2017 TIERED-FULL MONITORING AT THE COMMENCEMENT BAY NON-DISPERSIVE UNCONFINED OPEN-WATER DREDGED MATERIAL DISPOSAL SITE

FINAL DATA REPORT

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Washington State Department of Natural Resources
Aquatic Resources Division
Olympia, Washington 98504

Submitted by:

115 2nd Avenue N, Suite 100
Edmonds, Washington 98020

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LIST OF ACRONYMS AND ABBREVIATIONS

ARI	Analytical Resources, Inc.
AFDW	ash-free dry weight
BCOC	bioaccumulative chemical of concern
BT	bioaccumulation trigger
COC	chemical of concern
CTS	Chemical Tracking System
CY	cubic yards
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DL	detection limit
DMMP	Dredged Material Management Program
DNR	Washington State Department of Natural Resources
DSMO	Disposal Site Management Objective
DW	dry weight
DY	dredge year
EPA	Environmental Protection Agency
HPAH	high molecular weight polycyclic aromatic hydrocarbon
LCL	lower confidence level
LPAH	low molecular weight polycyclic aromatic hydrocarbon
MIG	mean individual growth rate
ML	maximum level
MWLS	Mountain Whisper Light Statistical Consulting
NAS	Northwestern Aquatic Sciences
NCMA	mean normalized combined mortality/abnormality
ND	not detected
NOCN	no other conditions necessary
NSD	not statistically different
OSI	organism-sediment index
PAH	polycyclic aromatic hydrocarbon
PBDE	polybrominated diphenyl ethers
PCB	polychlorinated biphenyl
PSDDA	Puget Sound Dredged Disposal Analysis
PSEP	Puget Sound Estuary Program
QA	quality assurance
QC	quality control
RL	reporting limit
RPD	redox potential discontinuity
RSD	relative standard deviation

R/V	research vessel
SAP	sampling and analysis plan
SAIC	Science Applications International Corporation
SD	statistically different
SE	standard error
SL	screening level
SMARM	Sediment Management Annual Review Meeting
SMS	Sediment Management Standards
SPI	sediment profile imaging
SQS	Sediment Quality Standards
SVOA	semi-volatile organic analysis compound
SVPS	sediment vertical profiling system
TBT	tributyltin
TEF	toxic equivalent factor
TEQ	toxic equivalency
TOC	total organic carbon
TVS	total volatile solids
UCL	upper confidence limit
UEMP	Updated Environmental Monitoring Plan
U.S.	United States
USACE	U.S. Army Corps of Engineers, Seattle District
VSP	Visual Sampling Plan
WHO	World Health Organization

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1.0 INTRODUCTION

This report presents the results of the 2017 tiered-full monitoring program conducted at the Commencement Bay non-dispersive unconfined open-water dredged material disposal site in Tacoma, Washington. The Washington State Department of Natural Resources (DNR) conducted this study through a contract with NewFields.

DNR, the U.S. Army Corps of Engineers, Seattle District (USACE), the Washington State Department of Ecology (Ecology), and the U.S. Environmental Protection Agency, Region 10 (U.S. EPA) have formed an interagency partnership for the environmental management of dredged material in Washington State. This partnership, called the Dredged Material Management Program (DMMP), provides guidance for evaluating proposed dredged material to determine its suitability for unconfined, open-water disposal, obtaining disposal site use permits, and monitoring disposal sites following dredged material disposal. In Puget Sound, this guidance was first outlined 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 of 1988, and for north and south Puget Sound sites (Phase II) in September of 1989 (PSDDA 1988a-d, 1989a,b).

The baseline survey for the Commencement Bay dredged material disposal site was conducted in 1988 during the Phase I study (PTI 1988). Since then, a total of nine environmental monitoring surveys have been conducted at the Commencement Bay site:

1. 1995 full monitoring (SAIC 1995)
2. 1996 partial monitoring (SAIC 1996)
3. 1998 physical monitoring (SEA 1999)
4. 2001 full monitoring (SEA 2001, 2002)
5. 2003 tiered-full monitoring (SAIC 2003)
6. 2004 partial monitoring (SAIC 2004)
7. 2005 physical monitoring and phenol study (SAIC 2005)
8. 2007 full monitoring (SAIC 2008)
9. 2013 physical monitoring (NewFields 2013)

The DMMP initiated a tiered-full monitoring program in 2017 following the disposal of 474,115 cubic yards of dredged material at the disposal site since the last physical monitoring survey in 2013, and 926,225 cubic yards since the full monitoring program in 2007. Most of the dredged material taken to the Commencement Bay site since 2013 originated from the Port of Tacoma Pier 4 Reconfiguration Project, which was completed in February 2017.

The following objectives were identified for the 2017 tiered-full monitoring program:

- 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 Commencement Bay site.

- Conduct confirmatory analysis of tributyltin (TBT) to evaluate sampling procedures and disposal management from the Port of Tacoma Pier 4 Reconfiguration Project. Elevated TBT concentrations were found in some Pier 4 sediments, which were taken to an approved upland disposal facility as part of a time-critical Superfund removal. The confirmatory TBT analyses included in this monitoring event were used to verify that disposal of the remaining suitable sediments from Pier 4 at the Commencement Bay site did not incidentally introduce TBT- contaminated sediments to the disposal site.
- Contribute data for the annual review of the DMMP dredging and disposal site evaluation process.

2.0 REVIEW OF THE DMMP MONITORING PLAN

This section briefly describes the DMMP monitoring program design and presents modifications to the sampling and testing program as implemented in 2017. A comprehensive review of the program can be found in the Updated Environmental Monitoring Plan (UEMP) (SAIC 2007).

2.1 DMMP Monitoring Framework

The full DMMP monitoring plan (PSDDA 1988a-d) assesses the physical, chemical, and biological effects of dredged material disposal at approved Puget Sound unconfined aquatic disposal sites and their surrounding environments. Under the monitoring framework, specific hypotheses were formulated to answer three questions:

1. Does the dredged material stay on site?
2. Has dredged material disposal caused the biological effects conditions for site management to be exceeded at the site?
3. Are unacceptable adverse effects due to dredged material disposal occurring to biological resources off site?

A summary of the monitoring framework and the specific hypotheses and interpretive guidelines is presented in Table 2-1. Under a tiered-full monitoring program, samples are collected to address all three questions in the DMMP monitoring framework, but only samples to address the first two questions are initially analyzed. Analysis of archived samples to address the third monitoring question is contingent on answers to the first two questions. The monitoring framework included a sampling design that monitored eight station types at and in the vicinity of the disposal site. In addition, a Carr Inlet offsite reference was included to provide a control for sediment toxicity testing. The station types and their purpose are described in Table 2-2. Commencement Bay stations were identified with a “CB” prefix followed by a “station type” designation and a unique number.

Five monitoring parameters have been identified to assess the environmental effects of dredged material disposal: sediment profile imaging[1] (SPI), sediment chemistry, sediment toxicity, tissue chemistry, and benthic infaunal community structure (Table 2-3). Specific interpretive guidelines and trigger values have been established for each monitored parameter (see Table 2-1). If guideline values for a given parameter are exceeded during a monitoring event, a potential disposal impact is indicated, and the benchmark station monitoring and baseline data are compared and evaluated.

[1] Sediment profile imaging (SPI) is also referred to as sediment vertical profiling system (SVPS) imaging.

Table 2-1. The DMMP monitoring framework

Question	Hypothesis	Monitored Variable	Interpretive Guideline	Action Item (When exceedances noted)[1]
No. 1 Does the deposited dredged material stay on site?	1. Dredged material remains within the site boundary.	Sediment Profile Imaging (SPI) Onsite and Offsite	Dredged material layer is greater than 3 cm at the perimeter stations.	Further assessment is required to determine full extent of dredged material deposit.
	2. Chemical concentrations do not measurably increase over time at offsite stations due to dredged material disposal.	Sediment Chemistry Offsite	Washington State Sediment Quality Standards and Temporal analysis	Post-disposal benchmark station chemistry is analyzed and compared with appropriate baseline benchmark station data.
No. 2 Are the biological effects conditions for site management [PSDDA-defined Site Condition II] exceeded at the site due to dredged material disposal? (PSDDA 1988b)	3. Sediment chemical concentrations at the onsite monitoring stations do not exceed the chemical concentrations associated with PSDDA Site Condition II guidelines due to dredged material disposal.	Sediment Chemistry Onsite	Onsite chemical concentrations are compared to DMMP maximum levels.	DMMP agencies may seek adjustments of disposal guidelines and compare post-disposal benchmark chemistry with appropriate baseline benchmark station data.
	4. Sediment toxicity at the onsite stations does not exceed the PSDDA Site Condition II biological response guidelines due to dredged material disposal.	Sediment Bioassays Onsite	DMMP Bioassay Guidelines (Section 401 Water Quality Certification)	Benchmark station bioassays are performed (if archived after monitoring) and compared with baseline benchmark bioassay data.
No. 3 Are unacceptable adverse effects due to dredged material disposal occurring to biological resources off site?	5. No significant increase due to dredged material disposal has occurred in the chemical body burden of benthic infauna species collected downcurrent of the disposal site.	Tissue Chemistry Transect	Guideline values Metals: 3x the baseline concentrations Organics: 5x the baseline concentrations	Compare post-disposal benchmark tissue chemistry with baseline benchmark tissue chemistry data.
	6. No significant decrease due to dredged material disposal has occurred in the abundance of dominant benthic infaunal species collected downcurrent of the disposal site.	Infaunal Community Structure Transect	Guideline values Abundance of major taxa < ½ baseline macrobenthic infauna abundances.	Compare post-disposal benchmark benthic data with baseline benchmark data.

1 To determine if observed changes in chemical conditions or infaunal benthos are due to dredged material disposal, data from the benchmark stations are considered. All decisions are subject to DMMP agency review and best professional judgment.

Table 2-2. Station types and purpose for the DMMP sampling design

Station	Designation Letter	Location	Purpose
Zone	Z	Within disposal target zone.	Assess sediment chemistry and toxicity of dredged material deposited in the target area (Question 2).
Site	S	Within the site boundary but outside of the target zone.	In conjunction with zone data, site station sediment chemistry and toxicity are used to evaluate Question 1.
Random	R	Randomly-placed stations within the site boundary.	Random stations were tested for dioxin/furan congeners to evaluate whether dredged material disposal site management objectives are being met (DMMP 2010), and tested for TBT to verify that Pier 4 sediment with elevated TBT concentrations were not placed at the Commencement Bay site.
Perimeter	P	Located 0.125 nautical miles from the site boundary.	Physical and chemical data are obtained to determine if dredged material is present beyond the site boundary and document the chemical character of sediments outside the site boundary (Question 1).
Transect	T	Situated along a radial transect that extends outward from the perimeter line. Located in the direction of potential dredged material transport.	Sampled for benthic infauna abundance and infauna tissue contaminant body burden to evaluate biological resource impacts off site (Question 3).
Benchmark	B	Located in the vicinity of the disposal site, but beyond the region affected by disposal activity.	Used to identify potential changes in sediment quality that may be unrelated to dredged material disposal. Data are evaluated only if site, perimeter, or transect data indicate that conditions at or adjacent to the site have changed relative to baseline conditions and to test hypotheses that observed changes are due to dredged material disposal.[1] Data may be used to evaluate Hypotheses 2 through 6.
Central Transect	C	Situated along two perpendicular lines that bisect the disposal site and may extend beyond its boundaries.	Used for physical measurements to map the post-disposal distribution of dredged material (Question 1).
Floating	F	Located in areas inside and outside of the disposal site.	Utilized as necessary during the SPI survey to delineate the dredged material footprint.
Carr Inlet Reference	CR	Carr Inlet is an area documented to be free of potential sources of contamination. The specific location is selected based on grain size comparability with the bioassay test sediments.	Sediments used as a control for physical effects in toxicity testing.

1 All data types (physical, sediment chemistry, tissue chemistry, sediment toxicity, and benthic infauna) may be collected. Benchmark sediments are generally archived until disposal site analyses indicate benchmark data are needed for full evaluation. However, benchmark chemical analyses for mercury, sulfides, and ammonia are conducted in conjunction with disposal site sediments due to holding time constraints.

Table 2-3. DMMP disposal site station types and monitoring tools

Station	SPI	Sediment Chemistry	Bioassays	Benthic Infauna	Tissue Chemistry
Zone (Z)	●	●	●		
Site (S)	●	○	○		
Random (R)	●	●			
Perimeter (P)	●	●			
Transect (T)	●	● (A)		○	○
Benchmark (B)	●	● (A)	● (A)	○ (A)	○ (A)
Central Transect (C)	●				
Floating (F)	●				
Carr Inlet Reference (CR)			●		

○ Monitoring tools used for an intensive full monitoring program
● Monitoring tools used for a partial monitoring or tiered-full monitoring program
(A) Archived

2.2 2017 Modifications to Sampling and Testing Procedures

2.2.1 Random Station Sampling and Analysis

The 2017 sampling program included selection of random onsite stations for dioxin/furan congener and TBT analysis (see Section 1.0). Seven random onsite stations were tested for dioxin/furan congeners, and three of the seven random onsite stations were selected for TBT analysis. The DMMP identified the random onsite stations using the procedure described in the SAP:

- Using Visual Sample Plan (VSP), 20 random stations were generated within the site boundary.
- Starting from the top of the list, the first four random stations were selected that were at least 100 meters away from an existing dioxin station, including the onsite stations CBZ01, CBS01 and CBS08. The first four stations on the list (i.e. CBR01, CBR02, CBR03, and CBR04) met this criterion.
- The SPI survey results were used to select three additional random stations such that at least three of the seven random stations fell within the area that had recent dredged material deposits, and at least two stations fell outside the area with recent deposits. The additional stations also needed to be at least 100 meters away from an existing dioxin station. Based on these criteria, the DMMP agencies selected stations CBR05, CBR11, and CBR12 for sampling (CBR06, CBR07 and CBR09 had already been eliminated due to their proximity to other onsite stations; CBR08 was eliminated because it was within an area of recent deposits and two stations were needed outside the area with recent deposits).
- The target coordinates for any selected random stations located less than 25 meters away from the site boundary were moved to locations 25 meters within the boundary to ensure that the locations actually sampled fell within the site boundary. The target coordinates for random stations CBR05 and CBR11 were within 10 meters of the site boundary. These stations were moved to 25 meters away from the boundary.
- Random stations CBR03, CBR04, and CBR05 were selected for TBT analysis because they were located in areas that had received dredged material deposits deemed deep enough to be representative of the material placed from the Pier 4 project. These stations had deposits of greater than 6, 8, and 13 cm respectively (CBR01 and CBR02 were eliminated from consideration because they had only received about 2 cm of deposits).

2.2.2 Analytical Compound List

The 2017 Commencement Bay samples were analyzed for the standard list of marine DMMP conventional parameters and COCs (DMMP 2016), with the addition of dioxin/furan congeners, TBT (bulk sediment and interstitial water), PCB congeners, and PBDEs. The analytical parameters for each Commencement Bay sample are tabulated in Table 2-4. The DMMP included the analysis of the additional chemical parameters due to the following:

- Ten onsite sediment monitoring samples were collected and analyzed for dioxin/furan congeners to allow for statistical comparisons with the Puget Sound main basin/reference area dioxin/furan concentrations and verify compliance with the disposal site management objective (DMMP 2010).
- Three additional on-site samples were analyzed for TBT to evaluate the efficacy of sampling procedures and disposal management from the Port of Tacoma Pier 4 Reconfiguration project. Additional testing was particularly important since nearly all of the dredged material placed at the Commencement Bay site since 2013 originated from the Pier 4 project.
- To support on-going efforts by the DMMP to document the presence and distribution of bioaccumulative contaminants of concern (BCOCs), surface sediments (top 10 cm) from the

Commencement Bay onsite and perimeter stations were analyzed for PCB congeners and PBDEs using U.S. EPA Methods 1668B and 1614A, respectively to achieve low-level detection limits.

Lindane, 1,3-dichlorobenzene, and the volatile compounds trichloroethene, tetrachloroethene, ethylbenzene, and total xylenes were removed from the standard list of DMMP COCs for dredged material testing in 2011 (DMMP 2011). While these compounds were monitored at the Elliott Bay disposal site in 2013 (Integral 2014), monitoring of these compounds was not continued for the 2017 Commencement Bay disposal site monitoring program.

2.3 Summary of Baseline and Previous Monitoring Surveys

Table 2-5 provides a summary of findings for the Commencement Bay baseline and nine previous monitoring surveys within the context of the site monitoring objectives[2]. Additional summary information for each monitoring survey is provided in Appendix A.

[2] A summary that covered 1998 through 2007 was prepared by the DMMP agencies for the Supplemental Environmental Impact Statement for reauthorization of the Commencement Bay disposal site (SAIC 2009). Summary information for the 2013 physical monitoring survey was added as part of this reporting effort.

