

**PARTIAL MONITORING AT THE ELLIOTT BAY
NON-DISPERSIVE UNCONFINED OPEN-WATER
DREDGED MATERIAL DISPOSAL SITE**

Final Data Report

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ACRONYMS AND ABBREVIATIONS

AFDW	ash-free dry weight
aRPD	apparent redox potential discontinuity
ARI	Analytical Resources, Inc.
BT	bioaccumulation trigger
COC	chemical of concern
CSL	Cleanup Screening Level
CTS	Chemical Tracking System
DDT	dichlorodiphenyl trichloroethane
DGPS	differential global positioning system
DMMO	Dredged Material Management Office
DMMP	Dredged Material Management Program
DNR	Department of Natural Resources
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
HPAH	high molecular weight polycyclic aromatic hydrocarbon
Integral	Integral Consulting Inc.
LPAH	low molecular weight polycyclic aromatic hydrocarbon
MDL	method detection limit
ML	maximum level
ND	not detected
OC	organic carbon
OCDD	octachlorodibenzo- <i>p</i> -dioxin
OCDF	octachlorodibenzofuran
PAH	polycyclic aromatic hydrocarbon
PBDE	polybrominated diphenyl ether
PBT	persistent, bioaccumulative, and toxic
PCB	polychlorinated biphenyl
PSDDA	Puget Sound Dredged Disposal Analysis

PSEP	Puget Sound Estuary Program
QA	quality assurance
QA1	Quality Assurance Level 1
QC	quality control
R/V	research vessel
RSD	relative standard deviation
SAIC	Science Applications International Corporation
SAP	sampling and analysis plan
SL	screening level
SMARM	Sediment Management Annual Review Meeting
SMS	Washington State Sediment Management Standards
SQS	Washington State Sediment Quality Standards
SVOC	semivolatile organic compound
SWAC	surface-weighted average concentration
SPI	sediment profile imaging
TBT	tributyltin
TEF	toxic equivalent factor
TEQ	2,3,7,8-TCDD toxic equivalent
TOC	total organic carbon
USACE	U.S. Army Corps of Engineers
VOC	volatile organic compound

1 INTRODUCTION

This report presents the results of the 2013 partial monitoring program conducted at the Elliott Bay non-dispersive unconfined open-water dredged material disposal site in Puget Sound, Washington. The Washington State Department of Natural Resources (DNR) conducted this study through a contract with Integral Consulting Inc. (Integral).

DNR, along with the Washington State Department of Ecology (Ecology), the U.S. Army Corps of Engineers (USACE), Seattle District, and the U.S. Environmental Protection Agency (EPA), Region 10, is a cooperative partner in the Dredged Material Management Program (DMMP). The DMMP has responsibility for the environmental management of dredged material in western Washington, including the implementation and management of five non-dispersive dredged material disposal sites in Puget Sound. The DMMP provides guidance for determining the suitability of dredged material for unconfined, open-water disposal, for obtaining disposal site use permits, and for monitoring disposal sites after dredged material disposal. This guidance was first outlined for Puget Sound in the Puget Sound Dredged Disposal Analysis (PSDDA) program, which implemented a dredged material management plan for central Puget Sound sites (Phase I) in June 1988, and for north and south Puget Sound sites (Phase II) in September 1989 (PSDDA 1988a-d, 1989a,b).

The Elliott Bay disposal site is a gently sloping area in the center of Elliott Bay in Seattle, Washington. Depths at the site range from 200 ft at the south edge to 360 ft at the north edge, and currents are weak and variable (SAIC 2007). The baseline survey of the Elliott Bay disposal site was conducted in 1988 (PTI 1988). Since then, seven post-disposal monitoring events have been conducted:

- 1990, partial monitoring (SAIC 1991)
- 1992, full monitoring (SAIC 1992)
- 1995, side-scan survey (SAIC 1995)
- 2000, full monitoring (SAIC and Battelle 2000)
- 2002, tiered-full monitoring (Striplin 2002)
- 2005, contaminant investigation (SAIC 2005)
- 2007, dioxin/furan investigation (SAIC 2008).

The following objectives were identified for the 2013 partial monitoring program at the Elliott Bay site:

- Ensure that disposal activities comply with federal Clean Water Act Section 404(b)(1) guidelines.

- Verify DMMP predictions concerning site conditions following disposal events.
- Provide the State of Washington, federal agencies, and the public with disposal site monitoring information.
- Conduct increased monitoring of dioxin/furan concentrations at Puget Sound disposal sites in parallel with the updated regional dioxin/furan guidelines for dredged material disposal (DMMP 2010).
- Determine the concentrations of emerging chemicals of concern (COCs) polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyl (PCB) congeners in sediments at the Elliott Bay site (SMARM 2013a).
- Contribute data for the annual review of the DMMP dredging and disposal site evaluation process.

The remaining sections of this report describe the methods and results of the 2013 Elliott Bay disposal site monitoring survey. Section 2 reviews the DMMP monitoring plan and modifications to the sampling and testing procedures that were implemented during the 2013 event. Section 3 discusses the sampling methods for the 2013 event. Section 4 provides a summary of all physical, chemical, and biological data and results. Section 5 evaluates the data in relation to the monitoring program's questions and hypotheses. Section 6 presents the conclusions reached based on the evaluation of the data, and Section 7 provides recommendations for making management decisions based on 2013 monitoring results and improving the programmatic framework.

2 DMMP MONITORING PLAN REVIEW

Management plans were developed for each of the five non-dispersive dredged material disposal sites in 1988 and 1989 (PSDDA 1988a, 1989a). An updated monitoring plan, incorporating subsequent revisions and updates for physical, chemical, and biological monitoring, was published in 2007 (SAIC 2007). This section briefly describes the DMMP monitoring program design and modifications implemented in 2013, and presents a summary of the results of previous monitoring events at the Elliott Bay site.

2.1 The DMMP Monitoring Framework

Environmental monitoring of the disposal sites is conducted to ensure compliance with federal Clean Water Act Section 404(b)(1) guidelines, to verify predictions for site conditions following the disposal of dredged material, to keep the public and government agencies informed about disposal site monitoring activities, and to contribute data for the annual review of the DMMP dredging and disposal site evaluation process (SAIC 2007).

The monitoring program design addresses three primary questions related to the potential impacts from dredged material disposal (SAIC 2007):

1. Does the deposited dredged material stay on site?
2. Is the biological effects condition for the site exceeded because of dredged material disposal?
3. Are unacceptable adverse effects due to dredged material disposal occurring to biological resources off site?

Table 2-1 provides a summary of the monitoring framework, including the specific hypotheses, monitoring variables, interpretive guidelines, and action items related to each of the primary monitoring questions. The DMMP monitoring framework includes a sampling design that monitors seven station types at and in the vicinity of the disposal site; an offsite reference station is included to provide a control for sediment toxicity testing. Table 2-2 describes the station types and their purpose.

The type of disposal site monitoring conducted is based on the volume of material disposed at a site since the baseline or most recent monitoring survey. The current dredged material disposal volume trigger for additional monitoring at the Elliott Bay disposal site is 500,000 yd³ (SAIC 2007). A “partial” monitoring effort is conducted when intermediate levels of disposal have occurred, but not enough to trigger full monitoring (SAIC 2007). A partial monitoring program addresses questions one and two of the framework utilizing three monitoring parameters: sediment chemistry, sediment toxicity, and sediment profile imaging (SPI) (Table 2-3). Some

chemical and toxicity analyses are tiered and are conducted only if triggered by the interpretive guidelines (Table 2–1). If a monitoring event reveals that guideline values for a given parameter are exceeded, a potential disposal impact is indicated and the benchmark station monitoring data are compared and evaluated relative to the baseline data.

2.2 2013 Modifications to Sampling and Testing Procedures

The field, analytical, reporting, and quality assurance (QA) procedures for the 2013 study include those previously reported in the DMMP Elliott Bay monitoring documents with updates incorporated from the following:

- Updated Environmental Monitoring Plan (SAIC 2007)
- Dredged Material Evaluation and Disposal Procedures User Manual (DMMP 2013)
- Applicable Sediment Management Annual Review Meeting updates and clarification papers (SMARM 2013b).

Samples were analyzed for the standard list of DMMP conventional parameters and COCs (DMMP 2013), with the addition of tributyltin (TBT) (bulk sediment and interstitial water), lindane, 1,3-dichlorobenzene, hexachloroethane, trichloroethene, tetrachloroethene, ethylbenzene, and total xylenes. Although lindane, 1,3-dichlorobenzene, and the volatile compounds trichloroethene, tetrachloroethene, ethylbenzene, and total xylenes have been dropped from the standard list of DMMP COCs for dredged material testing, these compounds are still being monitored at disposal sites (DMMP 2011).

Concurrent with the partial monitoring event, samples were collected to support an investigation of dioxin/furan, PCB congener, and PBDE congener concentrations at the disposal site. Dioxin/furans were measured in sediment samples (0–10 cm) collected from 10 onsite stations (three traditional stations EBZ01, EBS02, and EBS04, and seven randomly-placed stations EBR01–EBR07). Dioxin/furans were also measured in sediment samples (0–2 cm) collected from four perimeter (EBP01, EBP03, EBP07, and EBP11) and four benchmark stations (EBB01–EBB04). The sediment samples from station EBZ01 and from the four perimeter and four benchmark stations were also analyzed for PCB and PBDE congeners.

2.3 Summary of 1988 Baseline Conditions (Full Monitoring)

Baseline conditions existing at the Elliott Bay disposal site before PSDDA dredged material disposal began are reported in PTI (1988). Environmental characteristics at the site were consistent with multiple sources of chemical contamination and environmental disturbance. Grain sizes at the site were variable with fine-grained material dominating at the majority of stations, but with cobbles and fine sand at northern stations EBP02 and EPB03 respectively

(associated with a relatively steep topographic rise approaching the Seattle shoreline from the northeast corner of the disposal site) and a fine sand component at stations EBS07, EBS08 and EBP11 on the southwest side of the site. Relict dredged material was noted at Stations EBS05, EBS06, and EBS07. Concentrations of multiple PSDDA COCs exceeded screening levels (SLs), but only mercury exceeded the maximum level (ML) value. Concentrations of organic chemicals and chemical groups in the sediment that exceeded PSDDA SLs included high molecular weight polycyclic aromatic hydrocarbons (HPAHs), low molecular weight polycyclic hydrocarbons (LPAHs), PCBs, and dibenzofuran. Sediment metal concentrations that exceeded SLs included antimony, copper, lead, mercury, nickel, and zinc. Relatively elevated concentrations of TBT were also reported. Onsite stations (particularly EBS02) accounted for a number of the highest concentrations of COCs reported as part of the Elliott Bay baseline dataset.

Benthic samples from the benchmark stations were sorted to the species level. Benthic samples collected from the transect stations were archived in 1988 and removed for analysis in 1992. Infauna from the baseline transect stations were sorted to major taxa only. Benthic infauna analysis showed relatively high macrobenthic abundance in the southern end of the site, and relatively low abundance in the eastern and northern benchmark stations. The dominant species for the benchmark station located nearest to the transect stations (EBB03) were *Axinopsida serricata* (bivalve), *Eudorella pacifica* (crustacean), and *Eudorellopsis integra* (crustacean). Bioassays did not exceed criteria at any station. Tissue body burden analyses were not conducted because no macrobenthic organisms were found in enough abundance to provide sufficient tissue for chemical analysis.

