.78 | 25.0% | $ 2,191.44 | $ 10,957.22 | 20% | $ 2,191.44 | $ 13,148.67 |
| SUB: Treatment Contractor | Laborer (OT) | Laborer | 12 | $ 42.28 | $/hr | 12 | day | $ 6,108.17 | 25.0% | $ 1,527.04 | $ 7,635.21 | 20% | $ 1,527.04 | $ 9,162.25 |
| SUB: Treatment Contractor | Hotel | | 4 | $ 100.00 | $/day | 12 | day | $ 4,816.14 | 10.0% | $ 481.61 | $ 5,297.76 | 20% | $ 1,059.55 | $ 6,357.31 |
| SUB: Treatment Contractor | Per diem | | 4 | $ 50.00 | $/day | 12 | day | $ 2,408.07 | 10.0% | $ 240.81 | $ 2,648.88 | 20% | $ 529.78 | $ 3,178.66 |
| SUB: Treatment Contractor | CAT 345 Rental | | 1 | $ 1,250.00 | $/day | 12 | day | $ 15,050.45 | 25.0% | $ 3,762.61 | $ 18,813.06 | 20% | $ 3,762.61 | $ 22,575.68 |
| SUB: Treatment Contractor | FOGM (Site equipment) | | 120 | $ 3.50 | $/gal | 12 | day | $ 5,056.95 | 10.0% | $ 505.70 | $ 5,562.65 | 20% | $ 1,112.53 | $ 6,675.18 |
| SUB: Treatment Contractor | On Site Scales | Full Length Portable | 1 | $ 175.00 | $/day | 12 | day | $ 2,107.06 | 10.0% | $ 210.71 | $ 2,317.77 | 20% | $ 463.55 | $ 2,781.32 |
| SUB: Treatment Contractor | Sediment Transportation | Liner | 512 | $ 40.00 | $/load | 1 | na | $ 20,480.08 | 5.0% | $ 1,024.00 | $ 21,504.08 | 20% | $ 4,300.82 | $ 25,804.90 |
| ***Subtotal*** | | | | | | | | **$ 81,481.82** | | **$ 14,116.20** | **$ 95,598.02** | | **$ 19,119.60** | **$ 114,717.63** |

**Task 7 - Load Class 1 Non-RCRA Stabilized Materials into Rail; Transport and Dispose at Landfill (Utah) [Open Areas]** — **85,889 tons** — **34.8 days** — **2,468 tons/day**

| | Resource | Resource Description | Quantity | Unit Rate | Units | Additional Units | Unit Description | Cost | Subcontractor Markup | Subcontractor Markup Amount | Total | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Wheel Loader (Cat IT62H) | | 1 | $ 269.00 | $/day | 35 | day | $ 9,361.20 | 25.0% | $ 2,340.30 | $ 11,701.50 | 20% | $ 2,340.30 | $ 14,041.80 |
| SUB: Dredger | Dredging PM | | 2 | $ 65.40 | $/hr | 35 | day | $ 4,551.84 | 25.0% | $ 1,137.96 | $ 5,689.80 | 20% | $ 1,137.96 | $ 6,827.76 |
| SUB: Dredger | Dredge Operator (ST) | Dredge Labor | 8 | $ 74.83 | $/hr | 35 | day | $ 20,832.25 | 25.0% | $ 5,208.06 | $ 26,040.32 | 20% | $ 5,208.06 | $ 31,248.38 |
| SUB: Dredger | Dredge Operator (OT) | Dredge Labor | 4 | $ 96.92 | $/hr | 35 | day | $ 13,490.90 | 25.0% | $ 3,372.72 | $ 16,863.62 | 20% | $ 3,372.72 | $ 20,236.34 |
| SUB: Dredger | Dredge Labor (ST) | Dredge Labor | 24 | $ 30.33 | $/hr | 35 | day | $ 25,335.54 | 25.0% | $ 6,333.89 | $ 31,669.43 | 20% | $ 6,333.89 | $ 38,003.31 |
| SUB: Dredger | Dredge Labor (OT) | Dredge Labor | 12 | $ 42.28 | $/hr | 35 | day | $ 17,654.31 | 25.0% | $ 4,413.58 | $ 22,067.89 | 20% | $ 4,413.58 | $ 26,481.47 |
| SUB: Treatment Contractor | CAT 345 Rental | | 1 | $ 1,250.00 | $/day | 35 | day | $ 43,500.00 | 25.0% | $ 10,875.00 | $ 54,375.00 | 20% | $ 10,875.00 | $ 65,250.00 |
| SUB: Dredger | Hotel | | 4 | $ 100.00 | $/day | 35 | day | $ 13,920.00 | 10.0% | $ 1,392.00 | $ 15,312.00 | 20% | $ 3,062.40 | $ 18,374.40 |
| SUB: Dredger | Per diem | | 4 | $ 50.00 | $/day | 35 | day | $ 6,960.00 | 10.0% | $ 696.00 | $ 7,656.00 | 20% | $ 1,531.20 | $ 9,187.20 |
| SUB: Dredger | Truck | | 2 | $ 75.00 | $/day | 35 | day | $ 5,220.00 | 25.0% | $ 1,305.00 | $ 6,525.00 | 20% | $ 1,305.00 | $ 7,830.00 |
| SUB: Dredger | FOGM | | 60 | $ 3.50 | $/gal | 35 | day | $ 7,308.00 | 10.0% | $ 730.80 | $ 8,038.80 | 20% | $ 1,607.76 | $ 9,646.56 |
| SUB: Mobile Lab Supplier | Mobile Laboratory | | 1 | $ 2,565.00 | $/day | 35 | day | $ 89,262.00 | 15.0% | $ 13,389.30 | $ 102,651.30 | 20% | $ 20,530.26 | $ 123,181.56 |
| SUB: Treatment Contractor | On Site Scales | Full Length Portable | 1 | $ 175.00 | $/day | 35 | day | $ 6,090.00 | 10.0% | $ 609.00 | $ 6,699.00 | 20% | $ 1,339.80 | $ 8,038.80 |
| SUB: Excavation Contractor | Sediment Transportation | Liner | 4090 | $ 50.00 | $/load | 1 | na | $ 204,498.25 | 5.0% | $ 10,224.91 | $ 214,723.17 | 20% | $ 42,944.63 | $ 257,667.80 |
| ***Subtotal*** | | | | | | | | **$ 458,623.10** | | **$ 59,688.22** | **$ 518,311.32** | | **$ 103,662.26** | **$ 636,015.38** |