Table 2-4. 2017 Commencement Bay sediment chemistry and bioassay samples

Sample ID	Sediment Depth Interval	Sulfides	Grain Size	TOC	Ammonia	TS	TVS	Metals (incl. Hg)	Hg (only)	TBT (bulk)	TBT (pore)	SVOA/PEST/ PCB Aroclors	PCB Congeners	Dioxin/Furan Congeners	PBDEs	Chemistry Archive	Bioassay
CBZ01	0-10 cm	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	(A)	✓
CBS01	0-10 cm	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	(A)	✓
CBS08	0-10 cm	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	(A)	✓
CBR01	0-10 cm			✓										✓		(A)	
CBR02	0-10 cm			✓										✓		(A)	
CBR03	0-10 cm			✓						✓	✓			✓		(A)	
CBR04	0-10 cm			✓						✓	✓			✓		(A)	
CBR05	0-10 cm			✓						✓	✓			✓		(A)	
CBR11	0-10 cm			✓										✓		(A)	
CBR12	0-10 cm			✓										✓		(A)	
CBP01-A	0-2 cm	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	(A)	
CBP01-B	0-2 cm	✓	✓	✓	✓	✓	✓	✓				✓				(A)	
CBP01-C	0-2 cm	✓	✓	✓	✓	✓	✓	✓				✓				(A)	
CBP03-A	0-2 cm	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	(A)	
CBP03-B	0-2 cm	✓	✓	✓	✓	✓	✓	✓				✓				(A)	
CBP03-C	0-2 cm	✓	✓	✓	✓	✓	✓	✓				✓				(A)	
CBP07-A	0-2 cm	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	(A)	
CBP07-B	0-2 cm	✓	✓	✓	✓	✓	✓	✓				✓				(A)	
CBP07-C	0-2 cm	✓	✓	✓	✓	✓	✓	✓				✓				(A)	
CBP11-A	0-2 cm	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	(A)	
CBP11-B	0-2 cm	✓	✓	✓	✓	✓	✓	✓				✓				(A)	
CBP11-C	0-2 cm	✓	✓	✓	✓	✓	✓	✓				✓				(A)	
CBT01_10cm	0-10 cm		(A)	(A)													
CBT01	0-2 cm	✓	(A)	(A)	✓	✓	(A)	(A)	✓	(A)		(A)	(A)	(A)	(A)		
CBT03_10cm	0-10 cm		(A)	(A)													
CBT03	0-2 cm	✓	(A)	(A)	✓	✓	(A)	(A)	✓	(A)		(A)	(A)	(A)	(A)		
CBT04_10cm	0-10 cm		(A)	(A)													
CBT04	0-2 cm	✓	(A)	(A)	✓	✓	(A)	(A)	✓	(A)		(A)	(A)	(A)	(A)		
CBB01_10cm	0-10 cm		(A)	(A)													
CBB01-A	0-2 cm	✓	(A)	(A)	✓	✓	(A)	(A)	✓	(A)		(A)	(A)	(A)	(A)	(A)	(A)
CBB01-B	0-2 cm	✓	(A)	(A)	✓	✓	(A)	(A)	✓			(A)				(A)	
CBB01-C	0-2 cm	✓	(A)	(A)	✓	✓	(A)	(A)	✓			(A)				(A)	
CBB02_10cm	0-10 cm		(A)	(A)													
CBB02-A	0-2 cm	✓	(A)	(A)	✓	✓	(A)	(A)	✓	(A)		(A)	(A)	(A)	(A)	(A)	(A)
CBB02-B	0-2 cm	✓	(A)	(A)	✓	✓	(A)	(A)	✓			(A)				(A)	
CBB02-C	0-2 cm	✓	(A)	(A)	✓	✓	(A)	(A)	✓			(A)				(A)	
CBB03_10cm	0-10 cm		(A)	(A)													
CBB03-A	0-2 cm	✓	(A)	(A)	✓	✓	(A)	(A)	✓	(A)		(A)	(A)	(A)	(A)	(A)	(A)
CBB03-B	0-2 cm	✓	(A)	(A)	✓	✓	(A)	(A)	✓			(A)				(A)	
CBB03-C	0-2 cm	✓	(A)	(A)	✓	✓	(A)	(A)	✓			(A)				(A)	
CR-23W	0-10 cm	✓	✓	✓	✓	✓	✓										✓
CR-10/20	0-10 cm	✓	✓	✓	✓	✓	✓										(A)

✓ Analyzed
(A) Archived

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Table 2-5. Summary of Commencement Bay site monitoring findings 1988–2013

Survey	DY-specific Disposal Volume (cy)	Cumulative Volume (cy)	Hypothesis No. 1 (Dredged Material Within Site Boundaries?)	Hypothesis No. 2 (Offsite Chemistry Within SQS?)	Hypothesis No. 3 (Onsite Chemistry Below DMMP MLs?)	Hypothesis No. 4 (Onsite Toxicity passes DMMP Guidelines?)	Hypothesis No. 5 (Tissue Chemistry Passes DMMP Guidelines?)	Hypothesis No. 6 (Benthic Infauna Abundance Passes DMMP Guidelines?)
1988 Baseline Survey	0	0	NA	Yes	Yes	No[1]	NA	NA
1995 Full Monitoring	290,857	308,405	Yes	Yes	Yes	Yes	Yes	Yes
1996 Partial Monitoring	460,684	769,089	Yes	Yes	Yes	Yes	--	--
1998 Physical Monitoring	693,540	1,462,629	No	Yes	--	--	--	--
2001 Full Monitoring	265,867	2,762,591	No	Yes	Yes	Yes	Yes	Yes
2003 Tiered-Full Monitoring	710,675	3,473,266	No	No[2]	Yes	Yes	Yes	Yes
2004 Partial Monitoring	1,205,993	4,679,259	No	Yes	Yes	Yes	--	--
2005 Physical Monitoring and Phenol Study	949,399	5,628,658	No	Yes (SVOA Only)	--	--	--	--
2007 Full Monitoring	1,324,254	7,763,912	Yes	Yes	Yes	Yes	Yes	Yes
2013 Physical Monitoring	452,110	8,216,022	Yes	--	--	--	--	--

cy cubic yards
DY Dredge year
NA Not applicable. Baseline values were used for guideline interpretation.
SVOA Semi-volatile organic analysis compounds
-- Hypothesis was not addressed during the monitoring event.
1. The 1988 baseline amphipod test did not pass the DMMP interpretive guideline for one of two reference sediment evaluations.
2. The SQS was exceeded for 1,2,4-trichlorobenzene (detection-limit exceedance only), butylbenzylphthalate, bis(2-ethylhexyl)phthalate, and phenol at one or more perimeter station. These chemicals were not detected at onsite stations and were below SQS at benchmark stations. Given that phthalates are common laboratory contaminants and phenols are created through decomposition of plant material, the DMMP agencies concluded that elevated phenol and phthalate concentrations at perimeter stations may have been due to factors not directly related to offsite migration of dredged material. Phthalate and phenol concentrations at perimeter stations were well below SQS in a partial monitoring study in 2004, as were phenols in a special study conducted in 2005.

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3.0 METHODS

This section provides a brief summary of the sampling design, data collection, and sampling method for the 2017 Commencement Bay tiered-full monitoring program. All sampling activities were conducted aboard the research vessel (R/V) *Kittiwake*. Detailed procedures of sampling and analysis methodologies are provided in the Sampling and Analysis Plan (SAP) (Appendix B). A complete description of schedule, site conditions, field procedures, and coordinates for occupied stations is found in the Cruise Report (Appendix C). The target and actual sampling station locations are shown in Figure 3-1, and a summary of samples collected and types of analyses is provided in Table 2-4. All potential sampling locations for the Commencement Bay site can be found in Figures 11 and 12 of the UEMP.

Physical monitoring (SPI survey) of the Commencement Bay site was conducted by the USACE on July 13 and 14, 2017 (Integral 2017). A total of 68 SPI stations were surveyed (Figure 3-2). The survey methods are discussed in the SPI report, which is provided as Appendix D of this report (Integral 2017).

3.1 Benthic Infaunal Sample Collection

Benthic infauna samples were collected using a 0.06 m^2 stainless Gray O'Hara box core. Five replicate samples were collected at each of three transect (CBT01, PGT03, and PGT04)[3] and three benchmark (CBB01, CBB02, and CBB03) stations for a total of 30 box core samples. Benthic infaunal collections were accomplished following the procedures detailed in the SAP (Appendix B). Each box core sample was divided into two sections: the top 10 cm (0 to 10 cm) and the remaining section of the core (>10 cm to bottom of core). The top 10 cm was sieved through 1.0 mm and 0.50 mm nested sieves. The >10 cm section was sieved through the 1.0 mm screen only.

In the field, benthic samples were preserved in a solution of 10% buffered formalin in seawater, and later transferred to an 80% ethanol solution. Benthic samples were archived at the NewFields office. Following completion of the monitoring program, all archived benthos samples were transferred to DNR for long-term storage.

3.2 Sediment Chemistry

Sediment samples were collected from three onsite (CBZ01, CBS01, and CBS08), four perimeter (CBP01, CBP03, CBP07, CBP11), three benchmark (CBB01, CBB02, and CBB03), and three transect stations (CBT01, CBT03, and CBT04), and chemically tested for the DMMP conventional and chemical parameters as summarized in Table 2-4. One additional sediment sample was collected at transect station CBT02 and archived based on the tissue sampling locations (see Section 3.1.3). Seven random onsite stations were sampled for dioxin/furan congener analysis (CBR01, CBR02, CBR03, CBR04, CBR05, CBR11, CBR12), and three of the seven random onsite stations were sampled for bulk and porewater TBT analysis (CBR03, CBR04, CBR05). Two reference stations (CR-23W, CR-10/20) were sampled in Carr Inlet for bioassays and tested for conventional chemical parameters. Collection methods were consistent with the SAP with the exception of sediment samples collected at CBZ01 and CBB02. The

[3] The SAP had originally targeted transect stations CBT13, CBT14, and CBT16 for benthic infauna collections. Based on the apparent trend of dredged material deposition observed during the SPI survey, the DMMP agencies selected alternative transect stations for benthic infauna sample collection (see Appendix C).

sediment sample at CBZ01 was collected 50 feet to the northwest of the target location due to the presence of rocks and large gravel. Due to highly unconsolidated sediments at CBB02, a solid-door stainless van Veen grab was used to collect an intact sediment sample. A full summary of sediment chemistry collections and station locations for all samples collected are tabulated in the cruise report (Appendix C).

Analyses of conventionals, metals, semi-volatiles (SVOAs), pesticides, PCB Aroclors, and dioxin/furan congeners were conducted by Analytical Resources, Inc., Tukwila, WA. Analyses of PCB congeners and PBDEs were conducted by Vista Analytical Laboratory, El Dorado Hills, CA. Statistical evaluation of perimeter chemistry using the Chemical Tracking System (CTS; SAIC and MWLS 1996) was conducted by TerraStat of Snohomish, WA.

3.3 Tissue Chemistry

Triplicate tissue samples of the sea cucumber *Molpadia intermedia* were collected at three transect (CBT01, CBT02[4], and CBT03) and three benchmark (CBB01, CBB02, and CBB03) stations. Under the tiered-monitoring approach, all tissue samples were archived for potential analysis of the DMMP bioaccumulative chemicals of concern (BCOCs) and dioxin/furan congeners.

3.4 Bioassays

Bioassay testing was conducted on three onsite station sediments (CBZ01, CBS01, and CBS08) from Commencement Bay and one reference sediment (CR-23W) collected from Carr Inlet, WA. The DMMP sediment bioassays included the 10-day acute amphipod test using *Eohaustorius*, the sediment larval test using *Dendraster excentricus*, and the 20-day *Neanthes* mean growth test. In addition, three benchmark samples (CBB01, CBB02, and CBB03) and one Carr Inlet sample (CR-10/20) were archived in accordance with the tiered DMMP testing strategy. Bioassay testing of the onsite and reference sediment was conducted by Northwestern Aquatic Sciences (NAS) of Newport, OR.

[4] Station CBT04 contained abundant wood debris and *M. intermedia* appeared to be absent during benthic and sediment chemistry sampling. Therefore, the DMMP agencies replaced station CBT04 with station CBT02 for the collection of tissue samples.

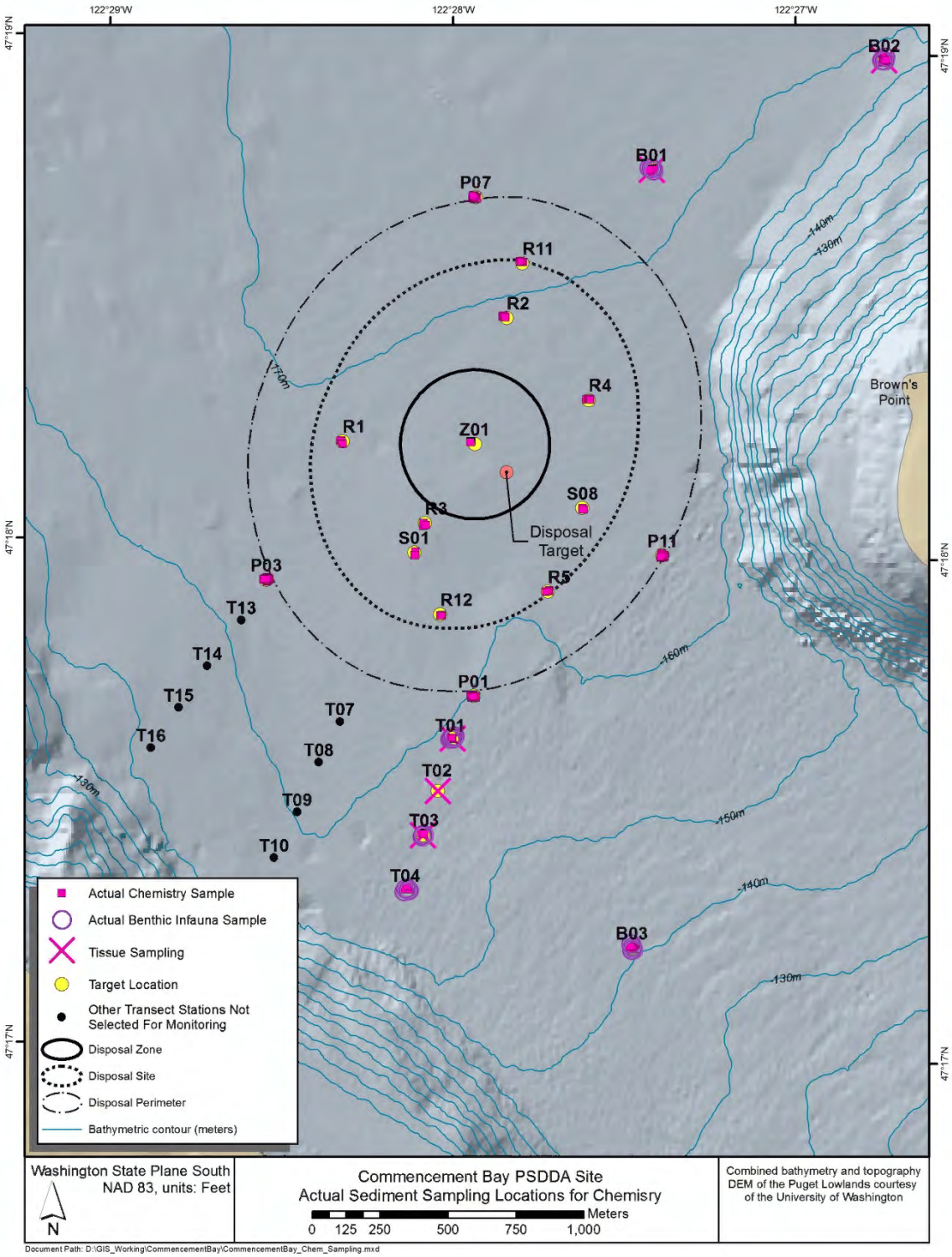


Figure 3-1. Sediment and tissue sampling stations selected for the 2017 Commencement Bay monitoring program

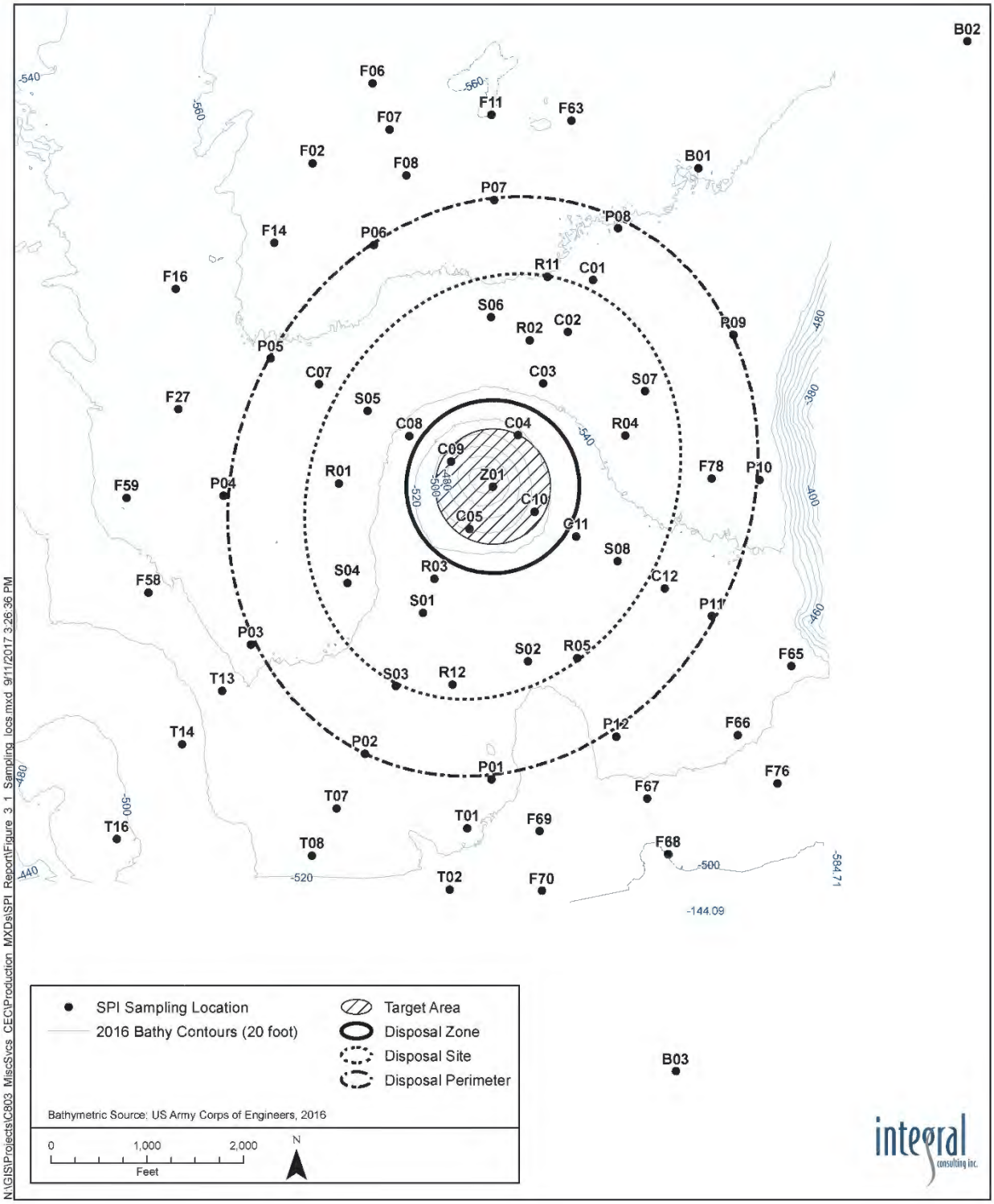


Figure 3-2. SPI stations selected for the 2017 Commencement Bay monitoring program

4.0 RESULTS

This section presents a summary of results for the SPI survey conducted by the USACE, and the results of the sediment chemistry analysis and bioassay testing conducted for the 2017 tiered-full monitoring of Commencement Bay. An evaluation of the data per the DMMP monitoring framework is provided in Section 5.0.

4.1 SPI Survey

The objective of the 2017 SPI survey was to map the distribution of recent dredged material at the Commencement Bay disposal site in support of Site Monitoring Question 1: "Does Dredged Material Stay Onsite?" SPI images from 68 stations were collected and analyzed as part of the 2017 Commencement Bay monitoring effort (Figure 3-2). The full SPI data report prepared by Integral (2017) is provided in Appendix D and the results are summarized in the following sections.

4.1.1 Ambient Sediment Characteristics

The ambient sediment characteristics observed near the disposal site in the 2017 survey were similar to previous surveys (SEA 2001; SAIC 2005, 2008; NewFields 2013). The sediments generally appeared as tan brown to gray unconsolidated silts and clays with minor amounts of fine sand, with relatively deep (greater than 3 cm) apparent redox potential discontinuity (aRPD) depths (average of 3.3 cm across the site). Feeding voids, indicating bioturbation by head-down deposit-feeding infaunal organisms, were observed (Integral 2017).

Data from the original disposal site evaluation studies in central Puget Sound indicate that ambient surface sediments to the north and northwest of the disposal site were generally coarser, and consisted primarily of medium to fine sands with silt (PSDDA 1988, NewFields 2013). The SPI survey grid utilized for this and the previous 2013 survey did not extend as far northwest as earlier surveys, but one station occupied northwest of the site in 2017 (CBF16) showed evidence of sandy ambient conditions (Integral 2017).

4.1.2 Dredged Material Distribution

Most of the dredged material taken to the Commencement Bay site since 2013 came from the Port of Tacoma Pier 4 project, and was described as predominately dark gray-brown fine sand with varying amounts of silt (Integral 2017). Therefore, the key feature used to identify dredged material in the Commencement Bay SPI images was the presence of sands, especially dark-colored fine sands (3–2 phi units) at the sediment surface.