2.4 Summary of 1990 Conditions (Partial Monitoring)

Conditions at the Elliott Bay site following the first dredged material disposal at the site are reported in SAIC (1991). The partial monitoring effort addressed the first two monitoring questions in Section 2.1. The 1990 SPI survey indicated that all recently deposited dredged material remained onsite and closely mirrored the shape of the disposal site boundary. Nine stations were sampled for sediment chemistry analyses—one onsite, four perimeter, and four benchmark stations. All chemical concentrations were below PSDDA MLs. Concentrations of chemicals and chemical groups that exceeded PSDDA SLs included mercury, silver, zinc, total HPAH, indeno(1,2,3-c,d)pyrene, total PCBs, and total dichlorodiphenyl trichloroethanes (DDTs). The majority of PSDDA SL exceedances occurred in single replicates of perimeter Station EBP07. SL exceedances of total DDTs, silver, and zinc occurred onsite at Station EBZ01. Monitoring guideline values in effect at that time (1.25 times baseline for metals and 1.47 times baseline for organics) were exceeded for 15 COCs at one or more perimeter stations during the 1990 partial monitoring event. Because many of the results were qualified as estimates in the 1990 data set, compared to guideline values based on nondetects or estimates from the 1988 data set, or did not exceed the guideline value in all replicates from any given station, these

results did not support a conclusion that the 1990 perimeter chemistry data reflected the influence of dredged material disposal on off-site stations.

The 1990 monitoring also determined that the dredged material was not causing on-site biological effects beyond the minor adverse effects allowed under Site Condition II. Sediments from the onsite station, EBZ01, scored a hit in the echinoderm larval test at the two-hit level. Because this result was not accompanied by a hit in another bioassay, it did not constitute an exceedance of PSDDA Site Condition II guidelines.

2.5 Summary of 1992 Conditions (Full Monitoring)

Full monitoring of Elliott Bay was conducted in 1992 (SAIC 1992). The full monitoring effort addressed all three of the monitoring questions presented in Section 2.1.

The SPI survey indicated that the dredged material deposit in 1992 was ovoid in shape, with the long axis trending NW/SE along the Elliott Bay trough. Recently deposited dredged material was not observed beyond the site boundary.

A total of 14 stations were sampled for sediment chemistry analyses: 3 onsite, 4 perimeter (in triplicate), three transect (in triplicate), and four benchmark (in triplicate) stations. Sediment samples collected from onsite, perimeter, and transect stations were analyzed for the PSDDA COCs and conventional parameters. Sediment samples collected from benchmark stations were analyzed for conventional parameters that were subject to limited holding times. Detected concentrations of chemicals and chemical groups that exceeded PSDDA SLs included mercury, copper, lead, silver, pyrene, indeno(1,2,3-c,d)pyrene, total HPAH and total PCBs. SL exceedances of copper occurred at the on-site station EBZ01. SL exceedances of mercury, copper, lead, pyrene, indeno(1,2,3-c,d)pyrene, total HPAH and total PCBs occurred at the on-site station EBS02. SL exceedances of copper, pyrene, indeno(1,2,3-c,d)pyrene and total HPAH occurred at the on-site station EBS04.

Monitoring guideline values (multipliers of 1.25 for metals and 1.47 for organics) for a total of 22 COCs were exceeded during the 1992 monitoring effort at one or more perimeter or transect station. Analytes showing exceedances included all the metals (except zinc), several LPAHs and HPAHs, three phthalates, phenol and dibenzofuran. The comparison of 1992 sediment chemical data to baseline data using the guideline value approach encountered several difficulties, as it did during 1990. Sample detection limits varied widely between baseline and the 1992 monitoring survey, and "J" qualified and nondetected chemical concentrations were being compared to low baseline values that were "E" qualified. In general, guideline exceedances were not considered real changes from baseline and were concluded to be largely due to analytical imprecision/uncertainty from one monitoring year to the next.

It was also determined that the dredged material did not cause biological effects beyond the minor adverse effects allowed at the site. No onsite chemistry measurements exceeded ML values, and onsite stations passed the PSDDA bioassay guidelines for non-dispersive sites (PSDDA 1988c).

The evaluation of potential offsite biological effects was made by comparing the 1992 monitoring abundances of major taxa to baseline infauna abundances. The 1992 abundances of major taxa were not reduced by one-half the baseline abundances (the benthic infauna guideline criteria, see Table 2-1). Thus, it was concluded that no adverse biological effects occurred offsite. The most abundant organisms overall were the cumacean *Eudorella pacifica* and the small bivalve mollusc *Axinopsida serricata*.

2.6 Summary of 2000 Conditions (Full Monitoring)

The next monitoring effort at the Elliott Bay site was a full monitoring effort in 2000 (SAIC and Battelle 2000). Sediment chemistry, sediment toxicity testing, SPI, and benthic infauna data were collected to address all three of the monitoring questions. Also, for the first time at this disposal site, adequate biomass of *Molpadia intermedia* was collected from two of the three transect stations (EBT03 and EBT05) and one benchmark station (EBB02, one replicate) to provide baseline tissue chemistry data for these three locations. The results of the 2000 SPI survey of the Elliott Bay site indicated that dredged material had not been deposited beyond the site boundary.

A total of 14 stations were sampled for sediment chemistry analyses—three onsite, four perimeter (in triplicate), three transect (in triplicate), and four benchmark (in triplicate) stations. Onsite and perimeter samples were analyzed for the DMMP COCs and conventional parameters. Transect and benchmark samples were analyzed for limited conventional parameters. The only SL exceedances at any station were for mercury and total PCBs. Mercury exceeded both the SL and SMS cleanup screening level (CSL) in at least one replicate at both the onsite station EBS02 and benchmark station EBB02. The SL for total PCBs was exceeded in at least one replicate at EBS02 and the perimeter station EBP07. Two of the replicates at EBP07 also exceeded the carbon-normalized SQS for PCBs. The bioaccumulation trigger (BT) for bulk TBT was exceeded in all replicates at the perimeter station EBP07 and benchmark stations EBB01 and EBB02. The only BT exceedance for TBT in porewater occurred in one replicate at the benchmark station EBB02. The other on-site stations – EBZ01 and EBS04 – had no SL exceedances. There were no exceedances of DMMP MLs at any station.

In 2000, Chemical Tracking System (CTS) time-trends analysis was first used at the Elliott Bay site to statistically measure changes in perimeter station chemistry for each chemical or for a guild of chemicals. This evaluation (along with comparisons to SQS) supplanted the perimeter station chemical guideline value comparison approach that had been in effect in 1990 and 1992

and which had often triggered false positive chemical exceedances. As chemical groups, the metals and organics time-trends analysis did not show significant changes in concentration over time for any of the perimeter stations. With these results, it was determined that chemical concentrations at offsite stations did not measurably increase over time.

Triplicate samples of *Molpadi*a tissue were collected at two of three transect stations (stations EBT03 and EBT05). Tissue was analyzed for metals, semivolatile organic compounds (SVOCs), pesticides/PCBs, and butyltin compounds. No organic compounds were detected in any of the tissue samples. Metals were detected in all replicate samples at low concentrations.

Sediment bioassay analyses (*Neanthes*, Microtox, amphipod, sediment larval) were conducted on onsite sediments (stations EBZ01, EBS02, and EBS04). Toxic responses at the one-hit level were observed for both the amphipod and sediment larval tests for station EBZ01. These results were not consistent with the sediment chemistry results and were not corroborated by other test results. It was determined that a high percentage of clay in the sediment at station EBZ01 may have contributed to the observed toxic response. Subsequent amphipod retests of the station EBZ01 sediment did not produce toxic responses, and therefore it was concluded that sediment toxicity at the onsite stations did not exceed the PSDDA Site Condition II Biological Response Guidelines.

The evaluation of potential offsite biological effects was made by comparing the 2000 monitoring abundances of major taxa to baseline infauna abundances. Crustacean abundances for each transect station measured in 2000 were less than one-half the baseline crustacean abundance. All other taxa showed an increase, or less than 50 percent reduction. The marked decrease in crustacean abundance may be attributed to different sampling methods. In 2000, the sediment from the top 10 cm of each box core was sieved through the 1.0 mm sieve. The baseline survey involved sampling the entire box core, with no sieving. The most abundant species at all three transect stations was the bivalve *Axinopsida serricata*, followed by the polychaete *Ampharete acutifrons*. Predominant species did not change significantly between baseline and the 1992 and 2000 monitoring surveys (SAIC and Battelle 2000).

2.7 Summary of 2002 Conditions (Tiered Full Monitoring)

Tiered full monitoring was conducted between May and July 2002. Sample collection for the monitoring event coincided with the collection of sediment and tissue samples for a separate special study to assess the occurrence and testing methods for chemicals on the 2002 revised bioaccumulative chemicals of concern Lists 1 and 2 (Striplin 2002, 2004). The analytical results of the special study were not used as part of the monitoring event and are not included in this summary.

SPI images were obtained from a total of 75 stations and the survey results indicated that recently deposited dredged material stayed within the boundaries of the site, although some older

deposits were observed outside the site boundary on its eastern flank. These older deposits terminate less than one-eighth of a nautical mile from the site boundary and did not extend to the perimeter stations sampled in that area (Striplin 2002).

A total of 17 stations were sampled for chemical analyses as part of the monitoring event: three onsite (EBZ01, EBS02, and EBS04); four perimeter (EBP01, EBP03, EBP07, and EBP11); three transect (EBT01, EBT03, and EBT05); four benchmark (EBB01–EBB04); and three reference (CR02, CR23W, and CR24) stations. Onsite and perimeter station samples were analyzed for PSDDA COCs and conventional parameters. Benchmark station samples were analyzed for grain size, mercury, and conventional parameters that have holding time constraints. There were no exceedances of the SQS criteria at any of the perimeter stations, and CTS time-trends analysis indicated no significant increases in overall chemical concentrations since 1988 (Striplin 2002). The analytical results showed the following organic compounds in sediment samples exceeded DMMP SLs: total DDTs (station EBZ01); chlordane (a+g) (stations EBS04, EBP07-A and EBP11-B); and total PCBs (station EBP07-B). No organic chemical concentrations exceeded DMMP ML, DMMP BT, or SMS SQS values. Among metals, mercury exceeded the SL and SQS at onsite stations EBS02 and EBS04 and at benchmark stations EBB02 (all replicates) and EBB03 (one replicate). As occurred in 2000, mercury also exceeded the SMS CSL at EBS02 and EBB02 (two replicates). None of the metals exceeded ML. Tributyltin was not analyzed in 2002.

Sediment bioassay analyses (*Neanthes*, amphipod, sediment larval) were conducted on onsite station sediments (EBZ01, EBS02, and EBS04); all passed the DMMP bioassay interpretive criteria.

Seven samples of benthic infauna were collected from three transect stations and four benchmark stations. Benthic infauna from only the three transect station samples (EBT01, EBT03, and EBT05) were analyzed; the benchmark station samples were archived. The 2002 benthic infauna community analysis at the transect stations showed that a significant reduction (greater than 50 percent) in mollusca abundance had occurred between 1988 and 2002 at EBT03 and EBT05. All other major taxa categories showed either an increase in abundance or a less than 50 percent reduction in 2002 compared to the 1988 baseline abundances. It was concluded that biological resources may be affected by dredged material deposition. However, the authors cited similar findings from Commencement Bay that indicated that mollusc abundance may be decreasing regionally and that this decrease may not be strongly related to dredged material disposal. The analysis of benthic infauna from one of the benchmark stations (station EBB04), which had water depths and physical characteristics similar to the transect stations, was recommended by the monitoring contractor to help determine whether this change was regional. However, before proceeding with this analysis, the DMMP first examined species composition at the three transect stations in the 1992, 2000 and 2002 data sets. It was found that *Axinopsida serricata*, an opportunistic species, was the dominant mollusc species at all three transect stations during 1992 and 2000, and at two of the three stations during 2002 (Anchor 2003). An earlier 20-year study of a benthic community in Puget Sound (Nichols, 1985) showed

wide fluctuations in abundance of individual species such as *Axinopsida serricata* at a 200-meter deep site removed from anthropogenic influences, due to natural cycles of variable recruitment, predation and interspecies competition. The DMMP considered this explanation to be the likely reason for the observed decrease in mollusc abundance, rather than dredged material disposal (Anchor 2003). Therefore, analysis of benthic infauna at benchmark station EBB04 was not conducted.