**Task 8 - Water Treatment** — **83 days**

| | Resource | Resource Description | Quantity | Unit Rate | Units | Additional Units | Unit Description | Cost | Subcontractor Markup | Subcontractor Markup Amount | Total | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Water Treatment Sub | Dredging PM | | 4 | $ 65.40 | $/hr | 83 | day | $ 21,769.31 | 25.0% | $ 5,442.33 | $ 27,211.63 | 20% | $ 5,442.33 | $ 32,653.96 |
| SUB: Water Treatment Sub | WWT Operator (ST) | Dredge Labor | 32 | $ 74.83 | $/hr | 83 | day | $ 199,261.71 | 25.0% | $ 49,815.43 | $ 249,077.14 | 20% | $ 49,815.43 | $ 298,892.57 |
| SUB: Water Treatment Sub | WWT Operator (OT) | Dredge Labor | 16 | $ 96.92 | $/hr | 83 | day | $ 129,041.19 | 25.0% | $ 32,260.30 | $ 161,301.48 | 20% | $ 32,260.30 | $ 193,561.78 |
| SUB: Water Treatment Sub | WWT Labor (ST) | Dredge Labor | 32 | $ 30.33 | $/hr | 83 | day | $ 80,778.64 | 25.0% | $ 20,194.66 | $ 100,973.30 | 20% | $ 20,194.66 | $ 121,167.95 |
| SUB: Water Treatment Sub | WWT Labor (OT) | Dredge Labor | 16 | $ 42.28 | $/hr | 83 | day | $ 56,288.17 | 25.0% | $ 14,072.04 | $ 70,360.21 | 20% | $ 14,072.04 | $ 84,432.25 |
| SUB: Dredger | Hotel | | 8 | $ 100.00 | $/day | 83 | day | $ 66,572.80 | 10.0% | $ 6,657.28 | $ 73,230.08 | 20% | $ 14,646.02 | $ 87,876.10 |
| SUB: Dredger | Per diem | | 8 | $ 50.00 | $/day | 83 | day | $ 33,286.40 | 10.0% | $ 3,328.64 | $ 36,615.04 | 20% | $ 7,323.01 | $ 43,938.05 |
| SUB: Dredger | Truck | | 4 | $ 75.00 | $/day | 83 | day | $ 24,964.80 | 25.0% | $ 6,241.20 | $ 31,206.00 | 20% | $ 6,241.20 | $ 37,447.20 |
| SUB: Dredger | FOGM | | 120 | $ 3.50 | $/gal | 83 | day | $ 34,950.72 | 10.0% | $ 3,495.07 | $ 38,445.79 | 20% | $ 7,689.16 | $ 46,134.95 |