The mapped distribution of dredged material during the 2017 SPI survey is shown in Figure 4-1. Dredged material at the site center was composed of dark grayish brown medium and fine sands with tan silt (Figure 4-2). SPI camera prism penetration was low at stations within the disposal zone due to the presence of coarse-grained material. The dredged material along the outer edges of the deposit (areas of thin dredged material deposition outside of the 3 cm contour in Figure 4-1) consisted of trace amounts of fine sand or thin layers (0.6 to 2.3 cm) of fine sand, overlying fine-grained sediments (Figure 4-3). Trace amounts of recent dredged material were observed at a few site perimeter stations (CBP06, CBP07, and CBP11) but did not exceed the 3 cm DMMP criterion for dredged material accumulation (Integral 2017).

Dredged material was detected at 30 stations, all located at or within the perimeter line of the disposal site. Some dredged material was present throughout most of the disposal site; the estimated 3-cm contour (red line in Figure 4-1) extended farther to the northeast, east, and southeast of the disposal zone than to the west. This was consistent with the pattern of dredged material deposition mapped in 2013, although the 2017 disposal mound was more extensive, reflecting the large volume of material placed at the site from October 2016 to mid-February 2017 (Integral 2017).

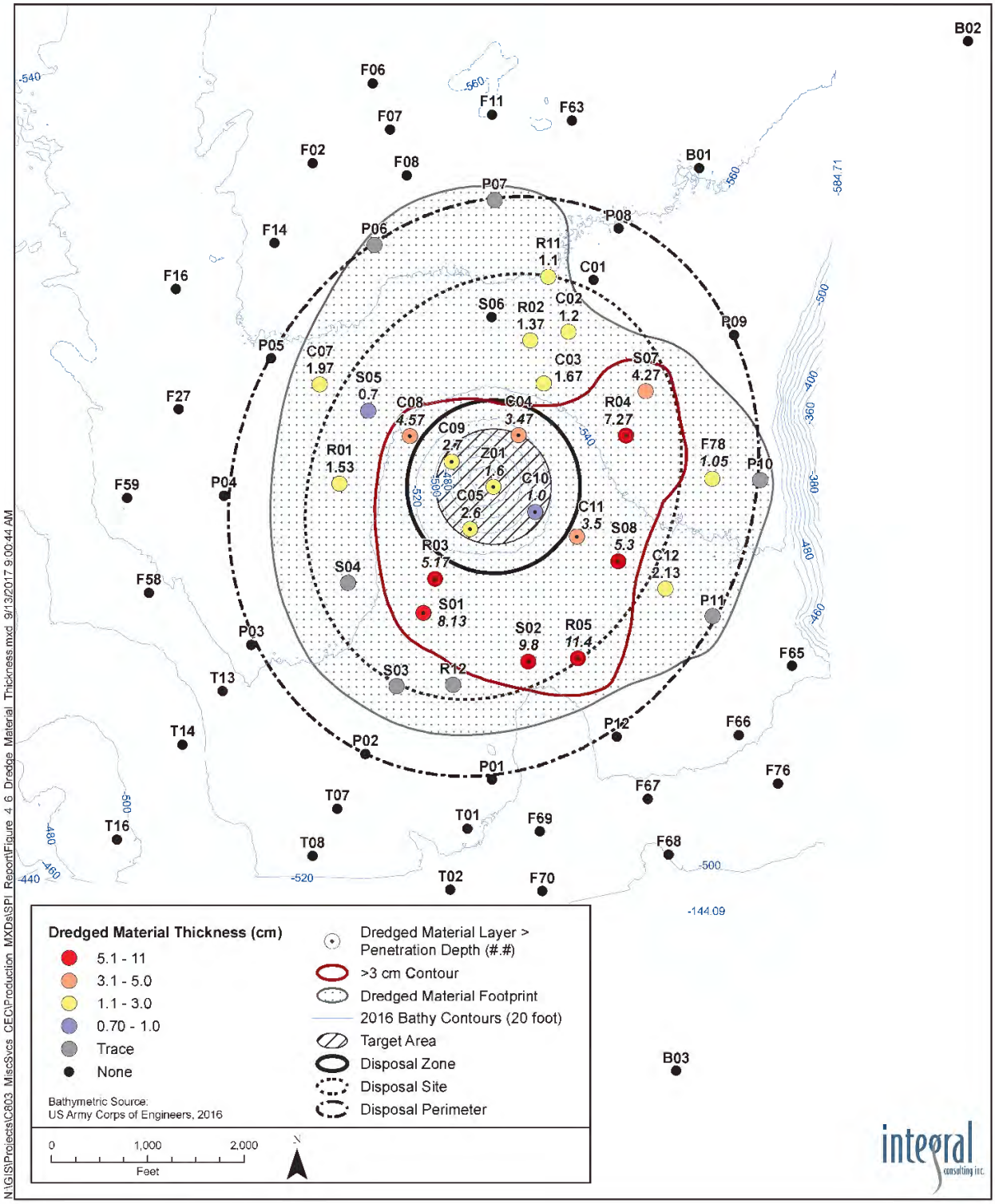
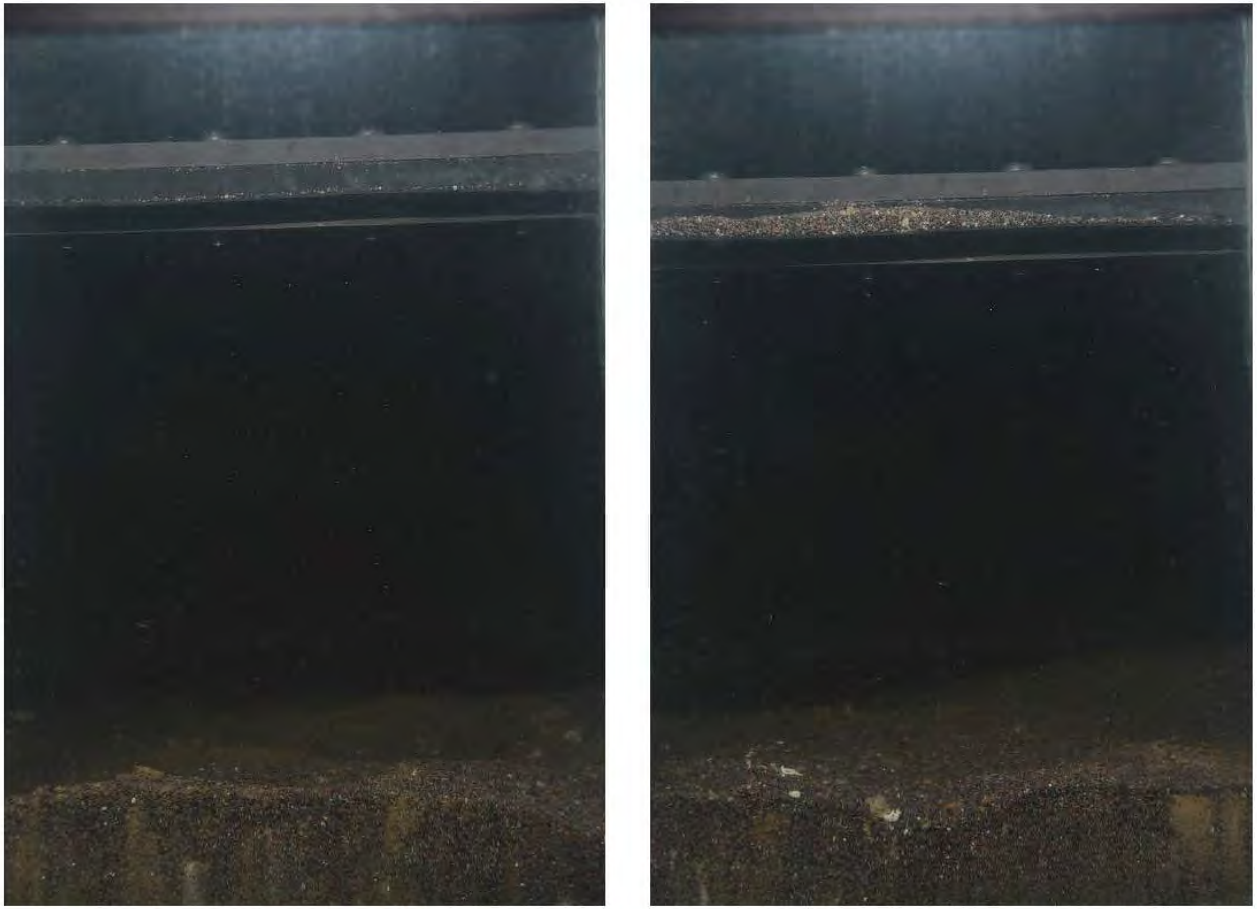


Figure 4-1. Distribution of dredged material thickness averaged by station (cm) (Integral 2017)



Station CBZ01 replicate B (CBZ01-B) and Station CBC05 replicate A (CBC05-A) showed recent dredged material deposits at the center of the disposal site consisting of dark grayish brown sands with minor subfractions of tan silt. Camera prism penetration depth was low due to the coarse-grained, compact nature of the dredged material deposit in the target area. Image width is 14.6 cm.

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SPI Images Showing Recent Dredged Material

Figure 4-2. SPI images showing recent dredged material accumulation greater than SPI prism penetration (Integral 2017)

Station CBC08-A (left) showed a 5+ cm (greater than penetration) sand layer and Station CBS05-C (right) showed a thin (< 1 cm) layer of sandy dredged material, approximately 1100 and 1600 ft northwest of disposal site center. Image width is 14.6 cm.

integral consulting inc.

SPI Images Showing Conditions Along the Flanks of the Dredged Material Deposit

Figure 4-3. SPI images showing dredged material along the flanks of the dredged material deposit (Integral 2017)

4.1.3 Physical and Sedimentary Features

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

Grain size major mode within the disposal zone generally consisted of fine sand (3 to 2 phi) due to the presence of the coarse-grained dredged material (Figure 4-4). Outside of the disposal zone, the sediment grain size generally consisted of very fine sand (4 to 3 phi), mixtures of very fine sand with fines (>4 to 3 phi), to silt-clays (> 4 phi). All stations beyond the site perimeter except for CBF16, which was ambient sand (Figure 4-2), were predominately silts and clays (> 4 phi), reflecting the ambient bottom in this portion of Commencement Bay (Integral 2017).

Penetration depths of the SPI camera prism into the sediment (in centimeters) are presented in Figure 4-5. Penetration depths are a function of the bearing capacity and shear strength of the sediments, and give an indication of the relative water content and consolidation of the sediment. The lowest prism penetration was measured in the disposal zone (1 to 4 cm) due to the compact, coarse-grained dredged material. Prism penetration was much deeper on the ambient bottom outside of the disposal site zone, with an average of 11.6 cm (Integral 2017).

Surface boundary roughness (Figure 4-6) was calculated as the vertical distance between the highest and lowest points of the sediment-water interface. The surface boundary roughness may be related to either physical structures (e.g., ripples, mud clasts) or biogenic features (e.g., burrow openings, fecal mounds, foraging depressions). The average boundary roughness measured per station across the site ranged from 0.97 to 6 cm. The majority of surface relief was identified as biogenic (83 percent of replicates) (Integral 2017). Similar to the 2013 survey, mean boundary roughness at stations within the disposal site boundary was generally less than surrounding areas, which appeared to be due to the lower surface relief maintained by sandy dredged material (NewFields 2013). The higher boundary roughness values observed were typically due to large biogenic mounds or burrows in fine-grained sediments (Integral 2017).

4.1.4 Chemical and Biological Features

Chemical and biological parameters obtainable from SPI data provide an overall assessment of the health of the benthic habitat. The key parameters included the aRPD depth and the benthic infaunal successional stage. The results for these parameters from the 2017 SPI survey are discussed below.

Apparent Redox Potential Discontinuity

The aRPD depth estimates the depth of oxygenation in the upper sediment column and provides an estimate of the biological mixing depth by infaunal organisms. It is a key SPI parameter for documenting changes (or gradients) that develop over time in response to benthic disturbance factors, such as sediment erosion or depositional events, demersal fish foraging, and temporal changes in environmental factors, such as water temperature and organic loading (Integral 2017).

Mean aRPD depths at the Commencement Bay site ranged from 1.3 to 5.4 cm and averaged 3.3 cm across the site (Figure 4-7). This was comparable to 2013 observations with an aRPD depth range of 1.7 to 5.7 cm and an average of 3.8 cm. The 2017 aRPD depth major mode was 3.0 to 3.5 cm, slightly shallower than the 2013 survey (major mode of 3.5 to 4.0 cm), but similar to that of the 2005 survey (Integral 2017). Overall, near-surface biogenic mixing levels across the survey area, as indicated by aRPD depths, were comparable to the levels observed in 2013 despite the large volume of material disposed from October 2016 to mid-February 2017 (Integral 2017).

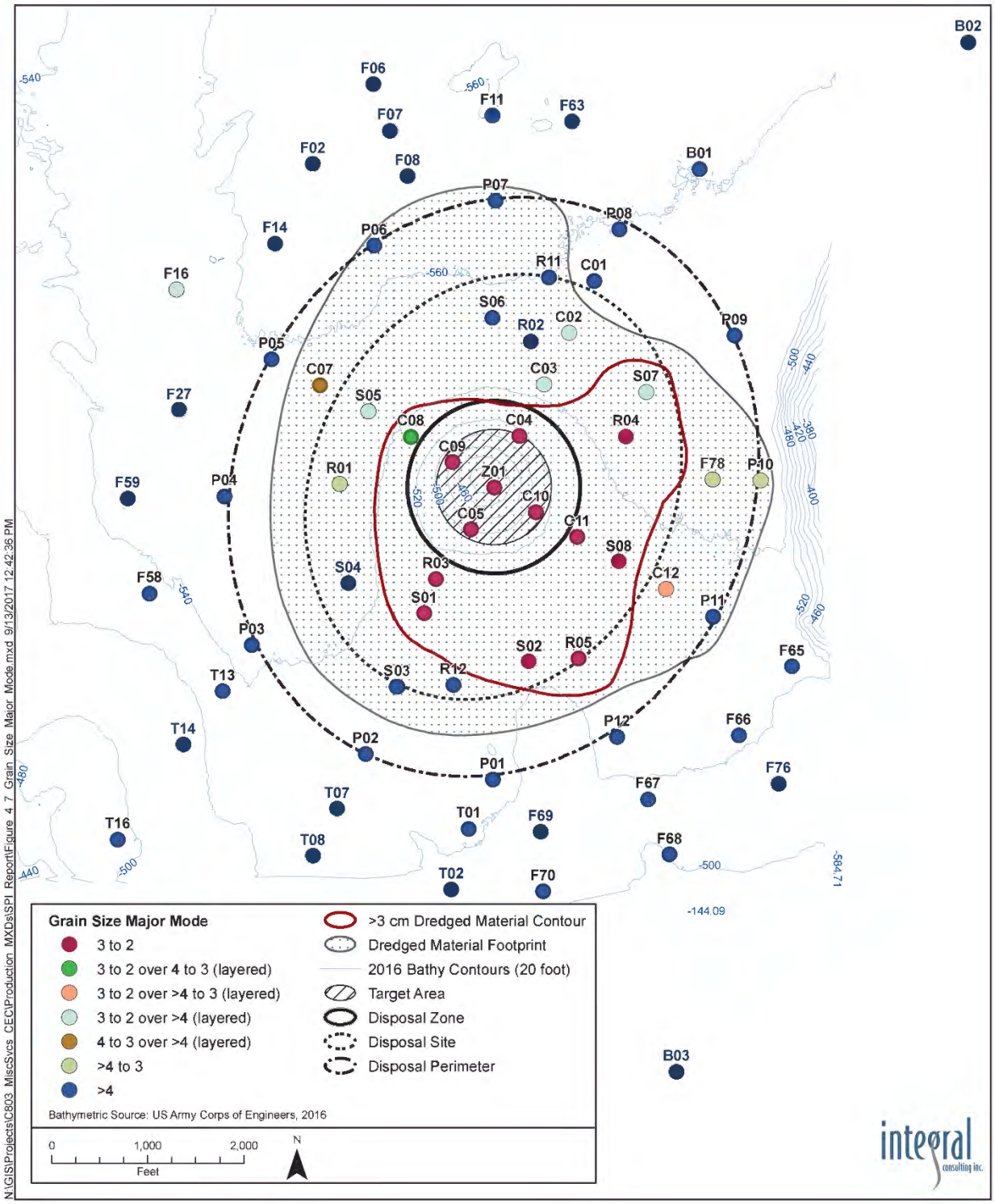

Figure 4-4. Distribution of grain size major modes (phi units)

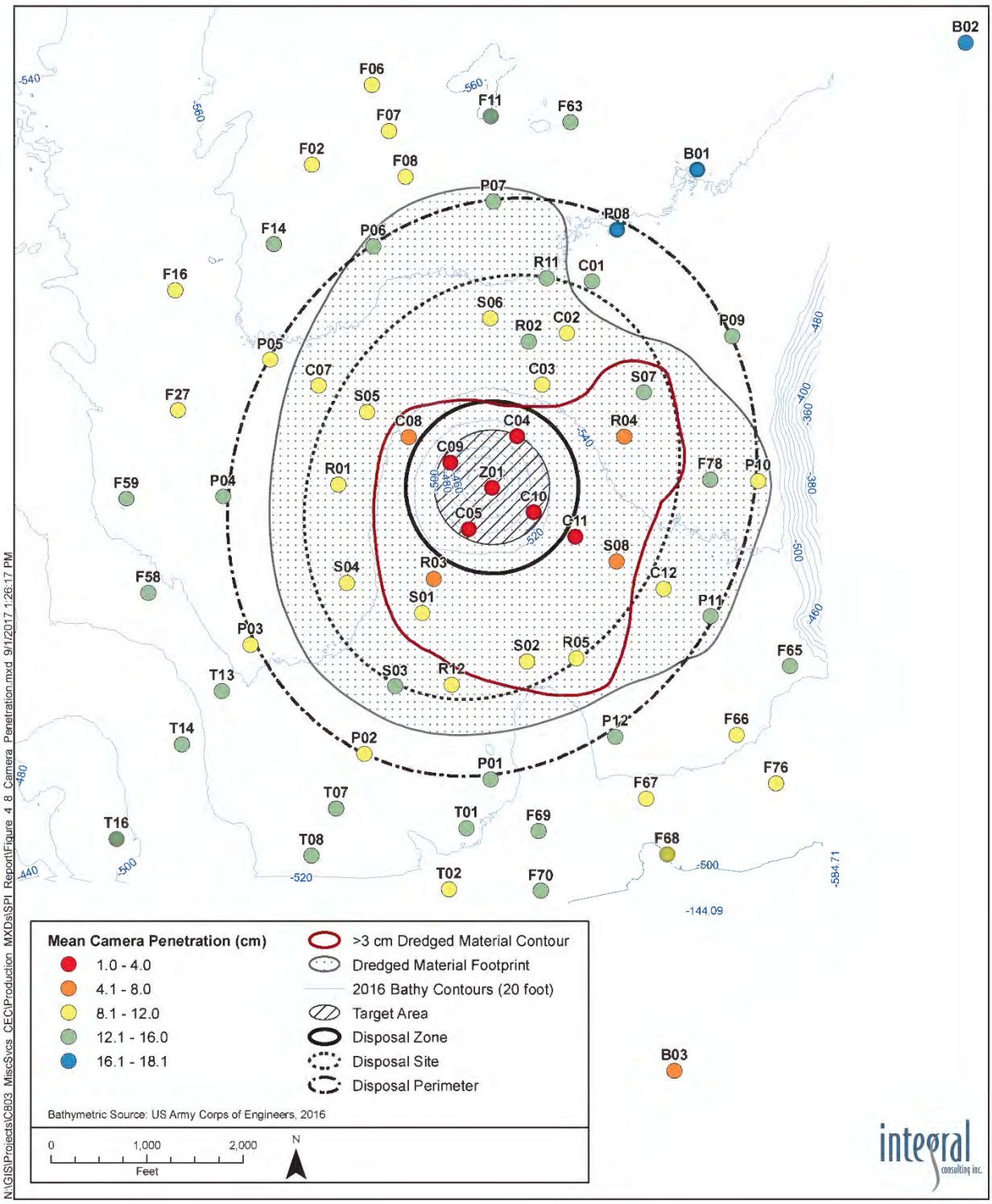

Figure 4-5. Station-averaged camera prism penetration (cm)