Samples of *Molpadia* tissue were collected at two onsite stations (EBS02 and EBS04), one perimeter station (EBP01), three transect stations (EBT01, EBT03, and EBT05), and one benchmark station (EBB04). Tissue samples were analyzed for mercury and lipids as part of the monitoring event. Mercury concentrations in these samples did not exceed the body burden guideline values derived from baseline data collected in 2000 (Striplin 2002).

2.8 Summary of 2005 Conditions (Contaminant Investigation)

A special contaminant investigation was conducted at the Elliott Bay disposal site in 2005, after dredged material from the Port of Seattle's East Waterway facility, which had been found suitable for in-water placement by the DMMP agencies, was disposed at the Elliott Bay site, and postdredge confirmatory testing at the East Waterway site revealed chemical concentrations that exceeded DMMP guidelines (SAIC 2005). This finding raised concerns that some of the material that had been disposed at the Elliott Bay site may not, in fact, have been suitable for open-water disposal. The investigation, conducted on June 20, 2005, included physical (SPI) monitoring and sediment sampling at three onsite locations (EBZ01, EBS02, and EBS04).

Triplicate SPI images and two composite sediment samples (0–10 cm and 0–2 cm) for chemical analysis were collected at each of the three stations. The 10-cm sediment samples were submitted for immediate analysis for DMMP conventional parameters and select contaminants of concern: mercury, bis-2-ethylhexyl phthalate (BEHP), chlorinated benzenes, PCBs and dioxins/furans. The 0–2 cm samples were collected for possible analysis pending the results of the 0-10 cm samples.

Mercury concentrations were found to be below the DMMP SLs, at concentrations similar to or lower than in 2002 (SAIC 2005). BEHP and chlorinated benzenes were either undetected or well below the DMMP SLs. Total PCB concentrations were higher than those measured in 2002. Total PCB concentrations exceeded the DMMP SL at stations EBS02 and EBS04, and the carbon-normalized concentration exceeded the SMS SQS at station EBS02. Dioxins and furans results were below the 2000 DMMP guideline values that would trigger bioaccumulation testing: a bulk sediment 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) concentration of 5 ng/kg or a total 2,3,7,8-TCDD toxic equivalent (TEQ¹) concentration of 15 ng/kg. 2,3,7,8-TCDD was

¹ SAIC uses the abbreviation "TEC." It was changed here for consistency of the definition of the term "TEQ" as "2,3,7,8-TCDD toxic equivalent."

undetected at all three stations. The highest TEQ concentration was measured at station EBS02 (8.81 ng/kg). Dioxin/furan analysis was performed in using EPA Method 8290.

Based on the PCB concentrations in the 0–10 cm sediment samples, samples collected from 0–2 cm at stations EBS02 and EBS04 were analyzed for total organic carbon (TOC) and PCBs. TOC concentrations in these 0–2 cm samples were similar to concentrations in the 0–10 cm samples. Total PCB concentrations were lower in the 0–2 cm samples than in the 0–10 cm samples, although still elevated when compared with previous monitoring years. The PCB concentration in the 0–2 cm sample from station EBS02 was slightly higher than the DMMP SL, but below the SQS.

The study concluded that dredged material placed at the site in 2005 contained higher PCB concentrations than were present at the site in 2002 (SAIC 2005). The lower PCB concentrations in the 0–2 cm interval compared with the 0–10 cm interval may have been due to the placement of dredged material from other dredging projects subsequent to the East Waterway dredging and disposal. Alternatively, it may be due to sediment turnover by “conveyor-belt” deposit feeders that may have brought cleaner sediment to the surface and deposited it on top of the sediment containing the higher PCB concentrations (SAIC 2005).

2.9 Summary of 2007 Conditions (Dioxin/Furan Investigation)

In conjunction with development of revised dioxin guidelines by the DMMP agencies, dioxin/furan concentrations were measured at all DMMP disposal sites, as documented in SAIC 2008.

A total of 14 Elliott Bay stations were sampled in 2007: three onsite (EBZ01, EBS02, and EBS04), four perimeter (EBP01, EBP03, EBP07, and EBP11), four benchmark (EBB01–EBB04), and 3 transect (EBT01, EBT03, and EBT05) stations. Three reference sediment samples were also collected from Carr Inlet (CR-02, CR-23, and MSMP-43). Dioxin/furan analysis was performed using EPA Method 1613B (SAIC 2008).

In addition, 11 of the Elliott Bay sediment stations sampled in 2007 were targeted for tissue sampling, which were to consist of one replicate each of a bivalve and polychaete species (SAIC 2008). However, bivalve populations were low; *Yoldia* and *Compsomyax* clams were present but not abundant enough for chemical analysis. A total of 12 polychaete samples (Glyceridae, Maldanidae, and *Travisia* polychaetes combined) were collected and submitted for dioxin/furan, percent lipids, and percent moisture analyses (SAIC 2008).

Dungeness crab and English sole samples were also collected from Elliott Bay by otter trawl in the 2007 investigation (SAIC 2008). Species collected included slender sole, blackbelly eelpout, spotted ratfish, and English sole. Only one Dungeness crab sample (consisting of five crabs) was able to be collected from a total of eight trawls. One Dungeness crab sample (both the

edible meat and hepatopancreas tissues) and three English sole tissue samples (all whole body) were collected and submitted for dioxin/furan analyses (SAIC 2008).

All dioxin/furan results were converted to total TEQ values² based on the World Health Organization 2005 mammalian toxic equivalent factors (TEF) (Van den Berg et al. 2006), substituting one-half the method detection limit (MDL) for nondetected congeners (SAIC 2008).

Elliott Bay sediment was found to contain the second highest dioxin/furan concentrations of all the non-dispersive disposal sites at which dioxin had been measured, second only to Bellingham Bay (SAIC 2008). The average TEQ for all the Elliott Bay stations was 7.91 ± 4.18 pg/g. The site, perimeter, transect, and benchmark stations had higher concentrations with more variability when compared with concentrations within the disposal zone (SAIC 2008). Stations EBZ01, EBS02, and EBS04 were sampled in both 2005 and 2007. The concentrations at EBZ01 and EBS02 were slightly higher in 2007 than those in 2005 (by less than 3.0 pg/g), which may have been due to the different analytical methods used. However, there was a significant increase at station EBS04, with concentrations of 1.55 pg/g and 17.03 pg/g in 2005 and 2007 respectively.

Among the five non-dispersive disposal sites, detected dioxin/furan concentrations in sediment from Elliott Bay showed the weakest correlation with TOC, showing an r^2 of 0.029 (SAIC 2008). The majority of samples across all disposal sites had a similar congener profile, with octachlorodibenzo-*p*-dioxin (OCDD) as the dominant congener detected, followed by 1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin, octachlorodibenzofuran (OCDF) and 1,2,3,4,6,7,8-heptachlorodibenzofuran. The perimeter station EBP11 was the only sediment sample that did not match the average congener profile, containing a higher percentage of OCDF and a lower percentage of OCDD than most samples (SAIC 2008).

Although few differences were found in tissue dioxin between disposal sites, tissue concentrations were highest at Elliott Bay, averaging 0.76 ± 0.70 pg/g wet weight TEQ (SAIC 2008). The highest concentrations occurred in two benchmark samples, EBB01-Glycerid and EBB02-Glycerid, both of which were collected near the shoreline and the mouth of the Duwamish River (SAIC 2008).

² SAIC (2008) uses the term "toxic equivalent quotient." It was changed here for consistency of the definition of the term "TEQ" as "2,3,7,8-TCDD toxic equivalent."

3 METHODS

This section provides a summary of the sampling design, data collection, and field sampling methods for the 2013 Elliott Bay partial monitoring program.

Sediment sampling for chemical and biological testing was conducted between August 5 and 14, 2013, aboard the research vessel (R/V) *Kittiwake*. Field sediment sampling and sample handling procedures followed those outlined in the 2013 sampling and analysis plan (SAP) and health and safety plan (these documents are provided in Appendix A). Target and actual sampling station locations are shown in Figure 3-1. This section provides brief descriptions of field sampling methodologies for the sediment sampling effort.

Physical monitoring (SPI survey) of the disposal site was conducted by the USACE on September 16 and 17, 2013 (NewFields 2013). A total of 79 SPI stations were surveyed (see Figure 3-2). The survey methods are discussed in the SPI report which is provided as Appendix B of this report (NewFields 2013).

3.1 Navigation

Daily positional checks were performed aboard the R/V *Kittiwake* using a Trimble NT300D differential global positioning system (DGPS). Station target for the docking position of the vessel (Slip J37, Elliott Bay Marina, Seattle, Washington) was determined by running the GPS for approximately 0.5 hours to effectively generate a small grouping of positions. The central position in this grouping was defined as the target position. All subsequent positional checks (two per day; once at the beginning of a field day, once at the end) were defined by a distance to this target. Positional checks were within 0.8 m of the target position; positional check documentation is provided in the field documentation appendix (Appendix C). Daily navigation to Elliott Bay field stations was accomplished using the DGPS aboard the R/V *Kittiwake* in conjunction with Nobeltec's Visual Navigation Suite®. All sediment grabs were collected within 2.4 m of the target station coordinates. Sampling station navigation information is provided in Appendix C.

3.2 Sample Collection and Handling

Detailed procedures of sampling and analysis methodologies are provided in the SAP (Appendix A). A summary of the samples collected and the analyses performed is provided in Table 3-1.

3.3 Sediment Chemistry

Elliott Bay stations sampled as part of this partial monitoring event include one onsite station (EBZ01), five perimeter stations (EBP01, EBP03, EBP04, EBP07, and EBP011), and four benchmark stations (EBB01–EBB04) sampled for DMMP conventional parameters and COCs plus dioxins/furans, and PCB and PBDE congeners. Nine additional onsite stations were sampled solely for dioxin/furan congener and TOC analyses (EBS02, EBS04, and EBR01–EBR07).

Sampling at station EBP04 was not originally called for in the SAP but was added in the field after recovery issues were encountered when sampling station EBP03. EBP03 was abandoned after one replicate was collected, and it was replaced by EBP04 after consultation with the Dredged Material Management Office (DMMO).

A single sample was collected from the onsite stations. The perimeter and benchmark stations, except for EBP03, were each sampled in triplicate, but only the first replicate from these stations was analyzed for dioxins/furans and PCB and PBDE congeners. Most benchmark samples for DMMP parameters were archived, except for selected parameters in the first replicate at each station as outlined in Table 3-1.

Two Carr Inlet reference stations, CR-23W and CR-24, were sampled for conventional parameters to support bioassay analyses (Section 3.4).

Copies of the field log, sample log, and chain-of-custody forms are provided in Appendix C. All sediment samples were collected by using a 0.1 m² van Veen grab sampler in either a single or double configuration. To the extent practicable, only sediment that did not come into contact with the walls or top screens of the sampler was collected. Exceptions were made at stations where over penetration could not be remedied; in those cases, only areas where the surface sediment did not extrude through the screen at the top of the van Veen were sampled. Sediment samples for VOCs and total sulfides analyses were collected immediately upon retrieval from an undisturbed, randomly chosen grab. Sediment samples were handled and stored according to conditions described in the SAP (Appendix A). Samples targeted for standard DMMP chemical and physical analyses were hand-delivered in four shipments to Analytical Resources, Inc. (ARI), Tukwila, Washington. Samples targeted for dioxins/furans and PCB congener analyses were delivered in two shipments to ALS Environmental, Houston, Texas. Similarly, samples for PBDE congener analysis were delivered in two shipments to Vista Analytical Laboratory in El Dorado Hills, California.

The 8 ounce jar of sediment collected for pesticides and PCB Aroclor analyses from the second replicate at perimeter station EBP11 (sample ID EBP11-2) was temporarily misplaced in the field and was not included in the cooler delivered to the laboratory containing the other sample containers from that replicate. ARI used sediment from another jar for the pesticide and PCB Aroclor analyses. The lost jar was located and submitted to ARI for analysis the following day. As a result, one extra analysis of pesticides and PCB Aroclors was run on the replicate EBP11-2.