**TABLE G-4c**
**Dredging Assumptions - Alternative 4**
*United Heckathorn Superfund Site, Richmond, California*

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Safety Supplies | | 9 | $ 25.00 | $/day | 83 | day | $ 18,723.60 | 10.0% | $ 1,872.36 | $ 20,595.96 | 20% | $ 4,119.19 | $ 24,715.15 |
| SUB: Water Treatment Sub | Transfer Pump | Scows to System | 1 | $ 125.00 | $/day | 83 | day | $ 10,402.00 | 25.0% | $ 2,600.50 | $ 13,002.50 | 20% | $ 2,600.50 | $ 15,603.00 |
| SUB: Water Treatment Sub | Influent Frac Tank | | 2 | $ 45.00 | $/day | 83 | day | $ 7,489.44 | 25.0% | $ 1,872.36 | $ 9,361.80 | 20% | $ 1,872.36 | $ 11,234.16 |
| SUB: Water Treatment Sub | WWT Manifolds | | 2 | $ 6,000.00 | $/day | 35 | day | $ 417,600.00 | 25.0% | $ 104,400.00 | $ 522,000.00 | 20% | $ 104,400.00 | $ 626,400.00 |
| SUB: Water Treatment Sub | Pumps | | 1 | $ 150.00 | $/day | 83 | day | $ 12,482.40 | 25.0% | $ 3,120.60 | $ 15,603.00 | 20% | $ 3,120.60 | $ 18,723.60 |
| SUB: Water Treatment Sub | Sand Filters (2 units) | | 1 | $ 150.00 | $/day | 83 | day | $ 12,482.40 | 25.0% | $ 3,120.60 | $ 15,603.00 | 20% | $ 3,120.60 | $ 18,723.60 |
| SUB: Water Treatment Sub | GAC Filters (2 units) | | 1 | $ 250.00 | $/day | 83 | day | $ 20,804.00 | 25.0% | $ 5,201.00 | $ 26,005.00 | 20% | $ 5,201.00 | $ 31,206.00 |
| SUB: Water Treatment Sub | Bag Filter Pods | RFR 2 Bag Units | 2 | $ 75.00 | $/day | 83 | day | $ 12,482.40 | 25.0% | $ 3,120.60 | $ 15,603.00 | 20% | $ 3,120.60 | $ 18,723.60 |
| SUB: Water Treatment Sub | Sand | RFR 4 Pod Unit, 8 Tons per Charge | 16 | $ 50.00 | $/ton | 1 | na | $ 800.00 | 25.0% | $ 200.00 | $ 1,000.00 | 20% | $ 200.00 | $ 1,200.00 |
| SUB: Water Treatment Sub | Granular Activated Carbon | 5000 lb per vessel per charge, Assume 2 charges | 20,000 | $ 2.50 | $/lb | 1 | na | $ 50,000.00 | 25.0% | $ 12,500.00 | $ 62,500.00 | 20% | $ 12,500.00 | $ 75,000.00 |
| SUB: Water Treatment Sub | 10 Micron Filter Bags, 4 per day | | 4 | $ 5.50 | ea | 83 | na | $ 1,830.75 | 25.0% | $ 457.69 | $ 2,288.44 | 20% | $ 457.69 | $ 2,746.13 |
| SUB: Water Treatment Sub | Backwash Supply Tank | RFR 20,000 Frac Tank | 1 | $ 45.00 | $/day | 83 | day | $ 3,744.72 | 25.0% | $ 936.18 | $ 4,680.90 | 20% | $ 936.18 | $ 5,617.08 |
| SUB: Water Treatment Sub | Backwash Waste Tank | RFR 20,000 Frac Tank | 1 | $ 45.00 | $/day | 83 | day | $ 3,744.72 | 25.0% | $ 936.18 | $ 4,680.90 | 20% | $ 936.18 | $ 5,617.08 |
| SUB: Water Treatment Sub | Effluent Holding Tank | RFR 20,000 Frac Tank | 1 | $ 45.00 | $/day | 83 | day | $ 3,744.72 | 25.0% | $ 936.18 | $ 4,680.90 | 20% | $ 936.18 | $ 5,617.08 |
| SUB: Water Treatment Sub | Chemicals | | 1 | $ 75.00 | $/day | 83 | day | $ 6,241.20 | 10.0% | $ 624.12 | $ 6,865.32 | 20% | $ 1,373.06 | $ 8,238.38 |
| SUB: Water Treatment Sub | Vendor start-up assistance and expenses | | 5 | $ 2,500.00 | $/day | 1 | na | $ 12,500.00 | 25.0% | $ 3,125.00 | $ 15,625.00 | 20% | $ 3,125.00 | $ 18,750.00 |
| SUB: Water Treatment Sub | Power/Electric | | 1 | $ 167.00 | $/day | 83 | day | $ 13,897.07 | 10.0% | $ 1,389.71 | $ 15,286.78 | 20% | $ 3,057.36 | $ 18,344.14 |
| SUB: Water Treatment Sub | Sand, GAC, TSS disposal allowance | | 1 | $ 50,000.00 | ea | 1 | na | $ 50,000.00 | 10.0% | $ 5,000.00 | $ 55,000.00 | 20% | $ 11,000.00 | $ 66,000.00 |
| SUB: Excavation Contractor | Water Treatment Residuals Transportation | | 26 | $ 10.00 | $/ton | 1 | na | $ 260.00 | 5.0% | $ 13.00 | $ 273.00 | 20% | $ 54.60 | $ 327.60 |
| SUB: Excavation Contractor | Water Treatment Residuals Transportation | Liner | 1.24 | $ 50.00 | $/load | 1 | na | $ 61.90 | 5.0% | $ 3.10 | $ 65.00 | 20% | $ 13.00 | $ 78.00 |
| SUB: Excavation Contractor | TSCA Disposal | Subtitle C Landfill | 26 | $ 80.00 | $/ton | 1 | na | $ 2,080.00 | 5.0% | $ 104.00 | $ 2,184.00 | 20% | $ 436.80 | $ 2,620.80 |
| ***Subtotal*** | | | | | | | | **$ 1,308,285.06** | | **$ 293,040.11** | **$ 1,601,325.17** | | **$ 320,265.03** | **$ 1,921,590.21** |

Assumes 24/7 Operations
Includes 4 People per Shift to Offload Water and Run the System

**Task 9 - Debris Removal and RCRA Subtitle D Disposal** **978 tons** **20 tons/day** **49 days**

| | Resource | Resource Description | Quantity | Unit Rate | Units | Additional Units | Unit Description | Cost | Subcontractor Markup | Subcontractor Markup Amount | Total | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Wheel Loader (Cat IT62H) | | 1 | $ 269.00 | $/day | 49 | day | $ 13,181.00 | 25.0% | $ 3,295.25 | $ 16,476.25 | 20% | $ 3,295.25 | $ 19,771.50 |
| SUB: Dredger | Dredging PM | | 1 | $ 65.40 | $/hr | 49 | day | $ 3,204.60 | 25.0% | $ 801.15 | $ 4,005.75 | 20% | $ 801.15 | $ 4,806.90 |
| SUB: Dredger | Dredge Operator (ST) | Dredge Labor | 2 | $ 74.83 | $/hr | 49 | day | $ 7,333.19 | 25.0% | $ 1,833.30 | $ 9,166.49 | 20% | $ 1,833.30 | $ 10,999.79 |
| SUB: Dredger | Dredge Labor (ST) | Dredge Labor | 2 | $ 30.33 | $/hr | 49 | day | $ 2,972.80 | 25.0% | $ 743.20 | $ 3,716.00 | 20% | $ 743.20 | $ 4,459.20 |
| SUB: Dredger | Hotel | | 0.5 | $ 100.00 | $/day | 49 | day | $ 2,450.00 | 10.0% | $ 245.00 | $ 2,695.00 | 20% | $ 539.00 | $ 3,234.00 |
| SUB: Dredger | Per diem | | 0.5 | $ 50.00 | $/day | 49 | day | $ 1,225.00 | 10.0% | $ 122.50 | $ 1,347.50 | 20% | $ 269.50 | $ 1,617.00 |
| SUB: Dredger | Truck | | 1 | $ 75.00 | $/day | 49 | day | $ 3,675.00 | 25.0% | $ 918.75 | $ 4,593.75 | 20% | $ 918.75 | $ 5,512.50 |
| SUB: Excavation Contractor | Sediment Transportation | | 978 | $ 10.00 | $/ton | 1 | na | $ 9,784.36 | 5.0% | $ 489.22 | $ 10,273.58 | 20% | $ 2,054.72 | $ 12,328.29 |
| SUB: Excavation Contractor | Sediment Transportation | Liner | 49 | $ 40.00 | $/load | 1 | na | $ 1,956.87 | 5.0% | $ 97.84 | $ 2,054.72 | 20% | $ 410.94 | $ 2,465.66 |
| SUB: Excavation Contractor | Disposal | Subtitle D Landfill | 394 | $ 50.00 | $/ton | 1 | na | $ 19,706.74 | 5.0% | $ 985.34 | $ 20,692.08 | 20% | $ 4,138.42 | $ 24,830.50 |
| SUB: Dredger | FOGM | | 60 | $ 3.25 | $/gal | 49 | day | $ 9,555.00 | 10.0% | $ 955.50 | $ 10,510.50 | 20% | $ 2,102.10 | $ 12,612.60 |
| ***Subtotal*** | | | | | | | | **$ 75,044.57** | | **$ 10,487.05** | **$ 85,531.62** | | **$ 17,106.32** | **$ 102,637.94** |