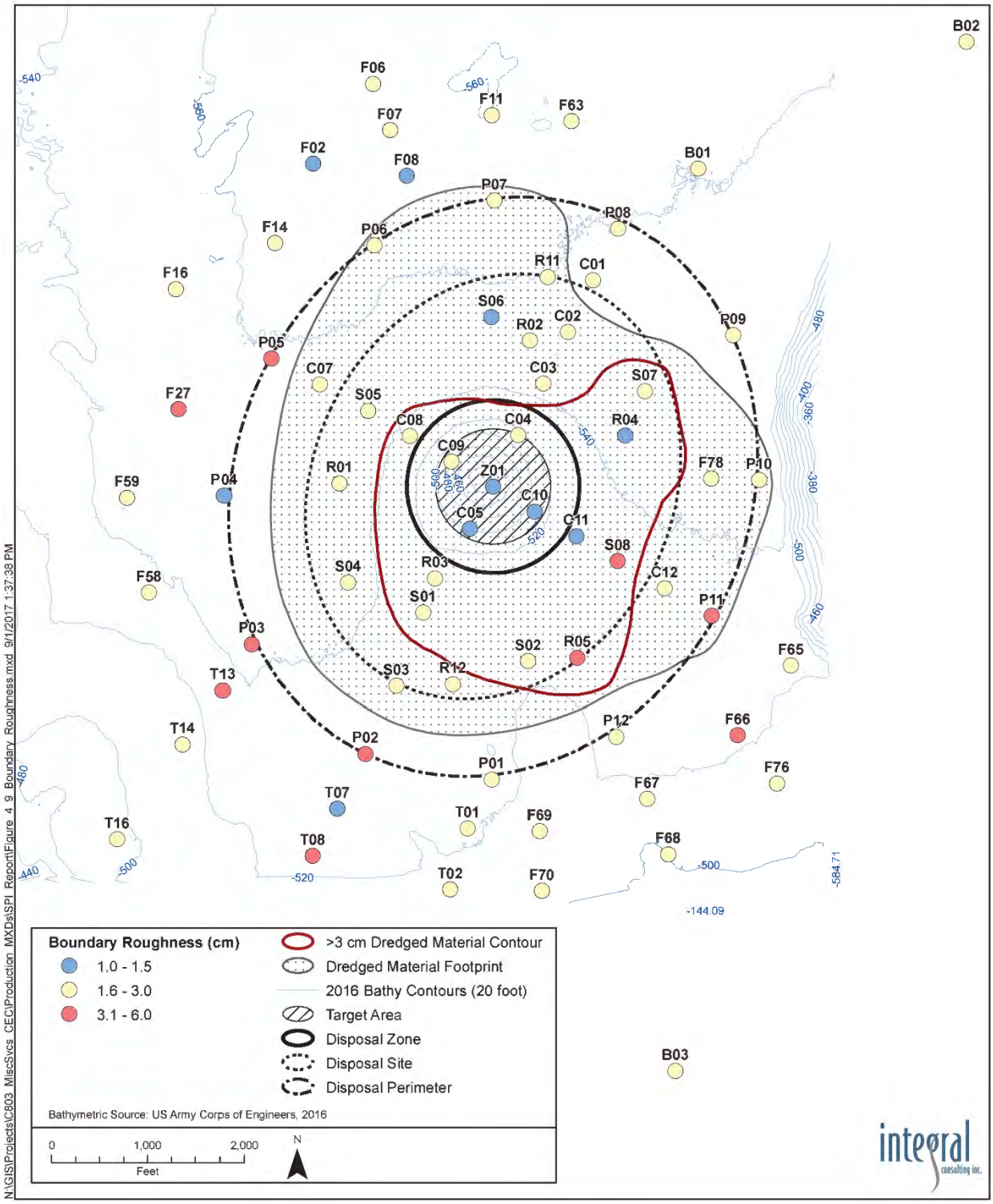

Figure 4-6. Boundary roughness averaged by station (cm)

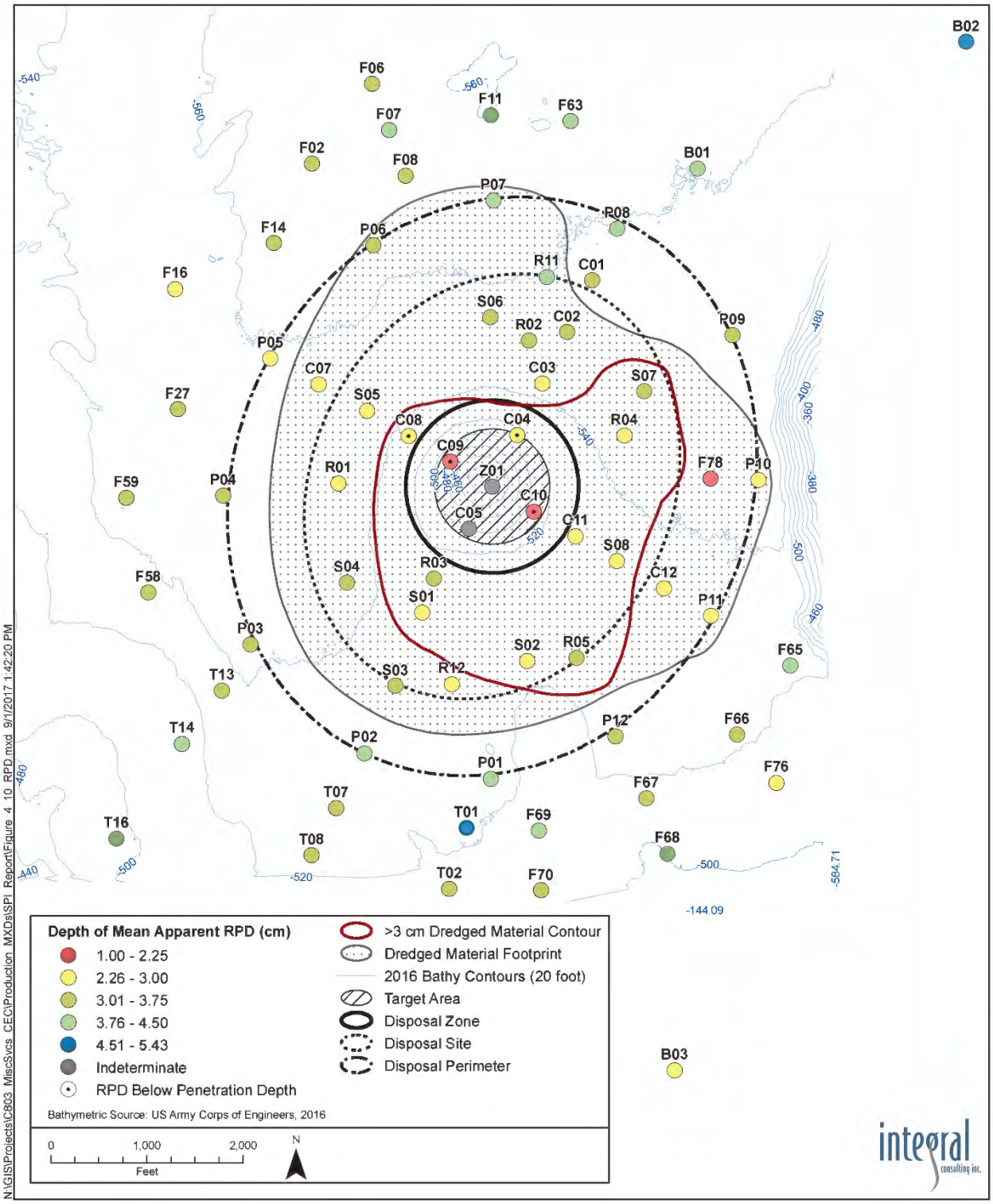

Figure 4-7. Apparent RPD depths averaged by station (cm)

Benthic Infaunal Successional Stage

Benthic infaunal communities generally follow a three-stage succession following a disturbance of the seafloor (Pearson and Rosenberg 1978, Rhoads and Germano 1986). Stage I infauna typically colonize the sediment surface soon after disturbance (e.g., following dredged material disposal). These opportunistic organisms may consist of small, tubicolous, surface-dwelling polychaetes. Stage II organisms are typically shallow-dwelling bivalves or tube-dwelling amphipods. Stage II communities are considered a transitional community before reaching Stage III, the high-order successional stage consisting of long-lived, infaunal deposit-feeding organisms. Stage III invertebrates may feed at depth in a head-down orientation and create distinctive feeding voids visible in SPI images.

The benthic infaunal successional stages observed in the 2017 SPI survey are presented in Figure 4-8. Overall, presence of Stage III succession (either as Stage III or Stage I on III[5]) was observed in at least one replicate at 62 stations, 18 of which were located within the disposal site boundary. Three stations (CBZ01, CBC11, and CBS02), all within the disposal site boundary, showed only Stage I succession. Station S02 exhibited layered well-sorted sands and silts in all three replicates that were deeply penetrated but revealed no evidence of subsurface biogenic activity (Integral 2017). Successional stage could not be determined in many of the replicates at the five stations within the disposal zone due to minimal camera penetration at these locations (see Figure 4-8). Low penetration precludes the detection of larger, deeper-dwelling infauna. None of the SPI images indicated benthic communities strictly in Stage II succession. Overall, recolonization and/or re-establishment of high-order successional infauna, i.e., larger, subsurface deposit feeders, was widespread at the disposal site outside the disposal zone (Integral 2017).

Organism Sediment Index

The OSI is a numerical index from -10 to +11, which provides a measure of general benthic habitat quality based on dissolved oxygen conditions, depth of the aRPD, infaunal successional stage, and presence or absence of sedimentary methane (Rhoads and Germano 1986). The lowest value is assigned to an area with low or no dissolved oxygen in the overlying bottom water, no apparent macrofaunal life, and the presence of methane gas in the sediment. The highest value is given to an aerobic bottom with a deep aRPD, evidence of a mature macrofaunal assemblage, and no methane gas bubbles. OSI values greater than or equal to +6 are generally considered to represent healthy or undisturbed benthic habitat quality.

Median OSI values per station from the 2017 SPI survey are shown in Figure 4-9. Median OSI values ranged from +5 (CBS02) to +11 across the survey area. OSI values could not be calculated from SPI images collected from eight stations within or in close proximity to the disposal zone due to indeterminate aRPD and/or successional stages resulting from shallow camera penetration depths (Integral 2017). Similar to 2013, the OSI values from most stations during the 2017 survey were equal to or greater than +6. These values indicated the presence of a robust and resilient benthic infaunal community beyond the immediate disposal zone, despite the large volume of dredged material placed at the site prior to the 2017 survey (Integral 2017).

[5] Stage I can be associated with Stage III succession, as the opportunistic Stage I species are able to take advantage of available organic matter at the sediment-water interface in habitats where Stage III infauna are also present.

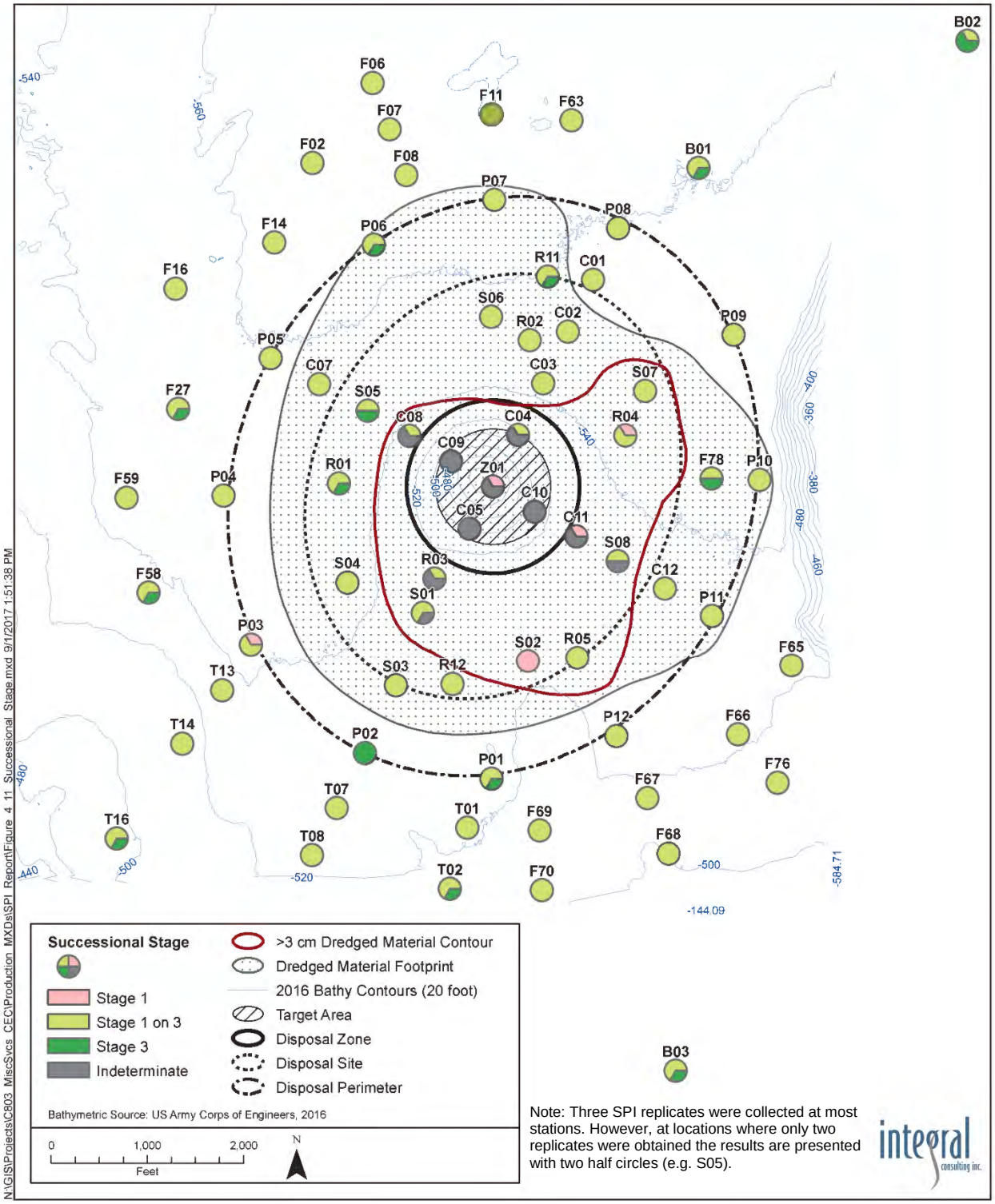

Figure 4-8. Infaunal successional stage by replicate

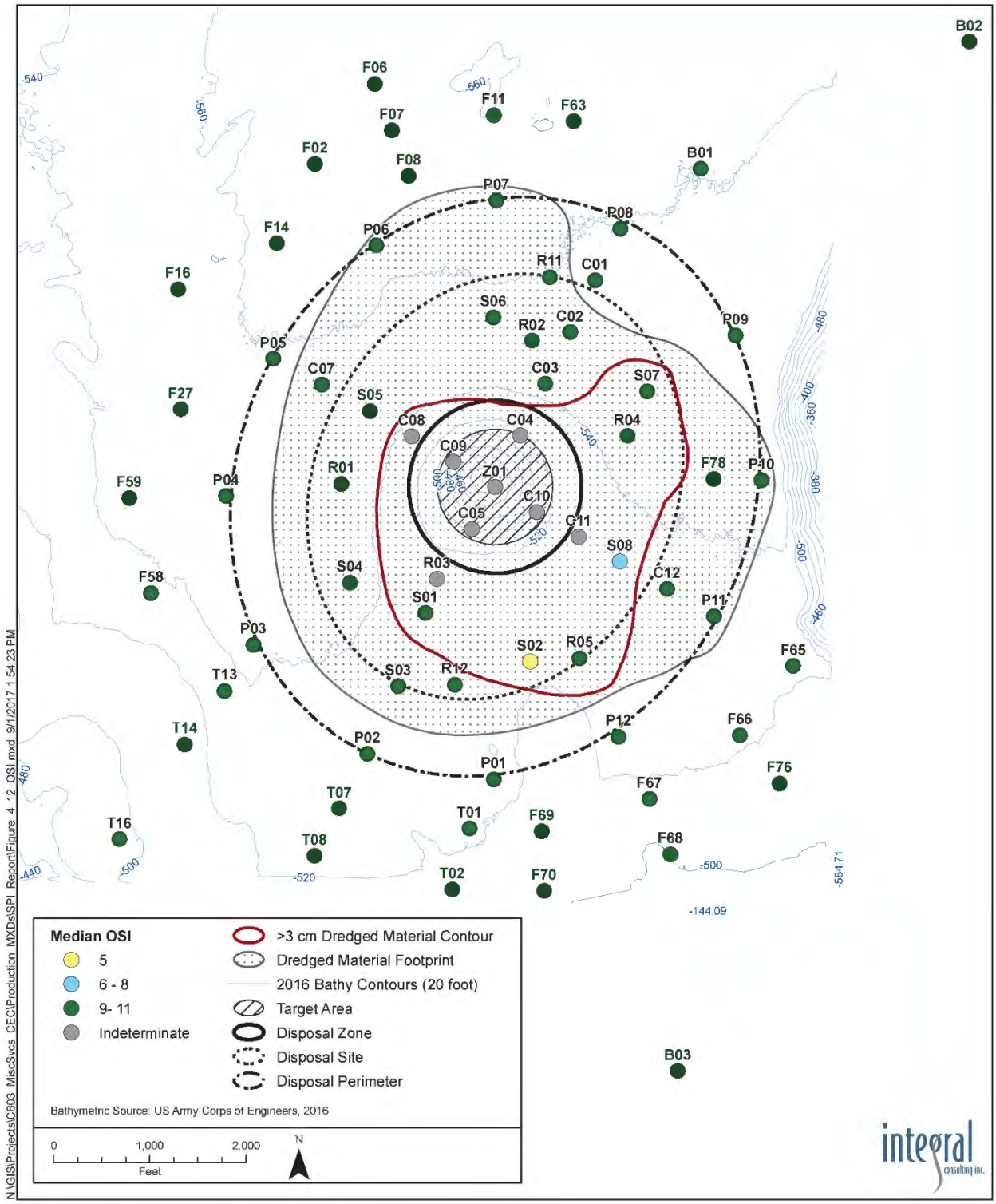

Figure 4-9. Median OSI value for each station

4.2 Sediment Chemistry

This section provides a summary of the sediment chemistry results for the 2017 tiered-full monitoring event. Independent data validation was conducted by Herrera Environmental Consultants, Inc. and EcoChem Inc., and demonstrated that the data were generally of high quality and suitable for use (as qualified) in addressing the DMMP monitoring questions and hypotheses. Validation included U.S. EPA Stage 2B (QA1) data validation for all DMMP chemical data, and Stage 4 validation of a minimum of 10% of the dioxin/furan congener, PCB congener, and PBDE data.