3.4 Bioassays (Toxicity Testing)

Surface sediment for toxicity testing was collected from five locations (onsite station EBZ01 and benchmark stations EBB01–EBB04). The toxicity test sediment was collected from the same composites as the sediment chemistry samples at these stations. The samples for toxicity testing were shipped to Northwestern Aquatic Sciences in Newport, Oregon.

The sediment grain size (percent fines) at stations slated for toxicity testing was estimated in the field by wet sieving, following the Puget Sound Estuary Program (PSEP) protocol (PSEP 1997), to determine the reference sediment grain size needed for the toxicity tests. Based on the wet-sieve results, sediment was collected from two reference stations in Carr Inlet: CR-24 (64 percent fines, wet sieve), and CR-23W (32 percent fines, wet sieve).

Three bioassay tests were conducted on each sample:

- Amphipod 10-day mortality (*Eohaustorius estuarius*)
- Larval combined mortality and abnormality (*Mytilus galloprovincialis*)
- 20-day growth (juvenile *Neanthes* growth rate endpoint).

Toxicity tests were conducted on sediment from one onsite station (EBZ01) and from the CR-24 reference sample. The samples from the benchmark stations (EBB01–EBB04) and CR-23W were archived, with bioassays to be conducted if triggered by onsite toxicity test results.

All biological testing was conducted in strict compliance with Recommended Guidelines for Conducting Laboratory Bioassays on Puget Sound Sediments (PSEP 1995), with appropriate modifications as specified in the 2013 DMMP User Manual (DMMP 2013). Further details on the toxicity testing methodology are provided in the SAP (Appendix A). The results of the toxicity testing are provided in Section 4.3.

4 RESULTS

This section presents the results of the SPI survey, sediment chemistry analysis, and bioassay testing conducted as part of the 2013 Elliott Bay partial monitoring investigation. An evaluation of the data per the DMMP monitoring framework is provided in Section 5.0.

4.1 SPI Survey

The primary purpose of the SPI survey was to map the distribution of dredged material at the Elliott Bay disposal site to help answer Site Monitoring Question 1: “Does Dredged Material Stay Onsite?” SPI images from 79 stations in and surrounding the Elliott Bay site were analyzed as part of the 2013 Elliott Bay monitoring effort (Figure 3-2). The SPI data report is provided in Appendix B (NewFields 2013). The results presented in NewFields (2013) are briefly summarized in the following sections.

4.1.1 Ambient Sediment Characteristics

The characteristics of ambient Elliott Bay sediment observed in 2013 SPI results are consistent with previous surveys, generally consisting of fine-grained sediment with relatively deep apparent redox potential discontinuity (aRPD) depths (discussed further in Section 4.1.) and feeding voids indicative of extensive bioturbation by head-down deposit-feeding infauna (NewFields 2013). Fine sand fractions are more prevalent in the southern portion of the bay due to sediment loading at the mouth of the Duwamish River (NewFields 2013).

4.1.2 Dredged Material Distribution

The recent dredged material deposits were found to be contained within the perimeter of the disposal site (Figure 4-1). In the disposal zone, dredged material appears as a light gray silt and clay with some very fine sand, or layers of reduced organic silt and fine sand. A layer of tan brown oxidized sandy silt overlies gray and light gray silt and clay deposits at the site center, and along the flanks of the disposal area recently deposited fine sandy dredged material overlie historic dredged material deposits (NewFields 2013). The historic dredged material footprint was found to be similar to that of the recent dredged material, indicating a relatively consistent depositional pattern at the site (see Figure 4-2 of Appendix B).

4.1.3 Physical and Sedimentary Features

Information on sediment physical features derived from the SPI survey includes grain size major mode (in phi sizes), camera prism penetration depths, and bottom boundary roughness measurements.

The grain size major mode was greater than 4 phi (silt or finer) at 81 percent of the stations in Elliott Bay (see Figure 4-21 in Appendix B; NewFields 2013). Coarser grain sizes (4–3 phi, very fine sand or coarser) were found at stations near the shoreline, in the southwestern portion of the bay along the bathymetric ridge extending from the mouth of the Duwamish River West Waterway, and on a nearshore slope in the northeastern site perimeter attributed to the Denny Hill regrade area (NewFields 2013).

Camera prism penetration depths are a function of sediment-bearing capacity (NewFields 2013). Sediments with higher water content, such as unconsolidated, fine-grained sediments undergoing bioturbation, generally have deeper prism penetration, compared with coarse-grained, compact sediments. Penetration depths obtained in the 2013 Elliott Bay survey ranged from 1.34 to 21.07 cm across the site (Appendix B; NewFields 2013). The deepest penetration depths were achieved in the northwestern perimeter stations and shallower penetration depths near the southeastern perimeter (see Figure 4-23 of Appendix B; NewFields 2013). Compact dredged material resulted in the lowest penetration depth within the disposal zone (NewFields 2013).

Boundary roughness observed at the Elliott Bay stations ranged from 0.2 to 7.39 cm, and was attributable to biogenic activity at 96 percent of the stations (Appendix B; NewFields 2013). Much of the high surface relief was attributed to large surface burrow excavations. Mean boundary roughness was generally less at stations within the disposal site boundary, and particularly near the disposal zone, than in surrounding areas because large burrows occurred less frequently in the dredged material (NewFields 2013).

4.1.4 Chemical and Biological Features

Key chemical and biological parameters obtainable from SPI data provide an overall assessment of the health of the benthic habitat in Elliott Bay. The key parameters include the aRPD depth and the benthic infaunal successional stage. The results for these parameters from the 2013 survey are discussed below.

4.1.4.1 Apparent Redox Potential Discontinuity

Aerobic near-surface marine sediments typically have higher reflectance relative to underlying hypoxic or anoxic sediments. These differences in optical reflectance are readily apparent in SPI images; the oxidized surface sediment contains particles coated with ferric hydroxide (an olive or tan color when associated with particles), while reduced and muddy sediments below this oxygenated layer are darker, generally gray to black (Fenchel 1969; Lyle 1983). The boundary between the colored ferric hydroxide surface sediment and underlying gray to black sediment identifies the aRPD. In general, the depth of the actual $E_h = 0$ horizon will be either equal to or slightly shallower than the depth of the optical reflectance boundary (Rosenberg et al. 2001). This is because bioturbating organisms can mix ferric hydroxide-coated particles downward into the bottom below the $E_h = 0$ horizon. As a result, the mean aRPD depth can be used as an

estimate of the depth of porewater exchange, usually through porewater irrigation (bioturbation). The depth of the aRPD in the sediment column is an important time-integrator of dissolved oxygen conditions within sediment porewaters (Germano et al. 2011), and can be used to infer the relative intensity of biogenic sediment across a surveyed area.

Mean aRPD depths observed in Elliott Bay ranged from 1.34 to 4.67 cm (Appendix B; NewFields 2013). The shallowest aRPD depths (less than 2.25 cm) were measured outside the disposal zone, with slightly deeper aRPD depths observed within the disposal zone, ranging from 1.39 to 4.38 cm, with an average of 2.83 cm, \pm 0.82 cm (Appendix B; NewFields 2013). Mean aRPD depths are shown in Figure 4-3.

4.1.4.2 Benthic Infaunal Successional Stage

The mapping of successional stages in SPI images is based on the theory that organism-sediment interactions in fine-grained sediments follow a predictable sequence after a seafloor perturbation such as dredged material disposal. This theory states that primary succession results in “the predictable appearance of macrobenthic invertebrates belonging to specific functional types following a benthic disturbance. These invertebrates interact with sediment in specific ways. Because functional types are the biological units of interest..., “[the] definition does not demand a sequential appearance of particular invertebrate species or genera” (Rhoads and Boyer 1982). This theory is presented in Pearson and Rosenberg (1978) and further developed in Rhoads and Germano (1982) and Rhoads and Boyer (1982). The history and application of this interpretative paradigm in marine environmental monitoring programs is described in Germano et al. (2011)

Infaunal successional stages are recognized in SPI images by the presence of dense assemblages of near-surface polychaetes and/or the presence of subsurface feeding voids; both may be present in the same image. This continuum of change in animal communities after a disturbance (primary succession) has been divided subjectively into four stages: Stage 0, indicative of a sediment column that is largely devoid of macrofauna, occurs immediately following a physical disturbance or in close proximity to an organic enrichment source; Stage I is the initial community of tiny, densely populated polychaete assemblages; Stage II is the start of the transition to head-down deposit feeders; and Stage III is the mature, equilibrium community of deep-dwelling, head-down deposit feeders. Stage III assemblages are most often revealed by the presence of distinctive feeding voids visible in SPI images (NewFields 2013).

The 2013 SPI survey at the Elliott Bay site indicates that deep-dwelling, head-down deposit feeders are present throughout most of the site (NewFields 2013). Stage III communities were present at 95 percent of the SPI stations following the most recent dredged material disposal (Figure 4-4). Just two stations within the site boundary (EBC06 and EBS29) and two perimeter stations (EBP03 and EBP08) showed the presence of only Stage I communities (see Figure 4-26 of Appendix B; NewFields 2013). These results indicate that the recent dredged material

disposal at the Elliott Bay did not result in widespread alteration of the benthic infauna community structure at the site.

4.2 Sediment Chemistry

This section presents a summary of the sediment chemistry results for the 2013 partial monitoring event, and comparisons of the results to the DMMP screening level/maximum level (SL/ML) list and SMS/SQS.

Figures 4.5 to 4.7 show the types of analyses performed. Tables in this section present summaries of detected analyte concentrations, frequency of detection, and location of analyte maxima for sediment analytical results. A full listing of all analytical results, including individual replicate results and calculated station averages, and comparisons to DMMP and SMS criteria, is presented in Appendix D.

4.2.1 Data Evaluation

The evaluation of analytical data from the 2013 Elliott Bay Monitoring event included data quality assurance (QA) evaluations, and data processing necessary to evaluate the data against DMMP and state SMS criteria.

4.2.1.1 Quality Assurance

Integral conducted the Quality Assurance Level 1 (QA1) data review of sediment chemistry results for conventional parameters, DMMP parameters, PCB congeners, and PBDEs; and the Stage 4 data validation for dioxin/furan. The QA1 review and Stage 4 data validation demonstrated that the data are of generally high quality, and suitable for use (as qualified) in addressing the PSDDA monitoring questions and hypotheses. The data quality summary, QA1 checklists, data validation report, and analytical laboratory data reports are found in Appendix E.

4.2.1.2 Data Management Rules

The chemical values discussed here were produced using the following data management rules.

Reporting of Results

Nondetected results are reported to the laboratory quantitation limits (referred to here as reporting limits, or RLs) for all analyses with the exception of dioxins/furans, PCB congeners, and PBDE congeners. Nondetected results for dioxins/furan, PCB congeners, and PBDE congeners were reported to the estimated detection limit. Detected results greater than the method detection limit but less than the laboratory RL are qualified "J".

Group Sums

The calculation of summed concentrations representing certain groups of chemicals for comparison to DMMP criteria followed DMMP (2013) guidance. Sums were calculated for the following groups:

- **LPAH**—naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene
- **HPAH**—fluoranthene, benzofluoranthenes, pyrene, benz(a)anthracene, chrysene, benzo(a)pyrene, indeno(1,2,3-c,d)pyrene, dibenz(a,h)anthracene, and benzo(g,h,i)perylene
- **Total DDT**—4,4'-DDD, 4,4'-DDE and 4,4'-DDT
- **Total chlordane**—*cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, *trans*-nonachlor, and oxychlordane
- **Total PCBs**—Aroclor® 1016, 1221, 1232, 1242, 1248, 1254, and 1260. When present, Aroclor 1262 and 1268 would be reported but not included in the total PCB summation. However, Aroclor 1262 and 1268 mixtures were not reported in the 2013 monitoring analytical results.