**Task 10 Mechanical Dredge Standby Time** **24 hrs**

| | Resource | Resource Description | Quantity | Unit Rate | Units | Additional Units | Unit Description | Cost | Subcontractor Markup | Subcontractor Markup Amount | Total | Contingency Multiplier | Contingency Amount | Total with Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Dredging PM | | 8 | $ 65.40 | $/hr | 1.0 | day | $ 523.20 | 25.0% | $ 130.80 | $ 654.00 | 20% | $ 130.80 | $ 784.80 |
| SUB: Dredger | Dredge Operator (ST) | Dredge Labor | 16 | $ 74.83 | $/hr | 1.0 | day | $ 1,197.26 | 25.0% | $ 299.31 | $ 1,496.57 | 20% | $ 299.31 | $ 1,795.88 |
| SUB: Dredger | Dredge Operator (OT) | Dredge Labor | 8 | $ 96.92 | $/hr | 1.0 | day | $ 775.34 | 25.0% | $ 193.83 | $ 969.17 | 20% | $ 193.83 | $ 1,163.01 |
| SUB: Dredger | Dredge Labor (ST) | Dredge Labor | 32 | $ 30.33 | $/hr | 1.0 | day | $ 970.71 | 25.0% | $ 242.68 | $ 1,213.39 | 20% | $ 242.68 | $ 1,456.07 |
| SUB: Dredger | Dredge Labor (OT) | Dredge Labor | 16 | $ 42.28 | $/hr | 1.0 | day | $ 676.41 | 25.0% | $ 169.10 | $ 845.51 | 20% | $ 169.10 | $ 1,014.62 |
| SUB: Dredger | Hotel | | 6 | $ 100.00 | $/day | 1.0 | day | $ 600.00 | 10.0% | $ 60.00 | $ 660.00 | 20% | $ 132.00 | $ 792.00 |
| SUB: Dredger | Per diem | | 6 | $ 50.00 | $/day | 1.0 | day | $ 300.00 | 10.0% | $ 30.00 | $ 330.00 | 20% | $ 66.00 | $ 396.00 |
| SUB: Dredger | Truck | | 5 | $ 75.00 | $/day | 1.0 | day | $ 375.00 | 25.0% | $ 93.75 | $ 468.75 | 20% | $ 93.75 | $ 562.50 |

**TABLE G-4c**
**Dredging Assumptions - Alternative 4**
*United Heckathorn Superfund Site, Richmond, California*

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB: Dredger | Dredge Rental | 40 x 80 Flat Deck Spud Barge with CAT 345 & 4 $yd^3$ Environmental Bucket and Support Equipment | 1 | $ 10,000.00 | $/day | 1.0 | day | $ 10,000.00 | 25.0% | $ 2,500.00 | $ 12,500.00 | 20% | $ 2,500.00 | $ 15,000.00 |
| SUB: Dredger | Tender Tug | | 1 | $ 550.00 | $/hr | 1.0 | day | $ 550.00 | 25.0% | $ 137.50 | $ 687.50 | 20% | $ 137.50 | $ 825.00 |
| SUB: Dredger | Scows | 30 ft x 60 ft, 700 $yd^3$ | 3 | $ 500.00 | $/day | 1.0 | day | $ 1,500.00 | 25.0% | $ 375.00 | $ 1,875.00 | 20% | $ 375.00 | $ 2,250.00 |
| SUB: Dredger | Tow Tug | | 1 | $ 550.00 | $/hr | 1.0 | day | $ 550.00 | 25.0% | $ 137.50 | $ 687.50 | 20% | $ 137.50 | $ 825.00 |
| SUB: Dredger | Equipment | Skiff | 1 | $ 100.00 | $/day | 1.0 | day | $ 100.00 | 25.0% | $ 25.00 | $ 125.00 | 20% | $ 25.00 | $ 150.00 |
| ***Subtotal*** | | | | | | | | **$ 18,117.92** | | **$ 4,394.48** | **$ 22,512.39** | | **$ 4,502.48** | **$ 27,014.87** |

| **Notes** | **Davis-Bacon Rates** | **Rate** | **Fringe** | **Taxes** | **Total** |
|---|---|---|---|---|---|
| Items do not include oversight effort | Dredge PM | $60.00 | -- | $5.40 | $65.40 |
| All cost based on estimates or RSMeans data | Operator (All) | $40.53 | $28.12 | $6.18 | $74.83 |
| All labor cost based on Davis-Bacon rates | Operator OT (All) | $60.80 | $28.12 | $8.00 | $96.92 |
| Scope details and assumptions provided elsewhere | Labor (All) | $21.91 | $5.92 | $2.50 | $30.33 |
| | Labor OT (All) | $32.87 | $5.92 | $3.49 | $42.28 |

U.S. Department of Labor. 2014. Davis Bacon Wage Determinations. http://www.wdol.gov/dba.aspx