Summary tables of the sediment chemistry analytical results for each sampling location are provided in Appendix E. Results are compared to the DMMP sediment SL/ML list, Washington State Sediment Management Standards (SMS)/Sediment Quality Standards (SQS), and bioaccumulation triggers (BT), where appropriate. The chemistry laboratory reports and independent data validation are provided in Appendix F.

4.2.1 Conventional Parameters

Sediment conventional parameter summary statistics are presented in Table 4-1. Sediments at the onsite stations contained a higher proportion of sand (average of 82.6%) relative to the perimeter stations (average of 29.5%). This finding was consistent with the presence of Port of Tacoma Pier 4 sandy dredged material observed at the onsite stations during the SPI survey. The presence of dredged material was also reflected in the other conventional parameters at the onsite stations. Both TOC and TVS concentrations were lower at the onsite stations compared to the perimeter stations. Similarly, total sulfides and ammonia concentrations at the onsite stations were lower than the perimeter, transect, and benchmark stations. Conversely, the total solids concentrations at the onsite stations (average of 62.7%) were higher than the perimeter, transect, and benchmark stations (average range of 37.9 to 45.3%).

Table 4-1. Conventional parameters summarized by station type

Parameter	Onsite			Perimeter			Transect			Benchmark			Site-Wide		
	Min	Max	**Avg.**	Min	Max	**Avg.**	Min	Max	**Avg.**	Min	Max	**Avg.**	Min	Max	**Avg.**
% Gravel	0	1.1	**0.37**	0	0.5	**0.21**							0	1.1	**0.24**
% Sand	72.8	89.9	**82.6**	13.3	47.7	**29.5**							13.3	89.9	**40.1**
% Silt	5.8	17.7	**11.3**	31.1	58.5	**46.3**							5.8	58.5	**39.3**
% Clay	3.2	9.4	**5.7**	21	28	**24**							3.2	28	**20.3**
% Fines	9	27.1	**17**	52.3	86.2	**70.3**							9	86.2	**59.6**
TOC (% DW)	0.22	1.39	**0.81**	0.96	1.65	**1.35**							0.22	1.65	**1.1**
Total Sulfides (mg/kg DW)	2.34	2.46	**2.4**	3.29	101	**28.3**	48.1	144	**102.7**	21.6	190	**109.1**	1.32	190	**60.6**
Ammonia (mg-N/kg DW)	0.58	3.82	**2.31**	3.67	12.8	**6.54**	3.94	4.77	**4.37**	4.93	7.58	**6.5**	0.58	12.8	**5.82**
TVS (%)	1.4	2.35	**1.86**	4.08	5.7	**4.96**							1.4	5.7	**4.34**
Total Solids (%)	50.6	74.2	**62.7**	40.1	51.2	**45.3**	40.9	51.2	**45.6**	32.1	47.4	**37.9**	32.1	74.2	**48.5**

DW dry weight
TOC total organic carbon
TVS total volatile solids

4.2.2 Metals

The full list of DMMP metals of concern were analyzed in the onsite station samples (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 for each benchmark sample due to holding-time constraints.

Detected metals results are summarized in Table 4-2. The reported concentrations fell well below their respective DMMP and SMS chemical criteria. Silver was not detected in any sample. Selenium had the second lowest frequency of detection and was not detected in the onsite samples. Mercury was detected at low levels in the perimeter and benchmark samples, and was also not detected in the onsite samples. All other metals were detected at low concentrations in the onsite and perimeter samples. Metals concentrations at the onsite stations were lower than the perimeter stations (Table 4-2). Of the onsite stations, CBS01 showed the maximum concentrations for all of the metals.

4.2.3 Tributyltins

Six onsite and four perimeter samples were analyzed for TBT in bulk sediment and porewater. TBT was not detected in any of the samples analyzed (Table 4-2).

4.2.4 DMMP Organic Compounds

A summary of detected organic compounds in Commencement Bay sediments is provided in Table 4-3. Most of the low molecular weight polycyclic aromatic hydrocarbons (LPAH) and high molecular weight polycyclic aromatic hydrocarbons (HPAH) were detected at low levels in the majority of onsite samples and perimeter replicates. Exceptions were acenaphthylene, which was not detected in any onsite samples and only in 4 of 12 perimeter replicates, and benzo(a)pyrene, indeno(1,2,3-cd)pyrene and benzo(g,h,i)perylene, which were detected in most of the perimeter replicates, but in only 1 of 3 onsite samples. LPAH and HPAH concentrations were well below DMMP SLs.

All chlorinated hydrocarbons were undetected with the exception of hexachlorobenzene, which was detected at low concentrations at onsite station CBS01 (1.39 µg/kg DW; “J”-qualified) and one replicate at perimeter station CBP07-B (0.74 µg/kg DW).

Of the phthalates, diethylphthalate and di-n-butylphthalate were the most commonly detected at both onsite and perimeter stations. All concentrations were well below DMMP criteria, with the exception of perimeter sample CBP01-A, which had an initial concentration of 1690 µg/kg DW (134 mg/kg organic-carbon [OC] normalized) for diethylphthalate. The reported concentration was “E”-qualified by the laboratory, which signified that the analyte concentration exceeded the upper limit of the calibration range. Due to the significant difference of this concentration relative to the other replicates at CBP01, and phthalates being a common laboratory contaminant (see Table 2-5), sample CBP01-A was reanalyzed. The reanalysis of sample CBP01-A found diethylphthalate undetected. It is possible that the initial diethylphthalate concentration may have been related to a piece of plastic or contamination from a personal care product (S. Dunnihoo, personal communication 2017). Given the low concentrations of diethylphthalate measured in all other samples and the lack of detection during the reanalysis, the DMMP agencies concluded that the initial diethylphthalate concentration for CBP01-A was likely an outlier. However, the original analysis result was retained for this evaluation and was included in the data summary provided in Table 4-3.

Butylbenzylphthalate was detected only at CBP01-A at a very low concentration well below the DMMP SL. Bis(2-ethylhexyl)phthalate was detected in five perimeter sample replicates and at low concentrations, also well below the DMMP SL.

Table 4-2. Metals analysis summary by station type

	DMMP			Overall	Onsite					Perimeter					Benchmark				
Metals mg/kg DW	**SL**	**BT**	**ML**	**Freq.**	**Min**	**Max**	**Avg.**	**Freq.**	**Max Sample**	**Min**	**Max**	**Avg.**	**Freq.**	**Max Sample**	**Min**	**Max**	**Avg.**	**Freq.**	**Max Sample**
Antimony	150	--	200	14/15	0.573	0.904	0.695	3/3	CBS01	0.692	1.59	1.079	11/12	CBP01-B	--	--	--	--	--
Arsenic	57	507.1	700	14/15	0.928	1.53	1.23	2/3	CBS01	3.65	6.24	5.02	12/12	CBP03-C	--	--	--	--	--
Cadmium	5.1	--	14	15/15	0.193	0.289	0.229	3/3	CBS01	0.288	0.458	0.383	12/12	CBP03-C	--	--	--	--	--
Chromium	260	--	--	15/15	12.5	16.2	13.8	3/3	CBS01	17.8	25.9	22.3	12/12	CBP01-B	--	--	--	--	--
Copper	390	--	1300	15/15	11.6	15.1	12.8	3/3	CBS01	23.1	33.6	28.1	12/12	CBP01-B	--	--	--	--	--
Lead	450	975	1200	15/15	2.19	4.84	3.32	3/3	CBS01	8.15	13.0	11.2	12/12	CBP03-A, CBP03-C	--	--	--	--	--
Mercury	0.41	1.5	2.3	21/24	0.023 U	0.037 U	0.029 U	0/3	na	0.057	0.122	0.098	12/12	CBP03-A	0.085	0.163	0.128	9/9	CBB02-A
Nickel	--	--	--	15/15	9.94	11.3	10.4	3/3	CBS01	14.2	20.6	17.9	12/12	CBP07-A	--	--	--	--	--
Selenium	--	3	--	5/15	0.65 U	0.75 U	0.70 U	0/3	na	0.96	1.3	1.09	5/12	CBP01-A	--	--	--	--	--
Silver	6.1	--	8.4	0/12	0.393 U	0.438 U	0.414 U	0/3	na	0.532 U	0.722 U	0.631 U	0/12	na	--	--	--	--	--
Zinc	410	--	3800	15/15	21.3	27.4	23.6	3/3	CBS01	35.9	53.2	46.7	12/12	CBP03-B	--	--	--	--	--
Bulk tributyltin ion (µg/kg)	--	73	--	0/10	4.70 U	4.98 U	4.80 U	0/6	na	4.80 U	4.93 U	4.89 U	0/4	na	--	--	--	--	--
Porewater tributyltin ion (µg/L)	--	0.15	--	0/10	0.0052 U	0.0052 U	0.0052 U	0/6	na	0.0052 U	0.0052 U	0.0052 U	0/4	na	--	--	--	--	--

DMMP Dredged Material Management Program
SL screening level
BT bioaccumulation trigger
ML maximum level
DW dry weight
Freq. frequency of detection
U analyte is not detected above the applicable reporting or detection limit
na not applicable

Table 4-3. Summary of detected organic compounds by station type

	DMMP			Onsite					Perimeter				
Detected Compounds	**SL**	**BT**	**ML**	**Min**	**Max**	**Avg.**	**Frequency**	**Maximum Sample**	**Min**	**Max**	**Avg.**	**Frequency**	**Maximum Sample**
LPAH in µg/kg DW													
Naphthalene	2,100	--	2,400	15.2	49.3	32.3	2/3	CBS01	19.5	56.3	37.2	12/12	CBP03-B
Acenaphthylene	560	--	1,300	18.8 U	19.8 U	19.2 U	0/3	na	5.8	10.0	7.3	4/12	CBP03-B
Acenaphthene	500	--	2,000	11.5	20.1	15.8	2/3	CBS01	8.0	23.3	13.9	9/12	CBP03-B
Fluorene	540	--	3,600	10	28.2	19.1	2/3	CBS01	7.0	18.8	13.4	11/12	CBP03-B
Phenanthrene	1,500	--	21,000	8.8	96.9	42.1	3/3	CBS01	21.4	75.3	49.8	12/12	CBP03-B
Anthracene	960	--	13,000	5.6	16.8	9.7	3/3	CBS01	8.7	25.6	15.6	12/12	CBP03-B
2-Methylnaphthalene	670	--	1,900	5.5	26.0	15.8	2/3	CBS01	9.5	38.7	26.7	12/12	CBP07-A
HPAH in µg/kg DW													
Fluoranthene	1,700	4,600	30,000	8.9	50.8	23.9	3/3	CBS01	21.3	65.4	44.5	12/12	CBP03-B
Pyrene	2,600	11,980	16,000	6.5	53.7	23.3	3/3	CBS01	26.6	72.2	47.5	12/12	CBP03-C
Benzo(a)anthracene	1,300	--	5,100	7.1	23.9	15.5	2/3	CBS01	14.2	32.4	23.0	12/12	CBP01-C
Chrysene	1,400	--	21,000	7.5	33.2	20.4	2/3	CBS01	18.1	46.5	34.8	12/12	CBP03-B
Benzofluoranthenes	3,200	--	9,900	11.2	35.9	23.6	2/3	CBS01	17.9	59	44.4	12/12	CBP03-B
Benzo(a)pyrene	1,600	--	3,600	23.8	23.8	23.8	1/3	CBS01	13	35.1	24.5	12/12	CBP03-C
Indeno(1,2,3-cd)pyrene	600	--	4,400	9.3	9.3	9.3	1/3	CBS01	8.8	25.1	16.4	11/12	CBP03-B
Dibenz(a,h)anthracene	230	--	1,900	1.5	3.7	2.6	2/3	CBS01	3.3	6.5	5.0	11/12	CBP03-B
Benzo(g,h,i)perylene	670	--	3,200	12.5	12.5	12.5	1/3	CBS01	10.9	28	20.8	11/12	CBP07-B
Chlorinated Hydrocarbons in µg/kg DW													
Hexachlorobenzene	22	168	230	1.39	1.39	1.39	1/3	CBS01	0.74	0.74	0.74	1/12	CBP07-B
Phthalates in µg/kg DW													
Diethylphthalate	200	--	1,200	25.9	27.5	26.7	2/3	CBS01	22.5	1690[a]	121[b]	12/12	CBP01-A
Di-n-butylphthalate	1,400	--	5,100	10.5	14.2	11.9	3/3	CBZ01	6.5	14.5	12.5	8/12	CBP11-C
Butylbenzylphthalate	63	--	970	4.7 U	4.9 U	4.8 U	0/3	na	2.5	2.5	2.5	1/12	CBP01-A

	DMMP			Onsite					Perimeter				
Detected Compounds	**SL**	**BT**	**ML**	**Min**	**Max**	**Avg.**	**Frequency**	**Maximum Sample**	**Min**	**Max**	**Avg.**	**Frequency**	**Maximum Sample**
Bis(2-ethylhexyl)phthalate	1,300	--	8,300	47.1 U	49.4 U	48.1 U	0/3	na	32.6	36.9	33.8	5/12	CBP01-B
Phenols in µg/kg DW													
Phenol	420	--	1,200	12	88.5	50.3	2/3	CBS01	12.6	131	39.7	11/12	CBP01-B
4-Methylphenol	670	--	3,600	4.7 U	4.9 U	4.8 U	0/3	na	6.1	96.1	18.3	12/12	CBP01-B
Miscellaneous Extractables in µg/kg DW													
Benzoic Acid	650	--	760	188 U	198 U	192 U	0/3	na	64.7	143	95.9	7/12	CBP01-B
Dibenzofuran	540	--	1,700	7.8	20.2	14	2/3	CBS01	8.7	12.9	10.0	6/12	CBP01-C
Hexachlorobutadiene	11	--	270	0.48 U	0.48 U	0.48 U	0/3	na	1.43	10.6	3.8	11/12	CBP07-C
Pesticides and PCB Aroclors in µg/kg DW													
4,4'-DDT	12	--	--	4.17	4.17	4.17	1/3	CBS01	0.96 U	1.00 U	0.99 U	0/12	na
Total 4,4'-DDx	--	50	69	4.17	4.17	4.17	1/3	CBS01	0.96 U	1.00 U	0.99 U	0/12	na
Aroclor 1248	--	--	--	3.9 U	3.9 U	3.9 U	0/3	na	2.2	285	32.2	10/12	CBP01-B
Aroclor 1254	--	--	--	3.9 U	3.9 U	3.9 U	0/3	na	2.2	891	77.4	12/12	CBP01-B
Aroclor 1260	--	--	--	3.9 U	3.9 U	3.9 U	0/3	na	1.8	5.1	3.2	11/12	CBP07-A
Total Aroclors	130	38	3,100	3.9 U	3.9 U	3.9 U	0/3	na	4.7	1176[c]	30.2[d]	12/12	CBP01-B

a. Initial analysis of CBP01-A measured diethylphthalate at 1690 µg/kg DW. Diethylphthalate was undetected during the reanalysis at the reporting limit of 19.9 µg/kg DW.

b. The average concentration of diethylphthalate at CBP01-A (average of the original and reanalysis results) was determined before calculating the average for all perimeter stations. The CBP01-A average using the full detection limit for the reanalysis result is 855 µg/kg DW. The average using half of the detection limit for the reanalysis result is 850 µg/kg DW.

c. Initial analysis of CBP01-B measured Total Aroclors at 1176 µg/kg DW. Four reanalysis results were lower, ranging from 15.4 to 23.5 µg/kg DW (Table 4-4).

d. The average concentration of Total Aroclors at CBP01-B (average of the original analysis and four reanalysis results is 252 µg/kg DW) was determined before calculating the average for all perimeter stations.

DMMP Dredged Material Management Program
SL screening level
BT bioaccumulation trigger
ML maximum level
DW dry weight
U analyte is not detected above the applicable reporting or detection limit

na not applicable
-- no value
exceeded SL & BT
exceeded ML

Phenol was detected in most of the onsite and perimeter samples at concentrations below the DMMP SL. Although undetected in onsite samples, 4-Methylphenol was detected in all perimeter samples at low concentrations.

The miscellaneous compounds benzoic acid, dibenzofuran, and hexachlorobutadiene were detected in some samples. Dibenzofuran was detected in the majority of onsite samples and half of the perimeter samples at concentrations well below the DMMP SL. Benzoic acid and hexachlorobutadiene were both undetected in onsite samples, but detected in the majority of perimeter samples at concentrations below the DMMP SLs.

The pesticide 4,4'- dichlorodiphenyltrichloroethane (4,4'-DDT) was the only pesticide detected at one onsite station (CBS01), and was below the DMMP SL. Total DDT was also observed at low concentrations during the 2004 and 2007 monitoring surveys (SAIC 2008).

PCB Aroclors were not detected in any of the onsite samples but were detected in the majority of the perimeter samples. The Aroclor mixtures detected were 1248, 1254, and 1260. Total PCB Aroclors were well below the DMMP criteria with the exception of CBP01-B with a measured concentration of 1176 µg/kg DW, which exceeded the DMMP SL and BT. Due to the significant difference of this concentration relative to the other replicates at CBP01, sample CBP01-B was reanalyzed to confirm the elevated concentration. Reanalysis and subsequent triplicate reanalysis of sample CBP01-B resulted in low concentrations of PCB Aroclors, which were comparable to the other replicates at CBP01 and the other perimeter stations (Table 4-4). It is possible that the initial PCB Aroclor concentration at CBP01-B may have been due to a small, discrete piece of PCB-containing material (such as a paint chip) that was present in the sediment sample. A paint particle the size of silt could be enough to account for the PCBs that were measured in the sediment sample at CBP01-B (S. Dunnihoo, personal communication 2017).

The source of the PCBs at CBP01 remains unclear as elevated PCB concentrations were not measured during the previous monitoring studies at the Commencement Bay site. Recent dredged material does not appear to be the source of PCBs (undetected at all onsite stations - Table 4-3) and recent dredged material was not observed at CBP01 during the SPI survey (see Figure 4-1). It is possible that the PCBs could have been related to legacy dredged material. The baseline studies at Commencement Bay (PTI 1988) observed coarse sediments and debris at the southeast portion of the site (stations CBP01, CBP12, CBS08, and CBP11) and grab samples produced large pieces of asphalt and sediments with oily sheen. It was likely that this material was dredged material placed at a former disposal site that was known to exist in the area (PTI 1988).