Group sums were calculated based on all detected concentrations of the constituent analytes; U qualified (nondetected) concentrations are not included. Estimated values (i.e., J qualified), between the MDL and the laboratory RL, were included using the J-qualified concentration at face value. In cases where all constituents of a group are U qualified, the group sum was reported as U qualified at the value of the highest laboratory RL (i.e., the highest U-qualified value of the constituent analytes). Appendix D includes both the group sums and the concentrations of individual constituents.

Dioxin/Furan and PCB Congener TEQs

TEQ values were calculated for both dioxin/furan and PCB congeners using World Health Organization Human and Mammalian TEFs from van den Berg et al. (2006). Congener concentrations are multiplied by their TEFs to estimate toxicity of the congeners relative to 2,3,7,8-TCDD, and the products are summed. Three TEQ values for dioxin/furan and PCB congeners were calculated for each sample, substituting values of 1) zero (ND=0), 2) half the estimated detection limit value (ND=½ DL), and 3) the full estimated detection limit value (ND=DL) for U-qualified results.

Station Averages

Station average concentrations were calculated for all analytes where replicate samples were collected at a given station. In cases where a replicate result for a given analyte was U qualified, the full value of the nondetected concentration was used in the station average calculation. If all replicate results were U qualified, the station average was reported as U qualified using the

average of the U-qualified replicate values. If any of the replicate values were J qualified for a given analyte at a station, that station average was reported as J qualified.

As mentioned in Section 3.3, pesticide and PCB Aroclor analyses were performed on two separate jars of homogenized sediment from replicate EBP11-2. The results for these two analyses are presented separately, but were averaged together before calculating the station average for EBP11 presented in Appendix D.

Organic Carbon (OC) Normalization

Certain organic chemical results require normalization to their corresponding OC content for comparison to SMS criteria. OC normalized values were calculated by dividing dry-weight concentrations in milligrams per kilogram by the decimal percent TOC value.

Percent Relative Standard Deviation (RSD)

RSD values were calculated for all analytes where results from three replicate samples from a given station were available. RSD values were calculated by dividing the standard deviation among the replicate values by their station average concentration. U-qualified results were included at the full value of the nondetected concentration.

4.2.2 Conventional Parameters

Sediment conventional parameter summary statistics are presented in Table 4-1. TOC in the 2013 samples ranged from an estimated 0.705 to 2.46 percent, a smaller range of values than in 2002, when TOC ranged from 1.1 to 5.7 percent across all samples (Striplin 2002). Percent fines across all 2013 samples from Elliott Bay ranged from 12.9 percent at Station EBP03-1 to 77 percent at Station EBB04-1 (Appendix D). Grain size analytical results show that the onsite Z station contained 59.9 percent fines, which is close to the wet-sieve field estimate of 55 percent fines. Grain size results for the Z station from previous years ranged from 34 percent fines in 2002 to 93 percent fines in 2000 (Striplin 2002). This variability apparently reflects the textural differences in the disposed dredged material from year to year. The 2013 percent fines at most perimeter and benchmark stations were similar to previous years. However, fines content was slightly lower at perimeter stations EBP01 and EBP07, and slightly higher at benchmark station EBB01, than in previous years.

4.2.3 Metals

The full list of DMMP metals of concern were analyzed in the onsite Z station sample (0-10 cm) and in each replicate from the perimeter stations (0-2 cm). Metals samples from the benchmark station replicates were archived except for mercury, which was analyzed in the first replicate at each benchmark station (Table 3-1) due to holding-time constraints.

Detected metals results are summarized in Table 4-2. Antimony and selenium were not detected in any sample. Silver had the second lowest frequency of detection and was not detected in the onsite sample. The only metal that exceeded DMMP SLs and state SMS criteria was mercury, although all mercury concentrations were below the DMMP ML (Figure 4-10). Concentrations were well below the 0.41 mg/kg DMMP SL in the onsite sample. However, concentrations above the SL and SMS SQS were found in all three replicates (and the station average) from perimeter station EBP04, the station on the northeast perimeter boundary added in 2013 to replace EBP03; one replicate from EBP11; and in the single replicates analyzed from benchmark stations EBB02 and EBB03 (Appendix D). The concentrations in the replicate from EBP11 (an estimated 0.860 mg/kg in EBP11-3) and the replicate from benchmark station EBB02 (0.710 mg/kg in EBB02-1) also exceeded the 0.59 mg/kg SMS CSL value.

The Elliott Bay disposal site vicinity has a history of mercury exceedances, including the baseline survey (PTI 1988), prior to any dredged material disposal under the PSDDA program. More recently, in 2002, mercury concentrations at onsite stations were 0.872 mg/kg at EBS02 (above the DMMP SL, SMS SQS, and SMS CSL) and 0.473 mg/kg at EBS04 (above the DMMP SL). Concentrations at these stations were slightly below the SL and SQS in the 2005 contaminant investigation (SAIC 2005), and were not analyzed for mercury in 2013, per the project scope.

Perimeter station samples from 2002 did not exceed the 0.410 mg/kg SL for mercury. The highest concentration in 2002 perimeter samples was detected in a replicate from EBP07, at 0.32 mg/kg.

Benchmark station EBB02 has consistently shown exceedances of mercury since 2000. Concentrations in 2000 ranged from 0.5 to 0.64 mg/kg in the three replicates from that station. In 2002, samples from benchmark stations EBB02 (all replicates) and EBB03 (one replicate) exceeded the DMMP SL and SQS, and two of the EBB02 replicates exceeded the SMS CSL (Striplin 2002). These stations were not sampled during the 2005 contaminant investigation (SAIC 2005).

4.2.4 Butyltins

One onsite, five perimeter, and four benchmark samples were analyzed for TBT in bulk sediment and porewater (Figure 4-7; Table 3-1). The results are summarized in Table 4-3.

TBT was not detected in either the bulk sediment or porewater from the onsite station EBZ01. At the perimeter stations it was detected in all bulk sediment samples, but in only one porewater sample (from EBP04). TBT was detected in both the bulk sediment and porewater samples collected from the three benchmark stations located within Elliott Bay proper (EBB01, EBB02, and EBB03). It was not detected in either the bulk sediment or porewater samples from EBB04, the westernmost benchmark station (Figure 3-2). No DMMP SLs exist for TBT, but all

detected TBT concentrations in sediment and porewater were below the DMMP BT values of 0.15 µg/L in porewater and 73 mg/kg in sediment.

4.2.5 Organic Compounds

The analysis scheme for organic compounds in sediment for the 2013 Elliott Bay monitoring event may be summarized as follows (Table 3-1):

- Sediment from station EBZ01 and at least one replicate from the five perimeter stations were analyzed for the standard list of DMMP organic compounds (comprising LPAHs, HPAHs, chlorinated hydrocarbons, phthalates, phenols, pesticides, total PCB Aroclors, and some miscellaneous extractable compounds [DMMP 2013]), plus lindane, 1,3-dichlorobenzene, hexachloroethane, trichloroethene, tetrachloroethene, ethylbenzene, and total xylenes. All sediment samples collected from benchmark stations for these analytes were archived.
- Additionally, onsite station EBZ01 and the first replicate from each of the five perimeter stations and four benchmark stations was analyzed for dioxins/furans, PCB congeners, and PBDE congeners.
- Dioxins/furans were also analyzed at seven additional randomly placed onsite stations.

The analytical results for these organic compounds are discussed below.

4.2.5.1 PAHs

The onsite Z station sample and 13 replicates from five perimeter stations were analyzed for PAHs. PAHs were detected in all samples analyzed, though all concentrations were well below DMMP SLs (Table 4-4). For all detected PAHs, average concentrations were much higher in the perimeter station samples than in the onsite Z station sample, and most (15 of the 18 detected PAH analytes) maximum concentrations were found in replicates from station EBP07. Three additional PAH compounds were detected in perimeter samples that were not in the onsite sample: acenaphthylene, indeno(1,2,3-pyrene), and benzo(g,h,i)perylene.

4.2.5.2 Chlorinated Hydrocarbons and VOCs

Chlorinated hydrocarbons and VOCs were analyzed in the onsite Z station and in each of the 13 replicate samples from the perimeter stations. As in previous monitoring events, VOCs were not detected in any of the samples analyzed in 2013. Chlorinated hydrocarbons have not been detected in monitoring events in the past. No chlorinated hydrocarbons were detected in the onsite sample this year, but two of these compounds were detected in perimeter stations. 1,2,4-trichlorobenzene was detected in two of the perimeter samples analyzed, and 1,4-dichlorobenzene was detected in each of the perimeter samples, all at low concentrations well below the

DMMP criteria (Table 4-4). Maximum concentrations of both these compounds occurred in replicates from perimeter station EBP07.

4.2.5.3 Phthalates, Phenols, and Miscellaneous Extractable Compounds

Four phthalates, five phenols, and two miscellaneous extractable compounds were detected among the samples collected from the onsite Z station and perimeter stations. All detected concentrations were well below their respective DMMP SLs (Table 4-4).

Of all these detected compounds, phenol was the only compound detected in the Z station sample but not in any of the perimeter station samples, and dimethyl phthalate was detected at a higher concentration in the Z station sample than in the perimeter samples. Six compounds were detected in the perimeter station samples that were not detected in the onsite Z station sample: dibutyl phthalate, butylbenzyl phthalate, 4-methylphenol, 2,4-methylphenol, pentachlorophenol, and benzoic acid. All maximum detected concentrations at the perimeter stations occurred in samples from perimeter stations EBP04 or EBP07.

4.2.5.4 Pesticides

The onsite Z station sample and 14 perimeter station replicate samples (including the one extra analysis from EBP11-2, discussed previously in Section 3.3) were analyzed for pesticides (including lindane).

No pesticides were detected in any sample analyzed; however, the RLs for 4,4' DDT and dieldrin were higher than DMMP SLs in the triplicates from perimeter stations EBP04 and EBP07. RLs for total chlordanes and heptachlor were also higher than SLs in the EBP04 triplicates. The elevated RLs in these samples were attributable to matrix interferences. The laboratory performed silica gel and sulfur cleanup procedures on these samples to minimize matrix interferences. The RLs in the triplicates from perimeter stations EBP04 can also be attributed to relatively high moisture content (58% to 60%). Detection limits for these compounds in these samples were below the DMMP SLs.

4.2.5.5 PCB Aroclors and PCB Congeners

As with pesticides, the onsite Z station sample and 14 perimeter station replicate samples (including the one extra analysis discussed previously in Section 3.3) were analyzed for PCB Aroclors (Figure 4-11). PCB Aroclors were not detected (8.9 U $\mu\text{g}/\text{kg}$) in the onsite sample, but Aroclors 1254 and 1260 were detected in each of the perimeter station samples analyzed (Table 4-4). Total Aroclor concentrations exceeded the 130 $\mu\text{g}/\text{kg}$ DMMP SL in each of the replicates from stations EBP04 (ranging from 181 to 217 $\mu\text{g}/\text{kg}$) and EBP07 (ranging from 250 to 280 $\mu\text{g}/\text{kg}$) as did their station average concentrations (195 and 267 $\mu\text{g}/\text{kg}$, respectively; (Appendix D)). None of the total PCB concentrations exceeded the 3,100 $\mu\text{g}/\text{kg}$ DMMP ML. OC-normalized

concentrations in all three replicates at EBP07 exceeded the 12 mg/kg-OC SMS SQS, but not the 65 mg/kg-OC SMS CSL (Appendix D). The Elliott Bay disposal site vicinity has a history of elevated PCB concentrations, as documented in the baseline survey (PTI 1988), prior to any dredged material disposal under the PSDDA program. The concentrations detected at the perimeter stations in 2013 are consistent with concentrations found at perimeter stations in 1988, which ranged from 40 to 1,400 ug/kg, with a median value of 190 ug/kg.

The nondetected concentration of PCB Aroclors in the onsite Z sample indicates a reduction from the 111 µg/kg concentration detected at the Z station during the 2005 contaminant investigation, and the 110 µg/kg concentration detected during the 2002 monitoring event (SAIC 2005, Striplin 2002). Total Aroclors were detected above the DMMP SL in the 0–10 cm samples from onsite stations EBS02 and EBS04 in 2005, but these stations were not analyzed for PCBs during this 2013 monitoring event. Concentrations at EBP07 appear to have increased since the 2002 monitoring event. At that time, concentrations in the replicates collected at EBP07 ranged from 100 to 160 µg/kg. Only the maximum concentration exceeded the DMMP SL, and none of the OC-normalized concentrations exceeded the SQS.