**TABLE G-5a**
**Water Treatment Assumptions - Alternative 2**
*United Heckathorn Superfund Site, Richmond, California*

| Sources | Units | Average Daily Flow | Peak Maximum Daily Flow | Assumptions |
|---|---|---|---|---|
| **Mass of In Situ Sediment** | | | | |
| Project Dredge Volume | $yd^3$ | 58,000 | 58,000 | Assumed |
| Estimated In Situ Density of Sediment | $ton/yd^3$ | 1.6 | 1.6 | Soft sediment and partial clay/hard sediment |
| Mass of In Situ Sediment | tons | 92,800 | 92,800 | |
| In Situ Sediment Solids Content | % | 40% | 40% | Assumed |
| Estimated Dry Solids in Sediment | tons | 37,120 | 37,120 | |
| Solids after Mechanical Dredging (In Scows) | % | 35% | 35% | Assumed additional 5% water while lifting the bucket |
| Total Mass Delivered to Offload | tons | 106,057 | 106,057 | |
| **Dredging Production Rate** | | | | |
| Dredging Production Rate | $yd^3/day$ | 1375 | 1375 | Assumed, based on two dredge units |
| Estimated Days to Complete Dredging | days | 42 | 42 | |
| Estimated Minutes to Complete Dredging | minutes | 60,742 | 60,742 | |
| Estimated Minutes per Day | minutes | 1,440 | 1,440 | |
| **Water from Dredged Material** | | | | |
| Total Mass of Water in Scow (Dredged Sediment) | tons | 68,937 | 68,937 | |
| Total Volume of Water in Scow (Dredged Sediment) | gal | 16,531,689 | 16,531,689 | Total volume of water present in the sediment in scow |
| Estimated Water Recovery from Scows | % | 10% | 10% | Free water on top of dredged sediment in scow |
| Mass of Water Recovered from Scows | tons | 6,894 | 6,894 | |
| Volume of Water Recovered from Scows | gal | 1,653,169 | 1,653,169 | Free water on top of dredged sediment in scow |
| **Gravity-drained Water** | | | | |
| Water Drained/Released from Stockpiles due to Gravity, | % by mass | 10% | 10% | Assumed |
| Mass of Water Drained/Released from Stockpiles due to | tons | 6,894 | 6,894 | |
| Volume of Water Drained/Released from Stockpiles due to | gal | 1,653,169 | 1,653,169 | |
| **Precipitation Volume** | | | | |
| Average Monthly Rainfall from May - October | inches | 3.1 | 3.1 | rssweather.com |
| Staging Pad Footprint Area | $ft^2$ | 75000 | 75000 | Assumed |
| Average Monthly Rainfall Volume from May - October | gal | 144,944 | 144,944 | |
| Flowrate for 7 Days/Week and 24 Hours a Day | gpm | 3 | 3 | |
| Total Rainfall Volume for the Project Duration | gal | 203,801 | 203,801 | |

**TABLE G-5a**
**Water Treatment Assumptions - Alternative 2**
*United Heckathorn Superfund Site, Richmond, California*

| Sources | Units | Average Daily Flow | Peak Maximum Daily Flow | Assumptions |
|---|---|---|---|---|
| **Water from Decontamination** | | | | |
| Volume of Sediment/Truckload | $yd^3$ | 14 | 14 | |
| Days of Work | days | 42 | 42 | |
| Volume of Sediment Dredged/Day | $yd^3$/day | 1375 | 1375 | |
| Estimated Trucks/Day | No. | 98 | 98 | |
| Minutes/Truck to Decon | ıinutes/truck | 3 | 3 | |
| Minutes of Decon/Day | minutes/day | 295 | 295 | |
| Power-washer Flowrate | gpm | 4 | 4 | |
| Total Decon Water Volume for Project | gal | 49714 | 49714 | |
| Flowrate for 24 Hours | gpm | 0.818 | 0.818 | |
| **Stormwater Event (10-year 24-hour)** | | | | |
| Staging Area | $ft^2$ | NA | 75000 | |
| 10-year 24-hour Precipitation Depth | inches | NA | 3.130 | |
| Storm Water Generated | gal | NA | 146328 | |
| Total Storm Water Volume as Influent | gal | NA | 146328 | |
| Runoff Flowrate/Pumpoff Rate | gpm | NA | 102 | |
| **Stormwater Event (25-year-24-hour)** | | | | |
| TSCA Staging Area | $ft^2$ | NA | 4000 | Assumed |
| 25-year 24-hour Precipitation Depth | inches | NA | 3.600 | |
| Stormwater Generated at TSCA Staging | gal | NA | 8976 | |
| Total Stormwater Volume as Influent | gal | NA | 8976 | |
| Runoff Flowrate/Pumpoff Rate | gpm | NA | 6 | |
| **Backwash Water** | | | | |
| Volume per Day for Backwash | gal/day | 2400 | 2400 | Assumed |
| Total Volume for Backwash for the Project | gal | 101236 | 101236 | |
| Backwash Flowrate (for 1 Hour) | gpm | 40 | 40 | Assumed that backwash volume will be pumped during a 1-hour period per day |
| **Evaporation Loss** | | | | |
| Evaporation Loss | % | 5 | 5 | Assumed to be lost while sitting in the scows/sumps, etc. |
| Total Amount of Water Lost due to Evaporation | gal | 177993 | 185758 | |

**TABLE G-5a**
**Water Treatment Assumptions - Alternative 2**
*United Heckathorn Superfund Site, Richmond, California*

| Sources | Units | Average Daily Flow | Peak Maximum Daily Flow | Assumptions |
|---|---|---|---|---|
| ***TOTAL*** | | | | |
| Volume of Free Water Recovered from Scows | gal/project | 1,653,169 | 1,653,169 | |
| Flowrate of Free Water Recovered from Scows | gpm | 27.2 | 27.2 | |
| Total Rainwater Volume Estimate | gal/project | 203,801 | 203,801 | |
| Total Rainwater Flowrate | gpm | 3.4 | 3.4 | |
| Pressure Wash Water Volume | gal | 49,714 | 49,714 | |
| Pressure Wash Water Flowrate | gpm | 0.8 | 0.8 | |
| Volume of Gravity-drained Water (from Stockpiles to Sump) | gal | 1,653,169 | 1,653,169 | |
| Volume of Gravity-drained Water (from Stockpiles to Sump) | gpm | 27.2 | 27.2 | |
| Volume of Backwash Water | gal | 101,236 | 101,236 | |
| Backwash Water Flowrate | gpm | 40.0 | 40.0 | |
| Volume of 10-year Stormwater to be Treated | gal | NA | 146,327.5 | |
| 10-year Stormwater Runoff Rate | gpm | NA | 101.6 | |
| Volume of 25-year TSCA only Stormwater to be Treated | gal | NA | 8,976.0 | |
| 25-year TSCA only Stormwater Runoff Rate | gpm | NA | 6.2 | |
| Evaporation Losses | gal | 177,992.6 | 185,757.8 | |
| Evaporation Losses | gpm | 2.9 | 3.1 | |
| **Total Estimated Water to be Treated (Total Influent)** | **gal** | **3,483,096** | **3,630,635** | 42 days |
| **Estimated Influent Flowrate Over Total Dredging Duration** (Average for 24 Hours) | **gpm** | **96** | **203** | |
| | | | | |
| **Water Treatment** | | | | |
| Water Treatment Uptime | | 80% | 100% | Assuming a 100% uptime during a 10-year 24-hour and 25-year 24-hour major storm event and 80% uptime during the rest. |
| Hours/Day | | 24 | 24 | |
| Uptime/Day (WWT System) | minutes | 1152 | 1440 | |
| Process Time Available for Duration | minutes | 48,593 | | |
| **WWT System Capacity Required** | **gpm** | **120** | **203** | |