4.2.5 PCB Congeners

PCB congeners were analyzed in the three onsite samples and in the first replicate from the four perimeter stations. The results of the PCB congener analyses are reported as toxic equivalency (TEQ) and summarized in Table 4-5. The concentration of PCB congeners are normalized to the toxicity of 2,3,7,8-TCDD using toxic equivalency factors (TEFs) established by the World Health Organization (WHO) in 2005 (Van den berg et al., 2006). The TEQ values discussed in this section were calculated using half of the estimated detection limit value for undetected congeners (ND = ½ DL). PCB congener TEQ values were relatively low with the lowest values in the onsite samples and higher values in the perimeter samples. Onsite station CBZ01 had a low of 0.0270 ng/kg DW TEQ and perimeter station CBP07-A had a high of 0.452 ng/kg DW TEQ. A listing of the full results of the PCB congener analyses is provided in Appendix E.

Table 4-4. PCB Aroclor analysis for CBP01-B

	Analysis 8/5/2017		Reanalysis 9/29/2017		Reanalysis 11/15/2017					
PCB Aroclors (µg/kg DW)	**CBP01-B**	**Q**	**CBP01-B**	**Q**	**CBP01-B**	**Q**	**CBP01-B**	**Q**	**CBP01-B**	**Q**
PCB-Aroclor 1016	19.9	U	3.9	U	4.0	U	4.0	U	4.0	U
PCB-Aroclor 1221	19.9	U	3.9	U	4.0	U	4.0	U	4.0	U
PCB-Aroclor 1232	19.9	U	3.9	U	4.0	U	4.0	U	4.0	U
PCB-Aroclor 1242	19.9	U	3.9	U	4.0	U	4.0	U	4.0	U
PCB-Aroclor 1248	285	J	3.9	U	10.5	J	8.2		11	J
PCB-Aroclor 1254	891		9.3		8.0	J	7.4	J	8.4	J
PCB-Aroclor 1260	19.9	U	6.1		4.6	J	4.0	J	4.1	J
PCB-Aroclor 1262	19.9	U	3.9	U	4.0	U	4.0	U	4.0	U
PCB-Aroclor 1268	19.9	U	3.9	U	4.0	U	4.0	U	4.0	U
Total Aroclors	**1176**		**15.4**		**23.1**		**19.6**		**23.5**	

Q laboratory qualifier
U analyte is not detected above the applicable reporting or detection limit
J estimated concentration value detected below the reporting limit

exceeded SL & BT

Table 4-5. Summary of PCB congener analysis by station type

	DMMP			Onsite					Perimeter				
Detected Compounds	**SL**	**BT**	**ML**	**Min**	**Max**	**Avg.**	**Frequency**	**Maximum Sample**	**Min**	**Max**	**Avg.**	**Frequency**	**Maximum Sample**
Total PCB Congeners in ug/kg DW													
Total PCB	--	--	--	0.322	1.99	1.07	3/3	CBS01	5.25	9.84	6.77	4/4	CBP07-A
PCB TEQ in ng/kg DW													
Total TEQ (ND=0)	--	--	--	0.000866	0.0909	0.0451	3/3	CBS01	0.165	0.452	0.273	4/4	CBP07-A
Total TEQ (ND=1/2 DL)	--	--	--	0.027	0.0988	0.0583	3/3	CBS01	0.184	0.452	0.279	4/4	CBP07-A

DMMP Dredged Material Management Program
SL screening level
BT bioaccumulation trigger
ML maximum level
TEQ toxic equivalency
ND not detected
DL detection limit
-- no value

4.2.6 Dioxin/Furan Congeners

Ten onsite station samples and the first replicate from each of the four perimeter stations were analyzed for dioxin/furan congeners (Figure 3-1). Seven of the onsite stations were selected randomly using the procedures outlined in Section 2.2. The results of the dioxin/furan analyses reported as TEQs are summarized in Table 4-6. The TEQ values discussed in this section were calculated using half of the estimated detection limit value for undetected congeners (ND = ½ DL).

The average onsite dioxin/furan concentration of 1.42 ng/kg DW TEQ was well below the DMMP disposal site management objective (DSMO) of 4 ng/kg TEQ. Onsite sample CBZ01 contained the lowest dioxin/furan concentration at 0.42 ng/kg DW TEQ. All samples were lower than the DSMO, with the exception of onsite sample CBR11 (4.70 ng/kg DW TEQ) and perimeter sample CBP07-A (4.96 ng/kg DW TEQ). Due to the low-level blank contamination observed in the dioxin/furan congener analyses (see Appendix F), the DMMP agencies decided to reanalyze the two samples that exceeded the DSMO to confirm the concentrations. The contribution from blank contamination for the original analysis was 0.294 ng/kg DW TEQ. The reanalysis confirmed that the dioxin/furan congener concentrations exceeded the 4 ng/kg TEQ DSMO for samples CBR11 and CBP07-A (Table 4-7), although blank contamination was still an issue in the reanalysis. The contribution from blank contamination for the reanalysis was 0.182 ng/kg DW TEQ.

A review of the dioxin/furan congener results for the 2007 Commencement Bay monitoring program showed that station CBP07 had a concentration of 5.2 ng/kg DW TEQ at that time, which also exceeded the 4 ng/kg TEQ DSMO (Table 4-8). Stations CBR11 and CBP07 are both located in the northern portion of the disposal site along the periphery of this year's recent dredged material footprint (Figure 4-10). The SPI survey identified 1.1 cm of recent dredged material at CBR11 and trace amounts of dredged material at CBP07 (see Figure 4-1). Onsite sediment samples are collected from 0-10 cm of the sediment surface, which suggests that the higher dioxin/furan congener TEQs measured at CBR11 and CBP07 may have been related to older dredged material present in those areas. During the 2007 monitoring program, the SPI survey identified 2.61 cm of recent and >10.67 cm of historic dredged material present at CBP07 (SAIC 2008).

4.2.7 PBDEs

PBDE congeners were analyzed in the three onsite samples and in the first replicate from the four perimeter stations. A summary of detected PBDE congeners is provided in Table 4-9. Overall, only 11 individual PBDE congeners and four sets of co-eluting congener pairs were detected. The onsite stations had higher concentrations and more frequent detection of PBDE congeners compared to the perimeter stations. Onsite station CBS01 had the maximum detected concentrations of all of the PBDE congeners detected with the exception of BDE-209, which had the highest concentration at CBP11-A.The results for all 43 individual PBDE congeners and 10 co-eluting pairs are provided in Appendix E.

4.2.8 Field Variability

For perimeter and benchmark samples collected in triplicate, an acceptability criterion of 50% relative standard deviation (RSD) between replicates was used for detected chemical parameters. The majority of field variability results were acceptable, with exceptions summarized in Table 4-10. The most frequent RSD values above 50% occurred at station CBP03, with the majority related to LPAH and HPAH concentrations. Total PCBs exceeded the 50% RSD at CBP01 due to the high concentration measured in replicate CBP01-B. Total sulfides had high RSD values for the majority of both benchmark and perimeter samples.

Table 4-6. Summary of dioxin/furan congener analysis by station type

	DMMP			Onsite					Perimeter				
Detected Compounds	**SL**	**BT**	**ML**	**Min**	**Max**	**Avg.**	**Frequency**	**Maximum Sample**	**Min**	**Max**	**Avg.**	**Frequency**	**Maximum Sample**
Dioxin/Furan Congeners in ng/kg DW													
Total TEQ (ND=0)	4	10	--	0.029	4.27	1.13	10/10	CBR11	2.23	4.27	3.16	4/4	CBP07-A
Total TEQ (ND=1/2 DL)	4	10	--	0.42	4.36	1.42	10/10	CBR11	2.53	4.66	3.44	4/4	CBP07-A

DMMP Dredged Material Management Program
SL screening level
BT bioaccumulation trigger
ML maximum level
TEQ toxic equivalency
ND not detected
DL detection limit
-- no value

Table 4-7. Dioxin/furan congener reanalysis results

Parameter	DMMP			Analysis 8/15/2017			Reanalysis 9/19/2017			Analysis 8/15/2017			Reanalysis 9/19/2017		
	SL	BT	ML	CBP07-A	Q	VQ	CBP07-A	Q	VQ	CBR11	Q	VQ	CBR11	Q	VQ
Dioxin/Furan Congeners (ng/kg)															
2,3,7,8-TCDD	---	---	---	0.342	J	U	0.29	J		0.283	J	U	0.22	J	
1,2,3,7,8-PeCDD	---	---	---	1.21	J	U	1.32	B		1.11			1.01	B	
1,2,3,4,7,8-HxCDD	---	---	---	0.841	J,B		0.844	J		0.798	J,B		0.788	J	
1,2,3,6,7,8-HxCDD	---	---	---	4.24			4.07	B		3.83			3.61	B	
1,2,3,7,8,9-HxCDD	---	---	---	2.93	B		2.44	B		2.36	B		2.25	B	
1,2,3,4,6,7,8-HpCDD	---	---	---	52.8	B		52.2	B		52	B		45.3	B	
OCDD	---	---	---	432	B		435	B		415	B		374	B	
2,3,7,8-TCDF	---	---	---	4.04			2.42			5.75			1.86		
1,2,3,7,8-PeCDF	---	---	---	4.71	B		1.44			2.83	B		1.5		
2,3,4,7,8-PeCDF	---	---	---	2.79	B		1.06	J		2.25	B		1.03		
1,2,3,4,7,8-HxCDF	---	---	---	7.14			2.91			3.81			4.84		
1,2,3,6,7,8-HxCDF	---	---	---	1.83			1.13			1.11			1.26		
1,2,3,7,8,9-HxCDF	---	---	---	1.37	B		0.792	J,B		0.831	J,B	U	1.05	B	
2,3,4,6,7,8-HxCDF	---	---	---	1.36			1.02	J		1.06			1.13		
1,2,3,4,6,7,8-HpCDF	---	---	---	14.5	B		13.6	B		11.9	B		15.5	B	
1,2,3,6,7,8,9-HpCDF	---	---	---	1.79	B		1.48	B		1.31	B	U	2.82	B	
OCDF	---	---	---	37.5	B		37.4			27.7	B		36		
Total TEQ (ND = 0)	4	10	---	4.19			4.35			4.51			4.02		
Total TEQ (ND = 1/2 DL)	4	10	---	4.96			4.35			4.70			4.02		

DMMP Dredged Material Management Program
SL screening level
BT bioaccumulation trigger
ML maximum level
TEQ toxic equivalency
-- no value

B analyte was detected in the method blank
J estimated concentration value detected below the reporting limit
Q laboratory qualifier

exceeded 4.0 ng/kg TEQ DSMO

Table 4-8. 2007 and 2017 dioxin/furan congener TEQ results in Commencement Bay

Station	2007		2017	
	DIOXIN TEQ (ND=0)	DIOXIN TEQ (ND=1/2 DL)	DIOXIN TEQ (ND=0)	DIOXIN TEQ (ND=1/2 DL)
CBZ01	14.2	14.3	0.029	0.42
CBS01	1.08	1.09	0.67	0.95
CBS08	1.14	1.25	0.39	0.62
CBP01	1.65	1.68	3.09	3.26
CBP03	1.43	1.45	3.06	3.32
CBP07	5.15	5.2	4.27	4.66
CBP11	1.25	1.28	2.23	2.53

ND not detected
DL detection limit
TEQ toxic equivalency in ng/kg

exceeded 4.0 ng/kg TEQ DSMO

Table 4-9. Summary of PBDEs by station type

	DMMP			Onsite					Perimeter				
Detected Compounds	**SL**	**BT**	**ML**	**Min**	**Max**	**Avg.**	**Frequency**	**Maximum Sample**	**Min**	**Max**	**Avg.**	**Frequency**	**Maximum Sample**
PBDE Congeners (pg/g)													
BDE-8/11	--	--	--	0.383	1.91	0.995	3/3	CBS01	0.314	0.516	0.388	3/4	CBP01-A
BDE-15	--	--	--	0.257	1.19	0.637	3/3	CBS01	0.163	0.266	0.208	3/4	CBP01-A
BDE-17	--	--	--	1.06	2.75	1.905	2/3	CBS01	0.383	0.656	0.494	3/4	CBP01-A
BDE-25	--	--	--	0.134	0.134	0.134	1/3	CBS01	0.0793 U	0.119 U	0.102 U	0/4	na
BDE-28/33	--	--	--	0.427	1.36	0.783	3/3	CBS01	0.172	0.384	0.287	4/4	CBP07-A
BDE-75/51	--	--	--	0.201	0.612	0.363	3/3	CBS01	0.0481 U	0.172 U	0.0902 U	0/4	na
BDE-49	--	--	--	3.02	3.02	3.02	1/3	CBS01	0.697	0.697	0.697	1/4	CBP01-A
BDE-47	--	--	--	4.24	11.1	6.96	3/3	CBS01	1.75	4.32	2.69	4/4	CBP07-A
BDE-79	--	--	--	0.307	0.307	0.307	1/3	CBS01	0.0749 U	0.108 U	0.0955 U	0/4	na
BDE-100	--	--	--	0.628	1.63	1.01	3/3	CBS01	0.269	0.349	0.301	3/4	CBP03-A
BDE-99	--	--	--	2.51	4.46	3.31	3/3	CBS01	0.780	1.24	1.04	4/4	CBP01-A
BDE-154/128	--	--	--	0.394	0.829	0.575	3/3	CBS01	0.167 U	0.240 U	0.193 U	0/4	na
BDE-153	--	--	--	0.51	0.51	0.51	1/3	CBS01	0.222 U	0.299 U	0.246 U	0/4	na
BDE-175	--	--	--	1.87	1.87	1.87	1/3	CBS01	0.148 U	0.190 U	0.160 U	0/4	na
BDE-209	--	--	--	10.4 U	19.8 U	15.1 U	0/3	na	70.0	70.0	70.0	1/4	CBP11-A

DMMP Dredged Material Management Program
SL screening level
BT bioaccumulation trigger
ML maximum level
TEQ toxic equivalent quotient
U analyte is not detected above the applicable reporting or detection limit
na not applicable
-- no value

Table 4-10. Field variability results exceeding 50% RSD

Parameter	CBP01 %RSD	CBP03 %RSD	CBP07 %RSD	CBP11 %RSD	CBB01 %RSD	CBB02 %RSD	CBB03 %RSD
Total Sulfides	70.5	73.4	83.0	-	68.3	70.1	-
LPAH							
Phenanthrene	-	54.2	-	-	na	na	na
2-Methylnaphthalene	-	55.7	-	-	na	na	na
Total LPAH	-	51.7	-	-	na	na	na
HPAH							
Benzofluoranthenes	-	51.3	-	-	na	na	na
Total HPAH	-	50.3	-	-	na	na	na
Phthalates							
Diethylphthalates	73.8	-	-	-	na	na	na
Phenols							
Phenol	-	-	129	-	na	na	na
Pesticides and PCBs							
Total PCBs	169	-	-	-	na	na	na

RSD relative standard deviation
\- RSD value is less than 50%
na not analyzed

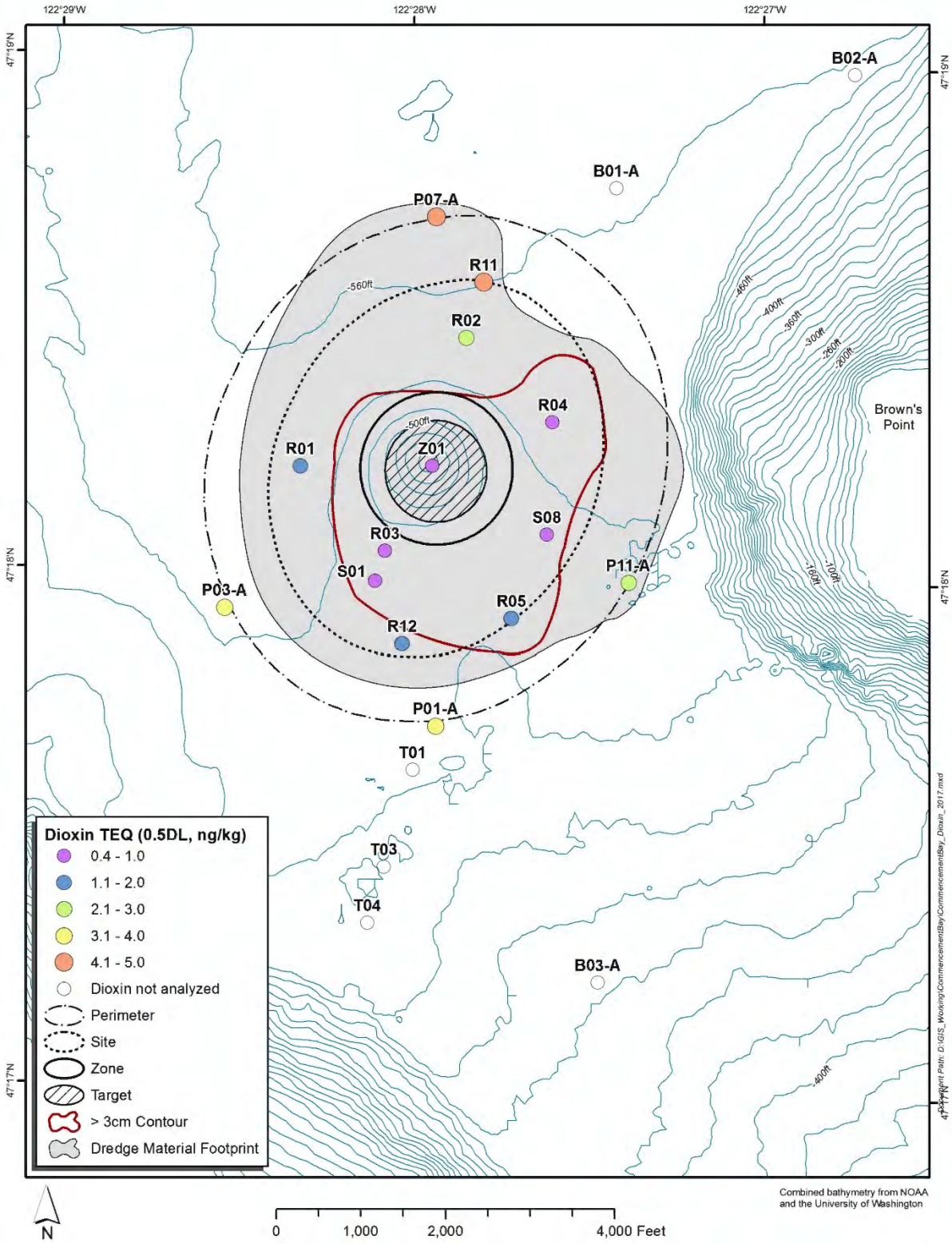

Figure 4-10. Dioxin/furan congener TEQs at the Commencement Bay site

4.3 Bioassays

DMMP bioassay testing was conducted on the three onsite station sediments from Commencement Bay (CBZ01, CBS01, and CBS08) and one reference sediment from Carr Inlet (CR-23W). The DMMP sediment bioassays included the 10-day acute amphipod test using *Eohaustorius estuarius*, the sediment larval test using *Dendraster excentricus*, and the 20-day *Neanthes* mean growth test. The *Neanthes* growth test was conducted using the ash-free dry weight (AFDW) procedure indicated in the 2013 Sediment Management Annual Review Meeting (SMARM) clarification paper (Kendall et al. 2013). The dry-weight results were also provided by the lab. The full bioassay laboratory reports and quality assurance review are provided in Appendix G.