As part of the 2013 monitoring event, the onsite Z station sample and the first replicate from the five perimeter stations and four benchmark stations were analyzed for PCB congeners (Figure 4-7; Table 3-1), which were detected in each sample analyzed. For evaluation, TEQ values were calculated from the PCB congener results, which are summarized in Table 4-5. Individual sample TEQ values are listed along with their corresponding TOC values in Table 4-6.

As shown, TEQ values were lowest in the onsite sample and highest in the benchmark sample from EBB02. A total of 82 individual congeners and 31 co-eluting congener groups were detected overall, 37 of which were detected in the onsite sample. A listing of the full results of the PCB congener analyses is provided in Appendix D.

4.2.5.6 Dioxins/Furans

Each of the 10 onsite station samples (0–10 cm) and the first replicate sample (0–2 cm) from each of the five perimeter and four benchmark stations were analyzed for dioxins/furans (Figure 4-6).

Dioxins/furans were detected in each of the samples analyzed; 2013 TEQ values are shown in Figure 4-12, summarized in Table 4-7 and individual TEQ values are listed, along with TOC concentrations and TEQ values from the 2007 dioxin investigation, in Table 4-8. Note that the 2013 samples were analyzed using the same analytical method as the 2007 samples (USEPA Method 1613B), whereas the 2005 samples were analyzed using USEPA Method 8290 (SAIC 2008; Section 2.9). For the purposes of comparison to the 2007 dioxin/furan investigation, 2013 dioxin/furan TEQ (ND= ½ DL) values are discussed here.

The Z station sample contained the lowest dioxin/furan concentration, an estimated 1.25 ng/kg TEQ (ND= ½ DL). Samples from half of the onsite stations (EBS02, EBS04, EBR03, EBR05, and

EBR07), three of the five perimeter stations (EBP04, EBP07, and EBP11), and three of the four benchmark stations (EBB01, EBB02, and EBB03) contained dioxin/furan concentrations above the 4 pp^{tr} TEQ Disposal Site Management Objective implemented by the DMMP in 2010 (Appendix D; DMMP 2013). Of these, only the sample from EBS02 (a 0-10 cm sample with an estimated 5.25 ng/kg TEQ) is located within the extent of the recent dredged material deposit, based on the findings of the SPI survey; however, it is located where recently disposed material is less than 3 cm thick, suggesting older dredged material was included in the sample (Figure 4-1; Appendix B). None of the three 0–10 cm samples collected from the disposal zone (EBZ01, EBR01, and EBR06), where the recent dredged material deposit was measured at over 12 cm thick, exceeded 4 pp^{tr} TEQ.

The highest concentration, an estimated 30.3 ng/kg TEQ (ND= ½ DL), occurred in the 0-10 cm sample from the onsite station EBS04, which the 2013 SPI survey showed to be beyond the extent of both recent and identifiable historical dredged material deposits. This concentration and those at perimeter station EBP11 [an estimated 12.6 ng/kg TEQ (ND= ½ DL)] and benchmark station EBB02 [an estimated 11.4 ng/kg TEQ (ND= ½ DL)] were above the 10 pp^{tr} DMMP BT (DMMP 2013). Average concentrations between the onsite, perimeter, and benchmark stations were similar, on the order of 6 ng/kg TEQ (ND=0) (Table 4-7). Compared to previous results, although concentrations appear to increase over time at stations EBS04 and EBP11, no consistent temporal pattern in dioxin/furan concentrations is apparent across all stations in Elliott Bay (Table 4-8; also see Figure 4-8).

The dioxin/furan and TOC results from the 2007 and 2013 investigations are also plotted by station type and year in Figure 4-8. As the 2007 study showed, the 2013 dioxin/furan concentrations do not show a strong correlation to TOC concentrations (Figure 4-8).

4.2.5.7 PBDE Congeners

PBDE congeners were analyzed in the onsite Z station sample and in the first replicate from the five perimeter stations and four benchmark stations sampled (Figure 4-7; Table 3-1). Overall, 27 individual PBDE congeners and six sets of co-eluting congener pairs were detected. However, only four of these were detected in the onsite sample (Table 4-9). Only three congeners, PBDE007, PBDE017, and PBDE049, were detected in all samples. Perimeter station samples contained the largest number of detected congeners, and most of the maximum detected concentrations occurred in the sample from perimeter station EBP03. The results for all 43 individual PBDE congeners and 10 co-eluting pairs are provided in Appendix D.

³ Parts per trillion is equivalent to units of nanograms per kilogram, or picograms per gram.

4.2.6 Field Variability

Field variability among replicate samples at a given monitoring station was evaluated by using an acceptability guideline of 50 percent RSD among field replicates for each parameter. The calculated RSD values are provided in Appendix D.

The majority of replicate results were acceptable; exceptions are summarized in Table 4-10. Analytes with RSD values greater than 50 percent include total sulfides, *N*-ammonia, gravel, mercury, butylbenzyl phthalate, diethyl phthalate, phenol, 4,4'-DDT, and Aroclor 1248. Perimeter station EBP11 had the most occurrences of RSD values above 50 percent. Total sulfides exceeded the acceptability criterion most frequently, at one perimeter station and three benchmark stations, but *N*-ammonia showed the highest RSD value, 136 percent, at benchmark station EBB02.

4.3 Bioassays

Sediment from one Elliott Bay onsite sample (EBZ01) and one Carr Inlet reference station (CR-24) were tested using the amphipod, larval, and growth bioassays as listed in Section 3.4. Reference sample CR-24 was selected because it best matched the grain size range of onsite sample EBZ01 based on wet-sieve field results. Laboratory grain size analysis determined that percent fines for EBZ01 and CR-24 were 60 and 56 percent, respectively (Table 4-11). A second reference sample (CR-23W) was collected and archived alongside sediment from four Elliott Bay benchmark samples (EBB01–EBB04) in the event that the onsite sample exceeded the Site Condition II biological response guidelines.

Northwest Aquatic Sciences conducted all tests using PSDDA-approved methods. *Eohaustorius estuarius*, an amphipod with tolerance for a wide range of grain size with clay fractions less than 20 percent, was used as both EBZ01 and CR-24 had clay fractions less than 19 percent. The larval test was performed using the standard protocol. The *Neanthes* growth test was conducted using the ash-free dry weight (AFDW) procedure indicated in the 2013 SMARM clarification paper (Kendall et al. 2013).

Toxicity test results are summarized in Table 4-11. Complete laboratory reports can be found in Appendix F. A data quality evaluation for each data package was performed in accordance with PSEP guidance (PSEP 1986) and the PSDDA Abbreviated Data Quality Evaluation (QA1) for Dredged Material Disposal Projects (PTI 1989) with revisions (PSEP 1995, PSDDA 1989a, PSDDA 1990, annual review process). Results of this evaluation are reported on worksheets in Appendix F and are summarized below.

Control and reference sediments were within DMMP performance criteria for all bioassays – the amphipod 10-day bioassay, the sediment larval bioassay, and the *Neanthes* 20-day bioassay (Table 4-12). The mean control growth rate for the *Neanthes* test (0.84 mg/individual-day) met

the recommended DMMP target growth rate of ≥ 0.72 mg/individual-day. The average initial weight of the worms was 0.55 mg, which is within the DMMP recommended range of 0.5–1.0 mg. All tests were initiated within 2 weeks, well within the DMMP maximum holding time of 8 weeks, and positive control performance for all tests was within the laboratory's acceptance limits.

Daily water quality measurements (every 3 days for the *Neanthes* 20-day test) were within acceptable ranges described in PSEP (1995) or PSDDA (1990 and the annual review minutes) (see the QA1 worksheets in Appendix F). The only exception was water salinity in one of the EBZ01 *Neanthes* replicates (30.5 ppt), which on Day 15 of the test slightly exceeded the recommended maximum salinity measurement (30 ppt). It was concluded that this minor deviation from target acceptable water quality range did not influence test results.

Measurements of total ammonia and total sulfides were made in overlying water at the beginning and end of each test. Total sulfides in overlying water were not detected at 0.02 mg/L. Total ammonia ranged from not detected at 0.1 mg/L to a maximum of 1.39 mg/L for the amphipod test, 3.62 mg/L for the *Neanthes* test, and 0.27 mg/L for the larval test. Total ammonia levels are considered when interpreting the data. However, the concentrations measured here are not considered a major concern. For several amphipod species, an acceptable total ammonia concentration in porewater is up to 30 mg/L (Striplin et. al. 1998), and *Neanthes* can tolerate unionized ammonia concentrations up to 0.7 mg/L (approximately 35 mg/L total ammonia) (PSEP 1995). The maximum unionized ammonia concentration in the *Neanthes* test was 0.21 mg/L.

In the larval test, one CR-24 replicate had a much lower number of normal larvae when compared to the other four replicates for this sample. The laboratory was not able to identify a reason for this and the water quality data do not indicate any issues (Appendix F). The laboratory presented data analysis both with and without the atypical replicate. Regardless of whether the replicate is included, CR-24 results meet DMMP larval reference sample performance standards (Appendix F). All presentation and discussion of data for CR-24 larval test results contained in this report therefore include data for all associated replicates.

As seen in Table 4-11, test results for station EBZ01 were as follows:

- Amphipod mortality: 14 percent
- *Neanthes* growth: 0.63 mg/individual-day on an AFDW basis
- Larval normalized combined mortality and abnormality: 10 percent.

Station EBZ01 sediment passed DMMP non-dispersive disposal site interpretation guidelines (Table 4-12). Consequently, no additional benchmark samples were submitted for bioassay testing.

5 EVALUATION OF MONITORING DATA

This section evaluates the results of the 2013 Elliott Bay disposal site monitoring per the DMMP monitoring framework and interpretive guidelines presented in Section 2.

5.1 Question 1: Does the Dredged Material Stay Onsite?

5.1.1 SPI Results

Hypothesis No.1: Dredged material remains within the disposal site boundary.

The 2013 SPI survey at Elliott Bay did not identify the presence of dredged material exceeding the 3-cm DMMP interpretive criteria beyond the disposal site perimeter (NewFields 2013). Both recent and historic dredged material remained within the disposal site, suggesting relatively stable dredged material deposition patterns. Under the monitoring framework for non-dispersive dredged material disposal sites, *Hypothesis No. 1 is not rejected* (i.e., dredged material remains within the disposal site boundary) (NewFields 2013).

5.1.2 Perimeter Chemistry

Hypothesis 2: Chemical concentrations at offsite stations do not measurably increase over time due to dredged material disposal.

A review of the 2013 perimeter station chemistry found that most detected chemicals were well below the Washington State SQS criteria, but that mercury (at EBP04 and EBP11), and PCBs (at EBP07) show exceedances.

A statistical time-trends analysis was conducted to determine if changes observed in perimeter site chemistry are significant over time. The number of station replicates available for the time-trends analysis at each perimeter station by year is shown in Table 5-1; EBP04 was not included due to a lack of replicated historical data. The time-trends analysis was conducted using the CTS as described in detail in SAIC and MWLS (1996). The chemical groups evaluated in the 2013 CTS analysis include conventional parameters, metals, LPAHs, HPAHs, chlorinated hydrocarbons, phthalates, phenols, miscellaneous extractables, and pesticides and PCBs. VOCs were never detected. The current CTS spreadsheet was not set up to include the dioxin/furan group (which were only available for one replicate per station in 2007 and 2013), so the dioxin data were addressed separate from the CTS analysis. The detailed CTS output is provided in Appendix G. The “global” maximum likelihood estimation for each perimeter station representing the estimate for all chemicals of concern and conventional parameters is reported in Table 5-2. However, the global estimation is no longer used for evaluating offsite chemical trends because it assumes that a common trend is present among all chemical concentrations,

including conventional parameters (SAIC 2003). Common trends among all groups have not been observed where CTS has been used to evaluate time trends in perimeter chemistry (e.g., Commencement Bay 1996, 2001, 2003, 2004; Elliott Bay 2000, 2002). Some chemicals show increasing trends and many others show decreasing trends at the disposal sites. In addition, some conventional parameters do not follow the same trend as the COCs (e.g., an increase in percent fines). Therefore, trends for individual chemicals and groups of chemicals (e.g., metals or HPAHs) are used to assess time trends in perimeter chemistry.