**TABLE G-5b**

**Water Treatment Assumptions - Alternative 3**

*United Heckathorn Superfund Site, Richmond, California*

| Sources | Units | Average Daily Flow | Peak Maximum Daily Flow | Assumptions |
|---|---|---|---|---|
| **Mass of In Situ Sediment** | | | | |
| Project Dredge Volume | $yd^3$ | 64,000 | 64,000 | Assumed |
| Estimated In Situ Density of Sediment | $ton/yd^3$ | 1.5 | 1.5 | Soft sediment and partial clay/hard sediment |
| Mass of In Situ Sediment | tons | 96,000 | 96,000 | |
| In Situ Sediment Solids Content | % | 40% | 40% | Assumed |
| Estimated Dry Solids in Sediment | tons | 38,400 | 38,400 | |
| Solids after Mechanical Dredging (In Scows) | % | 35% | 35% | Assumed additional 5% water while lifting the bucket |
| Total Mass Delivered to Offload | tons | 109,714 | 109,714 | |
| **Dredging Production Rate** | | | | |
| Dredging Production Rate | $yd^3/day$ | 1375 | 1375 | Assumed, based on two dredge units |
| Estimated Days to Complete Dredging | days | 47 | 47 | |
| Estimated Minutes to Complete Dredging | minutes | 67,025 | 67,025 | |
| Estimated Minutes per Day | minutes | 1,440 | 1,440 | |
| **Water from Dredged Material** | | | | |
| Total Mass of Water in Scow (Dredged Sediment) | tons | 71,314 | 71,314 | |
| Total Volume of Water in Scow (Dredged Sediment) | gal | 17,101,747 | 17,101,747 | Total volume of water present in the sediment in scow |
| Estimated Water Recovery from Scows | % | 10% | 10% | Free water on top of dredged sediment in scow |
| Mass of Water Recovered from Scows | tons | 7,131 | 7,131 | |
| Volume of Water Recovered from Scows | gal | 1,710,175 | 1,710,175 | Free water on top of dredged sediment in scow |
| **Gravity-drained Water** | | | | |
| Water Drained/Released from Stockpiles due to Gravity, Handling, and Compression | % by mass | 10% | 10% | Assumed |
| Mass of Water Drained/Released from Stockpiles due to Gravity, Handling, and Compression | tons | 7,131 | 7,131 | |
| Volume of Water Drained/Released from Stockpiles due to Gravity and Compression | gal | 1,710,175 | 1,710,175 | |
| **Precipitation Volume** | | | | |
| Average Monthly Rainfall from May - October | inches | 3.1 | 3.1 | rssweather.com |
| Staging Pad Footprint Area | $ft^2$ | 75000 | 75000 | Assumed |
| Average Monthly Rainfall Volume from May - October | gal | 144,944 | 144,944 | |
| Flowrate for 7 Days/Week and 24 Hours a Day | gpm | 3 | 3 | |
| Total Rainfall Volume for the Project Duration | gal | 224,883 | 224,883 | |

**TABLE G-5b**

**Water Treatment Assumptions - Alternative 3**

*United Heckathorn Superfund Site, Richmond, California*

| Sources | Units | Average Daily Flow | Peak Maximum Daily Flow | Assumptions |
|---|---|---|---|---|
| **Water from Decontamination** | | | | |
| Volume of Sediment/Truckload | $yd^3$ | 14 | 14 | |
| Days of Work | days | 47 | 47 | |
| Volume of Sediment Dredged/Day | $yd^3$/day | 1375 | 1375 | |
| Estimated Trucks/Day | No. | 98 | 98 | |
| Minutes/Truck to Decon | minutes/truck | 3 | 3 | |
| Minutes of Decon/Day | minutes/day | 295 | 295 | |
| Power-washer Flowrate | gpm | 4 | 4 | |
| Total Decon Water Volume for Project | gal | 54857 | 54857 | |
| Flowrate for 24 Hours | gpm | 0.818 | 0.818 | |
| **Stormwater Event (10-year 24-hour)** | | | | |
| Staging Area | $ft^2$ | NA | 75000 | |
| 10-year 24-hour Precipitation Depth | inches | NA | 3.130 | |
| Storm Water Generated | gal | NA | 146328 | |
| Total Storm Water Volume as Influent | gal | NA | 146328 | |
| Runoff Flowrate/Pumpoff Rate | gpm | NA | 102 | |
| **Stormwater Event (25-year 24-hour)** | | | | |
| TSCA Staging Area | $ft^2$ | NA | 4000 | Assumed |
| 25-year 24-hour Precipitation Depth | inches | NA | 3.600 | |
| Stormwater Generated at TSCA Staging | gal | NA | 8976 | |
| Total Stormwater Volume as Influent | gal | NA | 8976 | |
| Runoff Flowrate/Pumpoff Rate | gpm | NA | 6 | |
| **Backwash Water** | | | | |
| Volume per Day for Backwash | gal/day | 2400 | 2400 | Assumed |
| Total Volume for Backwash for the Project | gal | 111709 | 111709 | |
| Backwash Flowrate (for 1 Hour) | gpm | 40 | 40 | Assumed that backwash volume will be pumped during a 1-hour |
| **Evaporation Loss** | | | | |
| Evaporation Loss | % | 5 | 5 | Assumed to be lost while sitting in the scows/sumps, etc. |
| Total Amount of Water Lost due to Evaporation | gal | 185004 | 192770 | |