Results of the bioassay tests are summarized in Table 4-11. Due to the very coarse grained nature of CBZ01 (9% fines), the DMMP agencies had decided to evaluate the test results for CBZ01 with the negative control in place of a coarse-grained reference sediment. However, when running the bioassays, the laboratory was not instructed to treat the control sediment as a test sediment for the larval test. Only a seawater control was run for the larval test. Therefore, the DMMP agencies decided to evaluate the test results for all onsite samples with the Carr Inlet reference CR-23W.

The negative control and reference sediment performance standards were met for all three bioassays (Table 4-12). For the amphipod test, mean mortality was low for all samples ranging from 0.0% for CBZ01 to 4.0% for CBS01. All samples passed the DMMP non-dispersive guidelines for the amphipod test (Table 4-14).

Mean normalized combined mortality/abnormality (NCMA) for the larval test exceeded 20% for CBS01 (25.5%) and CBS08 (41.5%). Under the non-dispersive interpretation guidelines, the NCMA for CBS08 was also found to be statistically significantly different from the reference (alpha = 0.10), but not more than 30 percent greater than the mean reference sediment NCMA (Table 4-13). Therefore, the larval test was considered a single hit for CBS08 under the 2-hit rule. Samples CBZ01 and CBS01 passed the non-dispersive guidelines for the larval test.

For the *Neanthes* mean growth test, the control sample, reference sample, as well as all of the test samples were above the target growth rate of 0.72 mg/individual/day. The mean individual growth rates (reported in AFDW) for all test sediments were much greater than 80% of the mean control growth rate (Table 4-13). Therefore, all samples passed the non-dispersive guidelines for the *Neanthes* growth test.

The larval test hit for CBS08 under the 2-hit rule was not corroborated by a hit in the amphipod mortality or *Neanthes* growth tests. Therefore, DMMP bioassay Site Condition II evaluation guidelines were not exceeded for the suite of bioassays (amphipod, larval, and *Neanthes* growth tests) at CBZ01, CBS01, and CBS08. Bioassay testing of the benchmark samples was not warranted.

Table 4-11. Bioassay results for control, reference, and onsite sediments

Sample	Grain Size (% fines)	Amphipod Test (*Eohaustorius estuarius*) Mortality (%)	Sediment Larval (*Dendraster excentricus*) NCMA (%)	20-Day *Neanthes* Mean Growth Rate (mg/indiv/day)	20-Day *Neanthes* Ash-Free Mean Growth Rate (mg/indiv/day)
Control	NA	0.0 ± 0.0	0.0 ± 7.0	0.99 ± 0.20	0.66 ± 0.13
CR-23W	30.5	2.0 ± 4.5	27.4 ± 10.9	0.93 ± 0.09	0.63 ± 0.06
CBZ01	9.0	0.0 ± 0.0	17.6 ± 10.5	0.86 ± 0.05	0.64 ± 0.05
CBS01	27.1	4.0 ± 5.5	25.5 ± 8.7	0.82 ± 0.04	0.62 ± 0.04
CBS08	14.8	1.0 ± 2.2	41.5 ± 13.7	0.86 ± 0.11	0.65 ± 0.07

NCMA Normalized combined mortality/abnormality
NA Not applicable (seawater control, or data not available)
CR-23W Reference sediment

Table 4-12. Bioassay performance standards results

Test	Negative Control		Reference Sediment	
	Performance Standard	Result	Performance Standard	CR-23W Result
Amphipod Mortality	$M_C \leq 10\%$	0.0%	$M_R - M_C \leq 20\%$	2.0%
Larval Development	$N_C/I \geq 0.70$	0.80	$N_R/ N_C \geq 0.65$	0.73
Juvenile Polychaete Growth	$M_C \leq 10\%$ and $MIG_C \geq 0.38$	0.0% 0.99	$M_R \leq 20\%$ and $MIG_R /MIG_C \geq 0.80$	0.0% 0.94

C negative control
I initial count
M mortality
MIG mean individual growth rate (mg/individual/day)
N number normal
R reference
T test sample

Table 4-13. Bioassay result interpretation under non-dispersive disposal site guidelines

Test	1-Hit Rule	2-Hit Rule	CBZ01	Result	CBS01	Result	CBS08	Result
Amphipod Mortality	M_T - M_C > 20% and M_T vs. M_R SD (p=.05) and		0.0% NA	Pass	4.0% NA	Pass	1.0% NA	Pass
	M_T - M_R > 30%	NOCN	-2.0%		2.0%		-1.0%	
Larval Development	N_T/N_C < 0.80 and N_T/N_C vs. N_R/N_C SD (p=.10) and		0.83 NA	Pass	0.75 NSD	Pass	0.59 SD	2-Hit
	N_R/N_C - N_T/N_C > 0.30	NOCN	-0.10		-0.02		0.14	
Juvenile Polychaete Growth (AFDW)	MIG_T/MIG_C < 0.80 and MIG_T vs. MIG_R SD (p=.05) and		0.97 NA	Pass	0.94 NA	Pass	0.98 NA	Pass
	MIG_T/MIG_R < 0.50	MIG_T/MIG_R < 0.70	1.02		0.98		1.03	

AFDW ash-free dry weight
C negative control
I initial count
M mortality
MIG mean individual growth rate (mg/ind/day)
N number normal
NA not analyzed
NOCN no other conditions necessary
NSD no statistically significant difference
R reference
SD statistically significant difference
T test sample

5.0 EVALUATION OF THE MONITORING FRAMEWORK

This section evaluates the 2017 environmental monitoring data collected at the Commencement Bay site using the DMMP interpretive guidelines described in Section 2.0. The evaluation is organized according to the questions and hypotheses of the DMMP monitoring framework.

5.1 Question 1: Does the Dredged Material Stay On Site?

5.1.1 SPI Survey Results

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

The 2017 SPI survey at Commencement Bay did not identify the presence of dredged material beyond the disposal site perimeter that exceeded the 3 cm DMMP interpretive criteria. Under the monitoring framework for non-dispersive dredged material disposal sites, ***Hypothesis No. 1 is accepted*** (i.e., dredged material remains within the disposal site boundary).

5.1.2 Perimeter Chemistry

Hypothesis No. 2: Chemical concentrations at offsite stations do not measurably increase over time due to dredged material disposal.

A review of the 2017 perimeter station chemistry found that all detected chemical concentrations were below the Washington State SQS criteria with the exception of Total PCBs for the original analysis of sample CBP01-B (88 mg/kg OC), which exceeded the Cleanup Screening Level (CSL) of 65 mg/kg OC and diethylphthalate for the original analysis of sample CBP01-A (134 mg/kg OC), which exceeded the CSL of 110 mg/kg OC (Appendix D). However, as discussed in Section 4.2.4, these elevated concentrations were not consistent with the other sample replicates at CBP01. Additionally, a reanalysis of the CBP01-A sample could not replicate the elevated concentration of diethylphthalate, and four subsequent reanalyses of the CBP01-B sample could not replicate the elevated concentration of Total PCBs. It is possible that a small, discrete piece of plastic was present in the first analysis of CBP01-A, and a PCB-containing paint chip was present in the first analysis of CBP01-B. A personal-care product could also have been the source of laboratory contamination of diethylphthalate.

Recent dredged material does not appear to be a source of PCBs or diethylphthalate as the 2017 chemical monitoring did not measure PCB Aroclors at any onsite stations, while the onsite concentrations of diethylphthalate were more than an order of magnitude less than that found in the original analysis of CBP01-A. Additionally, the SPI survey did not detect any recent dredged material at CBP01. Further evidence that recent dredged material was not the source of the elevated concentrations comes from a review of the analytical results from the Port of Tacoma's Pier 4 Reconfiguration project, which was the source of the majority of dredged material placed at the Commencement Bay site since the last monitoring event. PCB Aroclors were undetected in all but one dredged material management units from Pier 4. The Total PCB concentration in the one dredged material management unit in which Aroclors were detected was only 7.4 µg/kg DW. Similarly, diethylphthalate was undetected in all but one dredged material management units from Pier 4. The diethylphthalate concentration in the one dredged material management unit in which it was detected was only 170 µg/kg DW.

A statistical time-trends analysis was conducted to determine if changes observed in perimeter site chemistry are significant over time. The time-trends analysis was conducted using the Chemical Tracking System (CTS) as described in detail in SAIC and MWLS (1996). The analysis used perimeter chemistry data from the 1988 baseline and eight monitoring events (1995, 1996, 2001, 2003, 2004, 2005 [semi-

volatiles only], 2007, and 2017) conducted at Commencement Bay. The detailed CTS output is provided in Appendix H.

Table 5-1 presents a summary of the maximum likelihood trend estimates (slope estimates) for each chemical group at each perimeter station. The maximum likelihood method can be thought of as a process for determining the slope of increasing or decreasing chemical concentrations over time (mean percent change per year) that is most consistent with the data (SAIC and MWLS 1996).

A maximum likelihood estimate of the slope (log-scale mean percent change per year) is generated for individual chemicals, and the group-level summaries provided in Table 5-1 indicate the range of estimated temporal trends within each chemical group. At least four individual chemical results within a chemical group are required to determine the statistical significance of the mean slope for the group. Chemical groups with four or more slopes reported for the 2017 CTS analysis included conventional parameters, metals, LPAHs, HPAHs, and phthalates (station CBP03 only). The significance of the group trends could not be determined for the remaining organic chemical groups (chlorinated aromatics, phthalates [at all but station CBP03], phenols, miscellaneous extractables, volatiles, and pesticides/PCBs) because less than four individual chemicals had calculated slopes. To calculate a slope for an individual chemical, the minimum data requirements were three or more reported results, with at least two values above detection, and the detected values present in more than one year.

Table 5-1. Maximum likelihood results for Commencement Bay perimeter stations

	# slopes	Slope and Significance (Log 10)								direction	Mean Percent Change per Year	Outlier slopes[1]
		Mean	Max	Min	Median	S.E.	95% LCL	95% UCL	P-Value			
CBP01												
Global	48	-0.005	0.077	-0.046	-0.011	0.006	-0.017	0.007	0.38		-1.22	
Conventionals	9	0.005	0.032	-0.011	0.003	0.002	-0.001	0.011	0.08	+	1.19	
Metals	9	-0.011	0.014	-0.028	-0.012	0.009	-0.034	0.012	0.29	-	-2.48	
LPAHs	7	-0.014	0.028	-0.046	-0.011	0.018	-0.065	0.038	0.50	-	-3.12	
HPAHs	9	-0.025	-0.018	-0.035	-0.025	0.017	-0.067	0.016	0.18	-	-5.69	
Chl. Aromatics	3	-0.007	0.013	-0.021	-0.012	0.023	not calculable[2]				-1.54	
Phthalates	3	0.027	0.077	-0.016	0.020	0.016	not calculable				6.39	*
Phenols	2	0.031	0.043	0.019	0.031	0.029	not calculable				7.47	
Misc. Ext.	2	0.006	0.026	-0.014	0.006	0.026	not calculable				1.33	
Volatiles	3	0.002	0.004	-0.003	0.004	0.049	not calculable				0.38	
Pest/PCBs	1	0.050	0.050	0.050	0.050	0.050	not calculable				12.28	
CBP03												
Global	42	-0.007	0.109	-0.104	-0.009	0.006	-0.019	0.006	0.28		-1.49	
Conventionals	9	0.004	0.040	-0.005	0.001	0.003	-0.004	0.012	0.24	+	1.0	
Metals	9	-0.012	0.010	-0.031	-0.010	0.009	-0.034	0.009	0.22	-	-2.7	
LPAHs	7	-0.003	0.010	-0.015	-0.001	0.018	-0.054	0.049	0.90	-	-0.6	
HPAHs	9	-0.015	-0.010	-0.019	-0.015	0.016	-0.053	0.024	0.38	-	-3.3	
Chl. Aromatics	0											
Phthalates	4	0.015	0.109	-0.036	-0.007	0.013	-0.150	0.179	0.46	+	3.4	*
Phenols	2	0.000	0.010	-0.010	0.000	0.022	not calculable				0.0	
Misc. Ext.	1	-0.008	-0.008	-0.008	-0.008	0.040	not calculable				-1.9	
Volatiles	0											
Pest/PCBs	1	-0.104	-0.104	-0.104	-0.104	0.113	not calculable				-21.3	*

	# slopes	Slope and Significance (Log 10)								direction	Mean Percent Change per Year	Outlier slopes[1]
		Mean	Max	Min	Median	S.E.	95% LCL	95% UCL	P-Value			
CBP07												
Global	46	-0.008	0.081	-0.064	-0.014	0.005	-0.018	0.003	0.14		-1.8	
Conventionals	9	0.004	0.043	-0.010	0.003	0.004	-0.007	0.014	0.42	+	0.8	
Metals	9	-0.017	0.008	-0.040	-0.016	0.010	-0.041	0.006	0.12	-	-3.9	
LPAHs	7	-0.001	0.017	-0.017	-0.001	0.017	-0.048	0.046	0.95	-	-0.3	
HPAHs	9	-0.020	-0.016	-0.024	-0.019	0.015	-0.055	0.016	0.23	-	-4.4	
Chl. Aromatics	1	-0.057	-0.057	-0.057	-0.057	0.023	not calculable				-12.2	
Phthalates	4	0.025	0.081	-0.038	0.028	0.017	-0.191	0.241	0.38	+	5.9	*
Phenols	2	0.010	0.026	-0.005	0.010	0.031	not calculable				2.4	
Misc. Ext.	2	0.007	0.010	0.004	0.007	0.028	not calculable				1.7	
Volatiles	0											
Pest/PCBs	3	-0.044	-0.033	-0.064	-0.035	0.023	not calculable				-9.7	
CBP11												
Global	45	-0.008	0.077	-0.063	-0.011	0.005	-0.017	0.002	0.12		-1.72	
Conventionals	9	0.003	0.036	-0.008	0.001	0.003	-0.004	0.010	0.33	+	0.7	
Metals	9	-0.013	0.009	-0.035	-0.013	0.009	-0.034	0.009	0.20	-	-2.9	
LPAHs	7	-0.008	0.006	-0.032	-0.002	0.017	-0.054	0.038	0.66	-	-1.8	
HPAHs	9	-0.017	-0.011	-0.024	-0.018	0.014	-0.052	0.018	0.28	-	-3.8	
Chl. Aromatics	0											
Phthalates	4	0.019	0.077	-0.035	0.017	0.010	-0.113	0.151	0.32	+	4.4	*
Phenols	2	0.023	0.025	0.021	0.023	0.018	not calculable				5.3	
Misc. Ext.	2	-0.004	0.012	-0.020	-0.004	0.026	not calculable				-0.9	
Volatiles	0											
Pest/PCBs	3	-0.053	-0.040	-0.063	-0.055	0.0	not calculable				-11.4	

[1] A slope was flagged as an outlier by CTS if it was more than 3 standard deviations from the grand mean of all slopes.
[2] Confidence limits and p-values use n-3 degrees of freedom, so a minimum of 4 chemical slopes in a group are required for these summaries.

The "global" maximum likelihood estimation for each perimeter station, which represents the estimate for all chemicals of concern and conventional parameters is also reported in Table 5-1. However, the global estimation is no longer used for evaluating offsite chemical trends because it incorrectly assumes that a common trend was present among all chemicals, including conventional parameters (SAIC 2003). Common trends have not been observed where CTS has been used to evaluate time trends in perimeter chemistry (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., increase in percent fines). Therefore, trends for individual chemicals and guilds of chemicals (e.g., metals, HPAHs) are used to assess time trends in perimeter chemistry.

The maximum likelihood results showed no statistically significant increases ($p < 0.05$[6]) in chemical groups at the perimeter stations since 1988 (Table 5-1). Details for individual chemicals and group trends are discussed below, and presented in Tables 5-2 through 5-5 for stations CBP01 through CBP11, respectively. The intent of CTS is to provide an "early warning" of temporal trends of increasing offsite concentrations before SQS values are exceeded. Therefore, the discussion of individual chemical trends is focused on positive trends that are statistically significant. Conventional parameters (total solids, TVS, TOC, ammonia, grain size) are not regulated by SQS and both increasing and decreasing trends of these parameters are discussed.

Conventionals

As a group, the conventional parameters did not show statistically significant ($p < 0.05$) trends over time at any of the perimeter stations. For individual conventional parameters, statistically significant increasing trends were observed for ammonia (CBP01), and total solids (CBP07, CBP11), while significant decreasing trends were observed for TOC (CBP07, CBP11), and TVS (CBP07, CBP11). Grain size appeared to be fairly stable at all stations based on the small non-significant slopes for fines at all stations except CBP01. Station CBP01 had statistically significant positive trends for fines and negative trends for sand due to the single 1988 sample which had a high sand content (67%). Since 1995, grain size at this station was stable between 64 and 88 percent fines, and between 50 and 93 percent at the other three stations.

Metals

The metals group did not show a statistically significant trend at any of the perimeter stations. However, the slopes for most of the individual metals (As, Cu, Pb, Ni, Ag, Zn) indicated statistically significant ($p < 0.05$) decreases in concentrations over time at all stations. Mercury showed a statistically significant decrease at CBP07 only. The slopes for cadmium indicated statistically significant increases ($p < 0.05$) at CBP01 and CBP03.

[6] "p" is equivalent to "P-Value" referenced in Tables 5-1 through 5-5.