Average trends (the mean slope) within a chemical group for each perimeter station are reported in Table 5-2. The maximum likelihood estimations of the mean trend represent the mean percent change per year. The significance values for these slope estimates are indicated by the p-value, shown for the average group results if there are at least four individual slopes available within the group. P-values less than 0.05 are considered to be statistically significant.

The maximum likelihood results showed both increases and decreases in chemical groups at the perimeter stations since 1990 (Table 5-2). The mean slope for metals and phthalates indicated a decreasing trend at every station, but was statistically significant ($p < 0.05$) for metals only. The mean slope for LPAHs and miscellaneous extractables indicated an average increasing trend at every station. The HPAHs had a mean slope indicating an increasing trend at every station except EBP01. The remaining groups showed variable trends, the direction and magnitude of trends varying by individual chemical and by station, as described in more detail below and shown in Tables 5-3 through 5-6).

5.1.2.1 Conventional Parameters

The conventional parameters group shows an average positive trend at all stations, although none of these mean trends are statistically significant. The grain size distribution at each station is becoming coarser over time with percent gravel and sand increasing and percent fines decreasing at all stations except EBP03 (which showed the reverse pattern). Other than grain size, the statistically significant trends include TOC and total volatile sulfides significantly increasing at station EBP03; ammonia significantly decreasing at EBP07; and total solids significantly increasing at all stations except EBP03.

5.1.2.2 Metals

The metals group shows significantly decreasing mean trends in concentrations at all stations. In addition, statistically significant decreasing trends were observed for all of the individual metals at all stations except for the following:

- Arsenic at EBP01 showed a nonsignificant decrease ($p > 0.05$).
- Cadmium at EBP01 showed a statistically significant increase.
- Cadmium and mercury at EBP03 showed nonsignificant decreases ($p > 0.05$).

- Cadmium and mercury at EBP07 had nonsignificant trends (positive for cadmium, negative for mercury).
- Lead at EBP11 showed a non-significant decreasing trend ($p > 0.05$).
- Cadmium and mercury at EBP11 showed non-significant positive trends ($p > 0.05$).

5.1.2.3 PAHs

For the group of LPAHs, average trends were slightly positive at all perimeter stations, and the group mean was statistically significant at EBP11 only ($p < 0.05$). Only station EBP01 had any decreasing trends for the individual LPAHs. The greatest increases were shown by naphthalene, as much as 13 percent increase per year at station EBP11, and acenaphthylene with 12 percent increase per year at station EBP11. Station EBP11 had the greatest number of statistically significant positive trends for the individual LPAHs, as well as the trends with the greatest magnitude.

Acenaphthene and 2-methylnaphthalene were excluded from the group results for EBP03 because of insufficient detected concentrations. Acenaphthylene was excluded for EBP01 due to unstable maximum likelihood results because of limited detected concentrations and detection limits that often exceeded the detected values. There were only two years with detected concentrations: 8.6J, 16U, and 18U ug/kg in 1992 to 21, 19U, and 17J ug/kg in 2013. These results suggest that the concentration of acenaphthylene may be increasing, but additional detected data with low detection limits is needed to confirm.

The HPAHs group showed very little change in concentrations over time. Station EBP01 had a mean decreasing trend, all the other stations showed a slight positive mean trend for this chemical group. The average percent change ranged from -1.1 percent (EBP01) to + 0.8 percent (EBP03). The only statistically significant trend was a negative trend observed for dibenz(a,h)anthracene (EBP01).

5.1.2.4 Chlorinated Hydrocarbons

There were very few detected concentrations in the group of chlorinated hydrocarbons at the Elliott Bay perimeter stations. Only 1,4-dichlorobenzene and 1,2,4-trichlorobenzene had any detected concentrations, but the trend results for these compounds were unstable because the detected concentrations were observed only in 2013 and at concentrations within the range of RLs from previous years.

1,4-Dichlorobenzene showed consistent patterns at all four perimeters stations, with all nondetects in the years prior to 2013, and in 2013 detected values ranging from an estimated 3.8 to 5.3 $\mu\text{g}/\text{kg}$ at stations EBP01, EBP03, and EBP11. Station EBP07 had an average concentration of 14 $\mu\text{g}/\text{kg}$ in 2013. These results suggest that the concentration of 1,4-dichlorobenzene may be

increasing (particularly at EBP07), but additional detected data with low detection limits are needed to confirm.

For 1,2,4-trichlorobenzene, replicates 2 and 3 of Station EBP07 had detected concentrations in 2013 of an estimated 2.4 and 4.7 µg/kg. Prior-year sampling results had been reported as nondetected with RLs as low as 1.7 U µg/kg in 1992 and as high as 8.8 U µg/kg in 2001. These results suggest that the concentration of 1,2,4-trichlorobenzene may be increasing, but additional detected data with RLs is needed to confirm.

All the other chlorinated hydrocarbons in all samples were not detected with RLs in 2013 that were comparable to or less than all previous RLs. Other than 1,4-dichlorobenzene and 1,2,4-trichlorobenzene this group of compounds does not appear to be increasing at the perimeter stations.

5.1.2.5 Volatile Organics

There were no detected data for this group of compounds.

5.1.2.6 Phthalates

The average trend for phthalates was negative at all four perimeter stations. Bis(2-ethylhexyl)phthalate showed a non-significant positive trend at all stations except EBP01, ranging from 1.5 to 3.4 percent per year; EBP01 showed a significant negative trend ($p \leq 0.05$). All other members of the phthalates group with sufficient data to measure trends indicated decreasing trends. Dimethylphthalate was excluded for EBP07 due to unstable maximum likelihood results because the detected concentrations were observed only in 2013 and at concentrations lower than the range of RLs from previous years.

5.1.2.7 Phenols

The average trend for phenols was positive at EBP01 and EBP07, and negative at EBP03; there was insufficient data to evaluate trends at EBP11. For individual phenols, only 4-methylphenol at EBP07 showed a positive trend that was statistically significant.

2-Methylphenol was excluded for EBP01 and EBP11 due to unstable maximum likelihood results because the detected concentrations were observed only in 2013 and at concentrations less than all RLs from the previous years. 2,4-Dimethylphenol was excluded for EBP07 for similar instability although 2013 concentrations were within the range of RLs from previous years. Additional data are needed to confirm any trends that appear to be present in the phenols group.

5.1.2.8 Miscellaneous Extractables

The average trend for miscellaneous extractables was positive at EBP01, EBP07, and EBP11; there was insufficient data to evaluate trends at EBP03. Within this group of compounds, only benzoic acid and dibenzofuran had sufficient data to evaluate trends, and the observed trends were always positive. Dibenzofuran showed a statistically significant increasing trend at EBP01, EBP07, and EBP11. Station EBP03 had inadequate detected data to determine trends for any of the individual chemicals within this group of compounds.

Benzoic acid had unstable maximum likelihood results for station EBP01 and EBP11 because the detected concentrations were observed only in 2013 and at concentrations within the range of the detection limits from previous years. The concentrations reported in 2013 averaged an estimated 143 µg/kg at EBP01 and 97.3 µg/kg at EBP11, and the historical detection limits ranged from 6 to 200 µg/kg. Additional data are needed to confirm any trends that appear to be present in benzoic acid.

5.1.2.9 Pesticides/PCBs

As a group, the pesticides/PCBs showed mean decreasing trends at EBP07 and EBP11, and increasing at EBP01 and EBP03. Most of the individual compounds in this group had inadequate detected data to determine time trends.

Aroclor 1254 and alpha-chlordane showed increasing trends at every station, although the trends were statistically significant for Aroclor 1254 at EBP01 only. Aroclor 1260 showed a decreasing trend at every station. Dieldrin showed a positive trend at EBP01 and EBP03, and a negative trend at EBP07 and EBP11. Statistically significant decreasing trends were present for Aroclor 1260 (EBP07) and dieldrin (EBP11).

4,4'-DDD and 4,4'-DDE were excluded for Station EBP03 due to unstable maximum likelihood results. For both of these compounds the detected concentrations were limited to only one observation in each of two years, and the results reported in 2013 were nondetected at detection limits bounded by the previous detected concentrations. It does not appear that concentrations for these compounds are increasing, though additional detected data with low detection limits are needed to confirm this.

4,4'-DDD was excluded for EBP11 due to unstable maximum likelihood results. Concentrations were detected in 1992 at levels of 1.3 µg/kg or less and were nondetected at RLs of 1.3 µg/kg or less in 2002 and 2013. So, while trend results could not statistically be evaluated, there does not appear to be an increasing trend for this compound.

5.1.2.10 Dioxins/Furans

The dioxin/furan group was not included in the CTS analysis spreadsheet when it was constructed back in 1996. Since this group of compounds was only analyzed in one replicate during each of the 2007 and 2013 surveys, the change in dioxin/furans was evaluated as a simple comparison between individual results at each station from the two years. Individual dioxin/furans generally stayed relatively stable or decreased slightly at stations EBP01, EBP03, EBP07 and EBP11. The TEQs (ND=½ DL) showed a decrease in 2013 ranging from 35 percent of 2007 results (EBP01) to 83 percent (EBP03). However, Station EBP11, along the western edge of the site, showed a 2-fold increase, from 6.3 pptr TEQ in 2007 to 12.2 pptr TEQ in 2013, driven by an increase from 1.1 to 9.2 pptr of 1,2,3,7,8-pentachlorodibenzo-*p*-dioxin.

5.1.2.11 Summary

Chemical concentrations showing statistically significant positive trends at perimeter stations include cadmium, LPAH (naphthalene, acenaphthylene, acenaphthene, anthracene, fluorene, 2-methylnaphthalene), 4-methylphenol, dibenzofuran, and Aroclor 1254. None of the chemicals with 2013 SQS exceedances showed statistically significant increasing trends when examined in the CTS analyses (mercury at EBP11, and PCB Aroclors at EBP07). While mercury also exceeded the SQS in 2013 at EBP04, trend analysis could not be conducted because no prior data exists for that station.

Dioxin/furan TEQ values were relatively stable, with the exception of EBP11, which showed a 2-fold increase.

With the exception of dioxins/furans, concentrations of these chemicals are lower in onsite sediment than in perimeter sediment on average (Tables 4-2, 4-4, and 4-7), suggesting that the statistically significant increases seen at perimeter stations are likely attributable to sources other than the recently deposited dredged material. Therefore, *Hypothesis No. 2 is not rejected* (i.e., chemical concentrations do not increase over time at offsite stations due to dredged material disposal).

5.2 Question 2: Has Dredged Material Disposal Caused the Biological Effects Conditions for Site Management to Be Exceeded at the Site (Site Condition II [PSDDA 1988])?

5.2.1 Onsite Chemistry

Hypothesis No. 3: Sediment chemical concentrations at the onsite monitoring stations do not exceed chemical concentrations associated with PSDDA Site Condition II guidelines due to dredged material disposal.

The evaluation of site conditions relative to PSDDA Site Condition II guidelines is based on a comparison of onsite chemical concentrations to the DMMP MLs. The MLs are concentrations above which adverse biological effects are expected to occur. Sediment chemistry at the onsite station did not exceed the DMMP ML values; therefore, ***PSDDA Hypothesis No. 3 is not rejected*** (i.e., chemical concentrations at the onsite monitoring station did not exceed Site Condition II).