**TABLE G-5b**

**Water Treatment Assumptions - Alternative 3**

*United Heckathorn Superfund Site, Richmond, California*

| Sources | Units | Average Daily Flow | Peak Maximum Daily Flow | Assumptions |
|---|---|---|---|---|
| ***TOTAL*** | | | | |
| Volume of Free Water Recovered from Scows | gal/project | 1,710,175 | 1,710,175 | |
| Flowrate of Free Water Recovered from Scows | gpm | 25.5 | 25.5 | |
| Total Rainwater Volume Estimate | gal/project | 224,883 | 224,883 | |
| Total Rainwater Flowrate | gpm | 3.4 | 3.4 | |
| Pressure Wash Water Volume | gal | 54,857 | 54,857 | |
| Pressure Wash Water Flowrate | gpm | 0.8 | 0.8 | |
| Volume of Gravity-drained Water (from Stockpiles to Sump) | gal | 1,710,175 | 1,710,175 | |
| Volume of Gravity-drained Water (from Stockpiles to Sump) | gpm | 25.5 | 25.5 | |
| Volume of Backwash Water | gal | 111,709 | 111,709 | |
| Backwash Water Flowrate | gpm | 40.0 | 40.0 | |
| Volume of 10-year Stormwater to be Treated | gal | NA | 146,327.5 | |
| 10-year Stormwater Runoff Rate | gpm | NA | 101.6 | |
| Volume of 25-year TSCA only Stormwater to be Treated | gal | NA | 8,976.0 | |
| 25-year TSCA only Stormwater Runoff Rate | gpm | NA | 6.2 | |
| Evaporation Losses | gal | 185,004.5 | 192,769.7 | |
| Evaporation Losses | gpm | 2.8 | 2.9 | |
| **Total Estimated Water to be Treated (Total Influent)** | **gal** | **3,626,795** | **3,774,333** | 42 days |
| **Estimated Influent Flowrate Over Total Dredging Duration** (Average for 24 Hours) | **gpm** | **92** | **200** | |
| | | | | |
| **Water Treatment** | | | | |
| Water Treatment Uptime | | 80% | 100% | Assuming a 100% uptime during a 10-year 24-hour and 25-year 24-hour major storm event and 80% uptime during the rest |
| Hours/Day | | 24 | 24 | |
| Uptime/Day (WWT System) | minutes | 1152 | 1440 | |
| Process Time Available for Duration | minutes | 53,620 | | |
| **WWT System Capacity Required** | **gpm** | **116** | **200** | |

**TABLE G-5c**
**Water Treatment Assumptions - Alternative 4**
*United Heckathorn Superfund Site, Richmond, California*

| Sources | Units | Average Daily Flow | Peak Maximum Daily Flow | Assumptions |
|---|---|---|---|---|
| **Mass of In Situ Sediment** | | | | |
| Project Dredge Volume | $yd^3$ | 66,000 | 66,000 | Assumed |
| Estimated In Situ Density of Sediment | $ton/yd^3$ | 1.5 | 1.5 | Soft sediment and partial clay/hard sediment |
| Mass of In Situ Sediment | tons | 99,000 | 99,000 | |
| In Situ Sediment Solids Content | % | 40% | 40% | Assumed |
| Estimated Dry Solids in Sediment | tons | 39,600 | 39,600 | |
| Solids after Mechanical Dredging (In Scows) | % | 35% | 35% | Assumed additional 5% water while lifting the bucket |
| Total Mass Delivered to Offload | tons | 113,143 | 113,143 | |
| **Dredging Production Rate** | | | | |
| Dredging Production Rate | $yd^3/day$ | 1375 | 1375 | Assumed, based on two dredge units |
| Estimated Days to Complete Dredging | days | 48 | 48 | |
| Estimated Minutes to Complete Dredging | minutes | 69,120 | 69,120 | |
| Estimated Minutes per Day | minutes | 1,440 | 1,440 | |
| **Water from Dredged Material** | | | | |
| Total Mass of Water in Scow (Dredged Sediment) | tons | 73,543 | 73,543 | |
| Total Volume of Water in Scow (Dredged Sediment) | gal | 17,636,177 | 17,636,177 | Total volume of water present in the sediment in scow |
| Estimated Water Recovery from Scows | % | 10% | 10% | Free water on top of dredged sediment in scow |
| Mass of Water Recovered from Scows | tons | 7,354 | 7,354 | |
| Volume of Water Recovered from Scows | gal | 1,763,618 | 1,763,618 | Free water on top of dredged sediment in scow |
| **Gravity-drained water** | | | | |
| Water Drained/Released from Stockpiles due to Gravity, Handling, and Compression | % by mass | 10% | 10% | Assumed |
| Mass of Water Drained/Released from Stockpiles due to Gravity, Handling, and Compression | tons | 7,354 | 7,354 | |
| Volume of Water Drained/Released from Stockpiles due to Gravity and Compression | gal | 1,763,618 | 1,763,618 | |
| **Precipitation Volume** | | | | |
| Average Monthly Rainfall from May - October | inches | 3.1 | 3.1 | rssweather.com |
| Staging Pad Footprint Area | $ft^2$ | 75000 | 75000 | Assumed |
| Average Monthly Rainfall Volume from May - October | gal | 144,944 | 144,944 | |
| Flowrate for 7 Days/Week and 24 Hours a Day | gpm | 3 | 3 | |
| Total Rainfall Volume for the Project Duration | gal | 231,911 | 231,911 | |