5.2.2 Bioassays

Hypothesis No. 4: Sediment toxicity at the onsite stations does not exceed the PSDDA Site Condition II biological response guidelines due to dredged material disposal.

The 2013 Elliott Bay toxicity tests were evaluated according to the DMMP guidelines for non-dispersive disposal sites (PSDDA 1989b; DMMP 2013). The onsite station passed the DMMP bioassay interpretive criteria for all toxicity tests; therefore, ***PSDDA Hypothesis No. 4 is not rejected*** (i.e., sediment toxicity at the onsite monitoring station did not exceed Site Condition II).

6 CONCLUSIONS

Results of the 2013 DMMP monitoring framework data evaluations are presented in Table 6-1.

6.1 Does the Dredged Material Stay Onsite?

Recently placed dredged material was mapped well within the Elliott Bay disposal site boundary in 2013. In 2013, although there were two chemicals exceeding the SQS at three perimeter stations (mercury at EBP04 and EBP11, and PCBs at EBP07), these concentrations are greater than that found in the onsite sample and are likely not associated with recent dredged material disposal. The CTS time-trend analyses indicated significant increases in concentrations since 1988 for some chemicals at perimeter stations, but these concentration increases are also likely attributable to sources other than dredged material disposal. None of the chemicals with 2013 SQS exceedances showed statistically significant increasing trends when examined in the CTS analyses.

6.2 Is Site Condition II Exceeded?

Onsite sediment chemical concentrations were compared to DMMP ML values, which represent PSDDA Site Condition II chemical guidelines. No onsite sediment chemical concentrations exceeded DMMP ML values. To evaluate PSDDA Site Condition II biological response guidelines, the results of the DMMP bioassay tests are compared to DMMP bioassay interpretive criteria. No onsite bioassay results exceeded DMMP bioassay criteria.

6.3 Is the Site Management Objective for Dioxins/Furans Being Met?

The average dioxin concentration at the ten on-site stations sampled in 2013 was 6.90 ng/kg TEQ, which exceeds the site management objective of 4.0 ng/kg TEQ established by the DMMP agencies in 2010. However, the DMMP agencies acknowledged when the site management objective was implemented that it would take time to reach this goal since dredged material disposal does not provide a uniform cover over the entire extent of the site.

For the five sampling locations that fell within the dredged material footprint shown in Figure 4-13 (EBZ01, EBS02, EBR01, EBR04 and EBR06), the average dioxin concentration was 3.31 ng/kg TEQ (range = 1.25 to 5.25 ng/kg TEQ), which is below the site management objective. Further examination shows that the station within the dredged material footprint with the highest 2013 concentration (5.25 ng/kg TEQ at EBS02) was outside the 3-cm contour. This means that older dredged material would have been included in the 10-cm sample taken at EBS02 for dioxin analysis in 2013. The 2007 concentration at EBS02 was 9.66 ng/kg TEQ. So the

presence of older dredged material is likely the reason the dioxin concentration in the 10-cm sample exceeded the site management objective at that station in 2013.

The concentration of dioxin detected at station EBS04 (30 ng/kg TEQ), which lies outside the dredged material footprint, is clearly well above the site management objective. The dioxin concentration at this station in 2007 was 17 ng/kg TEQ. There is reason to believe the elevated dioxin at this station is associated with a dredging project that used the site prior to implementation of wide-scale dioxin testing for DMMP projects. Steps to address the elevated concentration of dioxin at EBS04 are discussed in the Recommendations section of this report.

In conclusion, while the site management objective of 4 ng/kg TEQ was not met over the entire site, the revised dredged material evaluation guidelines implemented in 2010 did result in the management objective being met within the footprint of recent dredged material deposits. This finding provides evidence that the evaluation guidelines and best management practices for dioxin are working as intended.

7 RECOMMENDATIONS

Recommendations for future Elliott Bay site monitoring as well as monitoring in general are proposed in this section.

7.1 Replace Perimeter Station EBP03 with EBP04 in Future Monitoring

Problems with sediment recovery at perimeter station EBP03, due to rocks and debris which prevented the grab sampler from closing, ultimately prompted the station to be abandoned after the collection of one replicate, and replaced by EBP04. Acceptable samples from EBP04 were readily obtained.

The bathymetry at EBP04 also makes this station a better sentinel station than EBP03 in detecting off-site movement of dredged material. EBP03 is located on the slope of a submarine promontory, likely the result of material deposited from the Denny Hill regrade. The water depth at EBP03 is approximately 145 ft (MLLW). In contrast, EBP04 is located to the south of the promontory in approximately 235 ft of water. Any dredged material moving off site to the northeast is much more likely to be detected at EBP04 than at EBP03.

EBP04 exhibited higher concentrations of mercury (above the DMMP SL and SMS SQS), total PCBs (above the DMMP SL, and slightly below the SMS SQS) and dioxins/furans (above the 4 ppb TEQ Disposal Site Management Objective) than at EBP03. In addition, concentrations of mercury and total PCBs detected in EBP04 replicates are higher than in samples from previous rounds of sampling at EBP03.

Based on these findings it is recommended that the DMMP replace EBP03 with EBP04 in future monitoring events. The 2013 chemistry results should be used as the baseline condition for EBP04 when assessing temporal trends in the future.

7.2 Upgrade CTS Software

The CTS software, built in 1996, does not operate properly on current versions of Microsoft Excel (2010). Because older versions of Excel are becoming less available, an upgrade to the CTS software that would allow it to operate on Excel 2010 is recommended.

7.3 Site Management Objective for Dioxins/Furans

The DMMP revised interim guidelines for dioxins implemented in 2010 (DMMP 2010) call for increased disposal site monitoring to track the effect of the updated guidelines on sediment quality at the non-dispersive disposal sites. Specifically, the guidelines state:

Non-dispersive Disposal Site Management Objective: Four pptr TEQ will be the objective for surface sediments within the boundary of a disposal site, to be achieved over time as the updated suitability guidelines are implemented. This objective will aid in case-by-case decision-making (see next paragraph) on the suitability of material for disposal and assure protection of human and ecological health. Disposal site monitoring will provide the feedback necessary to determine whether the site management objective is being met.

In Section 4.2.5.6 of this report, the dioxin concentrations measured at the Elliott Bay disposal site and surrounding stations in 2007 and 2013 are compared on a station-by-station basis. We recommend that future evaluations use a surface-weighted average concentration (SWAC) across the entire disposal site area to assess changes in sediment quality over time. Such an approach should be effective at documenting temporal change, especially given the randomized basis for selecting onsite station locations. Evaluating the data on a SWAC basis would also be consistent with the recently revised SMS rule for assessing clean up objectives at a sediment site. If the DMMP agencies want to pursue this, some discussion is warranted on the technical specifics of the approach, e.g., spatial coverage (onsite stations only, onsite plus perimeter stations, etc.) and geostatistical interpolation method (inverse distance weighting, Thiessen polygons, etc.).

7.4 Temporarily Shift Disposal Target Location

The following recommendation was made by Integral Consulting in the December 13, 2013 draft report:

The dioxin/furan results indicate concentrations within the disposal site boundary that exceed the 4 pptr TEQ Disposal Site Management Objective and the 10 pptr TEQ BT. The highest TEQ value within the disposal site boundary was found at station EBS04, which was also found to have a relatively high TEQ value during the 2007 dioxin investigation. EBS04 is located outside the limits of the recent and identifiable historical dredged material deposits and so does not reflect the quality of recently disposed dredged material. Future dredged material to be deposited at the Elliott Bay site will meet the 4 pptr TEQ volume-weighted average, but given past disposal trends, the high concentrations of dioxins at EBS04 could remain uncovered for many years without a more proactive strategy. In order to more quickly reach the Disposal Site Management Objective at the Elliott Bay site, the DMMP agencies should consider temporarily shifting the disposal target for one or more projects in the current dredging year eastward of its current location to cover the EBS04 area with cleaner material. Some disposal fate modeling may be warranted to locate the interim disposal zone such that disposed dredged material does not disperse beyond the eastern site boundary.

June 27, 2014 update from the DMMP agencies:

The Corps of Engineers dredged the upper Duwamish turning basin starting in December of 2013. Dredged material from the turning basin is predominantly sand and has been used several times in the past for beneficial use projects. However, for this cycle of maintenance dredging there were no beneficial use projects in need of this material. Therefore, the Corps planned to dredge the material and place it at the Elliott Bay site.

The DMMP agencies requested that the turning basin material be placed at EBS04 rather than the usual target coordinates at EBZ01. The Corps agreed and placed 20 barge loads of turning basin material, consisting of approximately 27,000 cubic yards, at station EBS04. The tracklines for these disposal loads are shown in Figure 4-14. As can be seen from the figure, station EBS04 was successfully targeted by the Corps' contractor. Verification of the anticipated reduction in dioxin concentration at this station as a result of the targeted placement will take place during the next monitoring event at the Elliott Bay site.

7.5 Time for a Comprehensive Monitoring Program Review?

As detailed in Section 2 for Elliott Bay and summarized in Revelas et al. (2012) for all five PSDDA non-dispersive disposal sites, 25 years of Puget Sound site monitoring (including these 2013 Elliott Bay results) have shown that:

- The original PSDDA disposal site management objectives are being met. In fact, only one adjustment in a site management practice has needed to be made since post-disposal site monitoring began in 1990⁴.
- The chemical and biological disposal site data have provided a feedback loop that indicates that the DMMP evaluation procedures effectively characterize dredge material quality and that suitability determinations accurately reflect the chemistry and toxicity of sediment disposed at the sites.

In parallel with this good news about the program's technical effectiveness, the program is under significant fiscal pressure and maintaining the programmatically prescribed level of monitoring does not appear to be sustainable (i.e., the program is no longer self-funding as originally designed through the collection of dredged material disposal fees). In addition, as noted above in Section 7.3, the recently adopted DMMP guidelines for dioxins call for increased disposal site monitoring for these compounds and potentially other persistent, bioaccumulative, and toxic compounds. These significant changes in the DMMP program have implications for long-term disposal site monitoring needs.

⁴ Based on the detection of offsite dredged movement at the Commencement Bay site in 2001, the target disposal release point was altered to ensure that material stayed within the site boundary.

Given the juxtaposition of the monitoring program's successful 25-year track record and the changing regional technical and regulatory landscape, it may be time to redefine the key site management objectives and re-assess the technical tools best used to meet those objectives. The overall goal of such a review would be to make sure the program continues to ensure the viability of the disposal sites while making optimal use of limited agency resources.

Table 2-1 details the existing monitoring program questions/hypotheses tested, monitoring tools, and interpretative guidelines. For discussion purposes, the 25-year monitoring data set shows that the monitoring objectives addressed by Question 2 (are the biological effects conditions for site management exceeded at the site due to dredged material disposal?) and Question 3 (are unacceptable adverse effects due to dredged material disposal occurring to biological resources off site?) have ALWAYS been achieved (i.e. the answers to Questions 2 and 3 have always been NO) at all of the non-dispersive disposal sites since the program's inception. These questions could be moved to second-tier monitoring program elements that would only be triggered/implemented if the tools used to address Question 1 show either that dredged material has moved offsite or the SPI data suggests benthic ecological recovery is not occurring on the dredged material mound. There is long-term precedent of this use of SPI technology in New England's DAMOS (Disposal Area Monitoring System) program (see Germano et al. 2011 for a summary). However, this would be a new use of the SPI data set within the DMMP program and warrants agency discussion.

In addition to retaining Question 1 as a main monitoring element (i.e., verifying that material stays on site and is not affecting benthic habitat quality), a new monitoring Question(4) could be added to measure onsite dioxin and other PBTs to assure protection of human and ecological health from these bioaccumulative compounds. This question could be addressed with the same kind of onsite sediment chemistry sampling design used in this 2013 Elliott Bay monitoring; i.e., disposal zone and randomized onsite sediment chemistry stations that would provide the feedback needed to determine whether the site management objectives for bioaccumulative compounds are being met.

We look forward to discussing these and other potential program modifications with DNR and the other DMMP agencies.

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FIGURES