**TABLE G-5c**
**Water Treatment Assumptions - Alternative 4**
*United Heckathorn Superfund Site, Richmond, California*

| Sources | Units | Average Daily Flow | Peak Maximum Daily Flow | Assumptions |
|---|---|---|---|---|
| **Water from decontamination** | | | | |
| Volume of Sediment/Truckload | $yd^3$ | 14 | 14 | |
| Days of Work | days | 48 | 48 | |
| Volume of Sediment Dredged/Day | $yd^3$/day | 1375 | 1375 | |
| Estimated Trucks/Day | No. | 98 | 98 | |
| Minutes/Truck to Decon | minutes/truck | 3 | 3 | |
| Minutes of Decon/Day | minutes/day | 295 | 295 | |
| Power-washer Flowrate | gpm | 4 | 4 | |
| Total Decon Water Volume for Project | gal | 56571 | 56571 | |
| Flowrate for 24 Hours | gpm | 0.818 | 0.818 | |
| **Storm Water Event (10-year-24-hour)** | | | | |
| Staging Area | $ft^2$ | NA | 75000 | |
| 10-year 24-hour Precipitation Depth | inches | NA | 3.130 | |
| Storm Water Generated | gal | NA | 146328 | |
| Total Storm Water Volume as Influent | gal | NA | 146328 | |
| Runoff Flowrate/Pumpoff Rate | gpm | NA | 102 | |
| **Storm Water Event (25 Year-24 hour)** | | | | |
| TSCA Staging Area | $ft^2$ | NA | 4000 | Assumed |
| 25-year 24-hour Precipitation Depth | inches | NA | 3.600 | |
| Stormwater Generated at TSCA Staging | gal | NA | 8976 | |
| Total Stormwater Volume as Influent | gal | NA | 8976 | |
| Runoff Flowrate/Pumpoff Rate | gpm | NA | 6 | |
| **Backwash Water** | | | | |
| Volume per Day for Backwash | gal/day | 2400 | 2400 | Assumed |
| Total Volume for Backwash for the Project | gal | 115200 | 115200 | |
| Backwash Flowrate (for 1 Hour) | gpm | 40 | 40 | Assumed that backwash volume will be pumped during a 1-hour period per day |
| **Evaporation Loss** | | | | |
| Evaporation Loss | % | 5 | 5 | Assumed to be lost while sitting in the scows/sumps, etc. |
| Total Amount of Water Lost due to Evaporation | gal | 190786 | 198551 | |
| ***TOTAL*** | | | | |
| Volume of Free Water Recovered from Scows | gal/project | 1,763,618 | 1,763,618 | |
| Flowrate of Free Water Recovered from Scows | gpm | 25.5 | 25.5 | |

**TABLE G-5c**

**Water Treatment Assumptions - Alternative 4**

*United Heckathorn Superfund Site, Richmond, California*

| Sources | Units | Average Daily Flow | Peak Maximum Daily Flow | Assumptions |
|---|---|---|---|---|
| Total Rainwater Volume Estimate | gal/project | 231,911 | 231,911 | |
| Total Rainwater Flowrate | gpm | 3.4 | 3.4 | |
| Pressure Wash Water Volume | gal | 56,571 | 56,571 | |
| Pressure Wash Water Flowrate | gpm | 0.8 | 0.8 | |
| Volume of Gravity-drained Water (from Stockpiles to Sump) | gal | 1,763,618 | 1,763,618 | |
| Volume of Gravity-drained Water (from Stockpiles to Sump) | gpm | 25.5 | 25.5 | |
| Volume of Backwash Water | gal | 115,200 | 115,200 | |
| Backwash Water Flowrate | gpm | 40.0 | 40.0 | |
| Volume of 10-year Stormwater to be Treated | gal | NA | 146,327.5 | |
| 10-year Stormwater Runoff Rate | gpm | NA | 101.6 | |
| Volume of 25-year TSCA only Stormwater to be Treated | gal | NA | 8,976.0 | |
| 25-year TSCA only Stormwater Runoff Rate | gpm | NA | 6.2 | |
| Evaporation Losses | gal | 190,785.9 | 198,551.1 | |
| Evaporation Losses | gpm | 2.8 | 2.9 | |
| **Total Estimated Water to be Treated (Total Influent)** | **gal** | **3,740,132** | **3,887,670** | 42 days |
| **Estimated Influent Flowrate Over Total Dredging Duration** (Average for 24 Hours) | **gpm** | **92** | **200** | |
| | | | | |
| **Water Treatment** | | | | |
| Water Treatment Uptime | | 80% | 100% | Assuming a 100% uptime during a 10-year 24-hour and 25-year 24-hour major storm event and 80% uptime during the rest |
| Hours/day | | 24 | 24 | |
| Uptime/Day (WWT System) | minutes | 1152 | 1440 | |
| Process Time Available for Duration | minutes | 55,296 | | |
| **WWT System Capacity Required** | **GPM** | **116** | **200** | |

**TABLE G-6**
**Short-term Monitoring Assumptions (Alternatives 2, 3, and 4)**
*United Heckathorn Superfund Site, Richmond, California*

| Item/Activity | Quantity | Unit | Unit Cost | Cost | Comments |
|---|---|---|---|---|---|
| Programmable Composite Water Column Sampler | 3 | LS | $ 4,400 | $ 13,200 | Teledyne ISCO / ISCO 6712 portable sampler |
| Pontoon Float to Support Water Column Sampler | 3 | LS | $ 1,100 | $ 3,300 | Rolyan buoys and floats / Rolyan pontoon float B4872PF |
| Multiparameter Sonde, Real-time Data Retrieval | 3 | LS | $ 24,100 | $ 72,300 | YSI / 6920 V2-2 sonde / turbidity monitoring system |
| Labor for First 2 Weeks | 112 | hrs | $ 80 | $ 8,960 | 1 person, 8 hrs/day, 14 days |
| Labor for Duration of Dredging | 240 | hrs | $ 80 | $ 19,200 | 1 person, 8 hrs/week, 30 weeks |
| Analytical | 145 | sample | $ 110 | $ 15,950 | 3 samples/day x 14 days, 3 samples/week x 30 weeks, 10% QC |
| Miscellaneous Monitoring Costs | 1 | LS | $ 30,000 | $ 30,000 | additional analyses, labor, buoy maintenance |
| TSS/Turbidity Correlation Event | 1 | LS | $ 8,000 | $ 8,000 | 2 people, 3 days |
| **Total** | | | | **$ 170,910** | |