Table 5-2. Chemical tracking system output for Commencement Bay station CBP01

Per Chemical Results:	Slope			Intercept				Slope as %		Slope
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	change/year	Outlier	Direction
Conventionals										
Total Organic Carbon (% DW)	-0.004	0.002	0.062	0.261	0.069	0.071	0.010	-0.916		-
Total Sulfides (mg/kg DW)	0.032	0.021	0.139	-0.631	0.722	0.686	0.128	7.609		+
Ammonia (mg-N/kg DW)	0.011	0.005	0.039	0.482	0.167	0.152	0.023	2.487		+
TVS (mg/kg DW)	0.000	0.002	0.919	0.643	0.065	0.067	0.010	0.045		+
Total Solids (%)	0.000	0.001	0.758	1.641	0.043	0.044	0.006	0.089		+
Percent Gravel (□2.0 mm)	Not calculated									
Percent Sand (<2.0 mm - 0.06 mm)	-0.011	0.003	0.002	1.731	0.105	0.108	0.016	-2.447		-
Percent Silt (0.06 mm - 0.004 mm)	0.008	0.002	0.001	1.417	0.073	0.075	0.011	1.882		+
Percent Fines (<0.06 mm)	0.006	0.002	0.005	1.652	0.069	0.071	0.010	1.468		+
Percent Clay (<0.004 mm)	0.003	0.003	0.318	1.265	0.112	0.115	0.017	0.779		+
Metals in mg/kg DW										
Antimony	-0.012	0.013	0.373	-0.055	0.426	0.417	0.068	-2.624		-
Arsenic	-0.011	0.004	0.014	1.173	0.140	0.143	0.022	-2.536		-
Cadmium	0.014	0.005	0.019	-1.229	0.183	0.187	0.028	3.207		+
Copper	-0.005	0.002	0.026	1.675	0.073	0.075	0.011	-1.188		-
Lead	-0.028	0.007	0.001	2.159	0.248	0.254	0.038	-6.139		-
Mercury	-0.007	0.005	0.148	-0.834	0.158	0.162	0.024	-1.603		-
Nickel	-0.012	0.003	0.003	1.653	0.117	0.120	0.018	-2.686		-
Silver	-0.026	0.009	0.007	0.086	0.281	0.251	0.041	-5.720		-
Zinc	-0.012	0.004	0.006	2.101	0.134	0.137	0.021	-2.748		-
LPAH in ug/kg DW										
Naphthalene	-0.006	0.013	0.630	1.314	0.450	0.443	0.069	-1.453		-
Acenaphthylene	-0.046	0.004	0.000	2.048	0.135	0.060	0.023	-10.069		-
Acenaphthene	0.028	0.020	0.176	-0.462	0.751	0.464	0.108	6.573		+
Fluorene	-0.004	0.017	0.813	0.828	0.605	0.439	0.101	-0.907		-

Per Chemical Results:	Slope			Intercept				Slope as %		
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	change/year	Outlier	Slope Direction
Phenanthrene	-0.026	0.012	0.039	2.352	0.408	0.416	0.062	-5.831		-
Anthracene	-0.030	0.016	0.079	1.997	0.576	0.556	0.102	-6.747		-
2-Methylnaphthalene	-0.011	0.013	0.393	1.360	0.441	0.448	0.074	-2.544		-
HPAH in ug/kg DW										
Fluoranthene	-0.035	0.012	0.006	2.815	0.396	0.405	0.059	-7.688		-
Pyrene	-0.033	0.010	0.004	2.784	0.356	0.365	0.052	-7.314		-
Benzo(a)anthracene	-0.024	0.013	0.082	2.101	0.454	0.452	0.072	-5.355		-
Chrysene	-0.026	0.011	0.032	2.347	0.385	0.392	0.059	-5.743		-
Total Benzofluoranthenes	-0.026	0.012	0.041	2.382	0.409	0.417	0.063	-5.785		-
Benzo(a)pyrene	-0.021	0.013	0.115	1.941	0.440	0.431	0.071	-4.671		-
Indeno(1,2,3-cd)pyrene	-0.023	0.011	0.058	1.858	0.394	0.383	0.061	-5.084		-
Dibenz(a,h)anthracene	-0.025	0.016	0.129	1.435	0.581	0.487	0.119	-5.555		-
Benzo(g,h,i)perylene	-0.018	0.013	0.176	1.648	0.440	0.424	0.077	-3.974		-
Chlorinated Aromatics in ug/kg DW										
1,3-Dichlorobenzene	0.013	0.050	0.797	-0.719	1.664	0.505	0.295	3.082		+
1,4-Dichlorobenzene	-0.012	0.030	0.691	0.074	0.986	0.495	0.294	-2.759		-
1,2-Dichlorobenzene	-0.021	0.036	0.559	0.192	1.170	0.584	0.352	-4.768		-
1,2,4-Trichlorobenzene	inadequate data									
Hexachlorobenzene	inadequate data									
Phthalate Esters in ug/kg DW										
Dimethylphthalate	inadequate data									
Diethylphthalate	0.148	0.041	0.001	-5.025	1.655	0.743	0.223	40.66	*	+
Di-n-Butylphthalate	0.020	0.015	0.213	0.118	0.579	0.378	0.080	4.650		+
Butylbenzylphthalate	excluded									
bis(2-Ethylhexyl)phthalate	-0.016	0.015	0.309	2.043	0.521	0.517	0.076	-3.621		-
Di-n-Octylphthalate	inadequate data									
Phenols in ug/kg DW										

Per Chemical Results:	Slope			Intercept				Slope as %		
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	change/year	Outlier	Slope Direction
Phenol	0.043	0.022	0.061	-0.240	0.793	0.647	0.117	10.525		+
2-Methylphenol	inadequate data									
4-Methylphenol	0.019	0.021	0.374	-0.045	0.798	0.602	0.160	4.492		+
2,4-Dimethylphenol	inadequate data									
Pentachlorophenol	inadequate data									
Miscellaneous Extractables in ug/kg DW										
Benzyl Alcohol	excluded									
Benzoic Acid	0.026	0.005	0.000	0.844	0.200	0.072	0.023	6.068		+
Dibenzofuran	-0.014	0.018	0.434	1.012	0.655	0.498	0.120	-3.200		-
Hexachloroethane	inadequate data									
Hexachlorobutadiene	excluded									
N-Nitrosodiphenylamine	inadequate data									
Volatile Organics in ug/kg DW										
Trichloroethene	-0.003	0.095	0.976	-1.331	3.280	1.149	0.720	-0.656		-
Tetrachloroethene	0.004	0.090	0.965	-1.438	3.105	1.089	0.680	0.915		+
Ethylbenzene	0.004	0.069	0.957	-1.034	2.411	0.858	0.538	0.888		+
Total Xylene	excluded									
Pesticides and PCBs in ug/kg DW										
4,4'-DDE	excluded									
4,4'-DDD	inadequate data									
4,4'-DDT	excluded									
Lindane	inadequate data									
Heptachlor	inadequate data									
Aldrin	inadequate data									
Dieldrin	inadequate data									
alpha Chlordane	inadequate data									
Aroclor-1016	inadequate data									

Per Chemical Results:	Slope			Intercept				Slope as %		
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	change/year	Outlier	Slope Direction
Aroclor-1242	inadequate data									
Aroclor-1248	inadequate data									
Aroclor-1254	0.050	0.053	0.359	-2.131	2.278	1.399	0.540	12.28		+
Aroclor-1260	excluded									
Aroclor-1221	inadequate data									
Aroclor-1232	inadequate data									

Notes:
"Not calculated" is shown for percent gravel, because the reporting of 0% gravel caused errors in the calculation of log-scale trends.
"inadequate data" is shown when the minimum data requirements of at least three observations in total, with at least two values above detection, are not met.
"excluded" is shown when the detected values do not span more than one year.
P-Value < 0.05

Table 5-3. Chemical tracking system output for Commencement Bay station CBP03

Per Chemical Results:	Slope			Intercept				Slope as %		Slope
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	change/year	Outlier	Direction
Conventionals										
Total Organic Carbon (% DW)	-0.005	0.003	0.181	0.362	0.116	0.120	0.018	-1.084		-
Total Sulfides (mg/kg DW)	0.040	0.027	0.154	-0.652	0.942	0.925	0.175	9.724		+
Ammonia (mg-N/kg DW)	0.006	0.007	0.371	0.787	0.235	0.215	0.032	1.447		+
TVS (mg/kg DW)	-0.004	0.002	0.057	0.854	0.069	0.071	0.010	-0.933		-
Total Solids (%)	0.002	0.001	0.081	1.575	0.033	0.034	0.005	0.402		+
Percent Gravel (□2.0 mm)	Not calculated									
Percent Sand (<2.0 mm - 0.06 mm)	-0.002	0.006	0.738	1.392	0.195	0.201	0.030	-0.448		-
Percent Silt (0.06 mm - 0.004 mm)	0.004	0.002	0.122	1.575	0.083	0.086	0.013	0.915		+
Percent Fines (<0.06 mm)	0.001	0.002	0.538	1.835	0.070	0.072	0.011	0.296		+
Percent Clay (<0.004 mm)	-0.004	0.003	0.110	1.525	0.090	0.092	0.014	-1.008		+
Metals in mg/kg DW										
Antimony	-0.004	0.012	0.769	-0.341	0.422	0.431	0.069	-0.845		-
Arsenic	-0.013	0.003	0.000	1.233	0.093	0.096	0.014	-2.902		-
Cadmium	0.010	0.004	0.018	-1.029	0.133	0.136	0.021	2.336		+
Copper	-0.009	0.002	0.000	1.827	0.073	0.076	0.011	-2.097		-
Lead	-0.031	0.007	0.000	2.278	0.231	0.238	0.036	-6.844		-
Mercury	-0.008	0.005	0.119	-0.771	0.174	0.180	0.027	-1.908		-
Nickel	-0.010	0.003	0.006	1.599	0.115	0.119	0.018	-2.369		-
Silver	-0.031	0.008	0.001	0.259	0.250	0.215	0.035	-6.872		-
Zinc	-0.012	0.004	0.004	2.109	0.126	0.130	0.020	-2.732		-
LPAH in ug/kg DW										
Naphthalene	0.007	0.013	0.611	0.836	0.468	0.450	0.077	1.601		+
Acenaphthylene	-0.001	0.011	0.933	0.607	0.426	0.307	0.076	-0.224		-
Acenaphthene	0.003	0.014	0.856	0.609	0.517	0.462	0.093	0.611		+
Fluorene	0.010	0.013	0.437	0.354	0.471	0.351	0.081	2.312		+

Per Chemical Results:	Slope			Intercept				Slope as %		Slope
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	change/year	Outlier	Direction
Phenanthrene	-0.015	0.012	0.234	1.900	0.418	0.428	0.064	-3.379		-
Anthracene	-0.010	0.014	0.489	1.281	0.474	0.455	0.086	-2.164		-
2-Methylnaphthalene	-0.012	0.014	0.380	1.425	0.468	0.478	0.082	-2.773		-
HPAH in ug/kg DW										
Fluoranthene	-0.016	0.010	0.129	2.047	0.357	0.366	0.054	-3.708		-
Pyrene	-0.015	0.010	0.155	2.111	0.358	0.369	0.052	-3.486		-
Benzo(a)anthracene	-0.011	0.012	0.340	1.549	0.401	0.392	0.066	-2.552		-
Chrysene	-0.013	0.009	0.157	1.808	0.312	0.319	0.048	-3.024		-
Total Benzofluoranthenes	-0.015	0.012	0.236	1.850	0.422	0.432	0.070	-3.395		-
Benzo(a)pyrene	-0.010	0.012	0.405	1.529	0.408	0.399	0.067	-2.263		-
Indeno(1,2,3-cd)pyrene	-0.019	0.012	0.120	1.658	0.418	0.397	0.074	-4.388		-
Dibenz(a,h)anthracene	-0.012	0.011	0.309	0.958	0.442	0.296	0.096	-2.714		-
Benzo(g,h,i)perylene	-0.019	0.013	0.169	1.616	0.466	0.442	0.091	-4.304		-
Chlorinated Aromatics in ug/kg DW										
1,3-Dichlorobenzene	inadequate data									
1,4-Dichlorobenzene	inadequate data									
1,2-Dichlorobenzene	inadequate data									
1,2,4-Trichlorobenzene	inadequate data									
Hexachlorobenzene	inadequate data									
Phthalate Esters in ug/kg DW										
Dimethylphthalate	inadequate data									
Diethylphthalate	0.109	0.023	0.000	-3.419	0.906	0.404	0.123	28.626	*	+
Di-n-Butylphthalate	-0.002	0.021	0.923	0.670	0.751	0.575	0.145	-0.481		-
Butylbenzylphthalate	-0.036	0.024	0.142	1.537	0.807	0.589	0.176	-7.894		-
bis(2-Ethylhexyl)phthalate	-0.013	0.008	0.120	1.808	0.270	0.266	0.039	-2.928		-
Di-n-Octylphthalate	inadequate data									
Phenols in ug/kg DW										

Per Chemical Results:	Slope			Intercept				Slope as % change/year	Outlier	Slope Direction
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)			
Phenol	-0.010	0.016	0.568	1.785	0.566	0.561	0.091	-2.167		-
2-Methylphenol	inadequate data									
4-Methylphenol	0.010	0.011	0.369	0.437	0.407	0.228	0.057	2.241		+
2,4-Dimethylphenol	inadequate data									
Pentachlorophenol	inadequate data									
Miscellaneous Extractables in ug/kg DW										
Benzyl Alcohol	excluded									
Benzoic Acid	excluded									
Dibenzofuran	-0.008	0.013	0.537	0.802	0.476	0.334	0.086	-1.880		-
Hexachloroethane	inadequate data									
Hexachlorobutadiene	excluded									
N-Nitrosodiphenylamine	inadequate data									
Volatile Organics in ug/kg DW										
Trichloroethene	inadequate data									
Tetrachloroethene	inadequate data									
Ethylbenzene	inadequate data									
Total Xylene	inadequate data									
Pesticides and PCBs in ug/kg DW										
4,4'-DDE	excluded									
4,4'-DDD	inadequate data									
4,4'-DDT	excluded									
Lindane	inadequate data									
Heptachlor	inadequate data									
Aldrin	-0.104	0.100	0.311	1.314	2.760	1.348	0.854	-21.263	*	-
Dieldrin	inadequate data									
alpha Chlordane	inadequate data									
Aroclor-1016	inadequate data									

Per Chemical Results:	Slope		P-Value	Intercept		sigma	SE(sigma)	Slope as % change/year	Outlier	Slope Direction
	beta	SE(beta)		alpha	SE(alpha)					
Aroclor-1242	inadequate data									
Aroclor-1248	excluded									
Aroclor-1254	excluded									
Aroclor-1260	excluded									
Aroclor-1221	inadequate data									
Aroclor-1232	inadequate data									

Notes:
"Not calculated" is shown for percent gravel, because the reporting of 0% gravel caused errors in the calculation of log-scale trends.
"inadequate data" is shown when the minimum data requirements of at least three observations in total, with at least two values above detection, are not met.
"excluded" is shown when the detected values do not span more than one year.
P-Value < 0.05

Table 5-4. Chemical tracking system output for Commencement Bay station CBP07

Per Chemical Results:	Slope			Intercept				Slope as %		Slope
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	change/year	Outlier	Direction
Conventionals										
Total Organic Carbon (% DW)	-0.008	0.003	0.005	0.427	0.083	0.073	0.011	-1.835		-
Total Sulfides (mg/kg DW)	0.043	0.036	0.243	-0.949	1.201	0.978	0.191	10.382		+
Ammonia (mg-N/kg DW)	0.005	0.010	0.648	0.612	0.327	0.246	0.037	1.051		+
TVS (mg/kg DW)	-0.008	0.002	0.001	0.964	0.068	0.060	0.009	-1.848		-
Total Solids (%)	0.004	0.001	0.000	1.536	0.024	0.022	0.003	0.846		+
Percent Gravel (□2.0 mm)	Not calculated									
Percent Sand (<2.0 mm - 0.06 mm)	0.005	0.003	0.105	1.380	0.104	0.091	0.013	1.237		+
Percent Silt (0.06 mm - 0.004 mm)	0.003	0.003	0.230	1.476	0.092	0.081	0.012	0.803		+
Percent Fines (<0.06 mm)	-0.002	0.002	0.391	1.851	0.065	0.057	0.008	-0.399		-
Percent Clay (<0.004 mm)	-0.010	0.002	0.001	1.673	0.079	0.070	0.010	-2.200		-
Metals in mg/kg DW										
Antimony	-0.003	0.015	0.840	-0.424	0.485	0.415	0.071	-0.687		-
Arsenic	-0.019	0.004	0.000	1.396	0.142	0.125	0.019	-4.270		-
Cadmium	0.008	0.006	0.226	-0.935	0.199	0.168	0.027	1.747		+
Copper	-0.014	0.002	0.000	1.933	0.063	0.055	0.008	-3.130		-
Lead	-0.040	0.007	0.000	2.562	0.233	0.204	0.031	-8.706		-
Mercury	-0.016	0.005	0.002	-0.500	0.150	0.132	0.020	-3.589		-
Nickel	-0.016	0.003	0.000	1.801	0.114	0.100	0.015	-3.542		-
Silver	-0.039	0.011	0.003	0.525	0.362	0.286	0.047	-8.545		-
Zinc	-0.019	0.004	0.000	2.333	0.121	0.106	0.016	-4.299		-
LPAH in ug/kg DW										
Naphthalene	0.005	0.013	0.706	0.836	0.425	0.347	0.058	1.115		+
Acenaphthylene	-0.001	0.014	0.931	0.434	0.489	0.297	0.097	-0.280		-
Acenaphthene	0.017	0.014	0.254	-0.160	0.507	0.308	0.084	3.909		+
Fluorene	0.017	0.009	0.079	0.152	0.330	0.201	0.041	3.997		+

Per Chemical Results:	Slope			Intercept						
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	Slope as % change/year	Outlier	Slope Direction
Phenanthrene	-0.017	0.010	0.092	2.020	0.323	0.284	0.042	-3.876		-
Anthracene	-0.014	0.011	0.218	1.425	0.377	0.299	0.050	-3.174		-
2-Methylnaphthalene	-0.014	0.012	0.262	1.507	0.404	0.354	0.055	-3.176		-
HPAH in ug/kg DW										
Fluoranthene	-0.020	0.009	0.042	2.206	0.315	0.277	0.041	-4.592		-
Pyrene	-0.019	0.010	0.059	2.226	0.319	0.282	0.040	-4.314		-
Benzo(a)anthracene	-0.018	0.009	0.051	1.806	0.294	0.255	0.039	-4.094		-
Chrysene	-0.016	0.008	0.055	1.968	0.261	0.230	0.034	-3.604		-
Total Benzofluoranthenes	-0.024	0.011	0.038	2.217	0.365	0.321	0.050	-5.424		-
Benzo(a)pyrene	-0.018	0.010	0.092	1.784	0.349	0.293	0.047	-4.111		-
Indeno(1,2,3-cd)pyrene	-0.023	0.010	0.029	1.796	0.332	0.275	0.048	-5.120		-
Dibenz(a,h)anthracene	-0.019	0.013	0.178	1.137	0.474	0.299	0.086	-4.174		-
Benzo(g,h,i)perylene	-0.019	0.011	0.109	1.670	0.387	0.321	0.057	-4.308		-
Chlorinated Aromatics in ug/kg DW										
1,3-Dichlorobenzene	inadequate data									
1,4-Dichlorobenzene	inadequate data									
1,2-Dichlorobenzene	inadequate data									
1,2,4-Trichlorobenzene	inadequate data									
Hexachlorobenzene	-0.057	0.023	0.021	1.534	0.808	0.268	0.094	-12.241		-
Phthalate Esters in ug/kg DW										
Dimethylphthalate	inadequate data									
Diethylphthalate	0.081	0.044	0.077	-2.437	1.644	0.571	0.170	20.548	*	+
Di-n-Butylphthalate	0.074	0.031	0.027	-1.843	1.151	0.413	0.093	18.523	*	+
Butylbenzylphthalate	-0.017	0.021	0.428	0.887	0.748	0.296	0.106	-3.837		-
bis(2-Ethylhexyl)phthalate	-0.038	0.010	0.001	2.508	0.324	0.243	0.038	-8.328		-
Di-n-Octylphthalate	inadequate data									
Phenols in ug/kg DW										

Per Chemical Results:	Slope		P-Value	Intercept		sigma	SE(sigma)	Slope as % change/year	Outlier	Slope Direction
	beta	SE(beta)		alpha	SE(alpha)					
Phenol	-0.005	0.021	0.824	1.587	0.698	0.585	0.098	-1.075		-
2-Methylphenol	inadequate data									
4-Methylphenol	0.026	0.028	0.378	-0.233	1.048	0.496	0.134	6.073		+
2,4-Dimethylphenol	inadequate data									
Pentachlorophenol	inadequate data									
Miscellaneous Extractables in ug/kg DW										
Benzyl Alcohol	excluded									
Benzoic Acid	inadequate data									
Dibenzofuran	0.010	0.009	0.267	0.230	0.327	0.199	0.045	2.436		+
Hexachloroethane	inadequate data									
Hexachlorobutadiene	0.004	0.026	0.874	0.275	0.928	0.321	0.108	0.958		+
N-Nitrosodiphenylamine	inadequate data									
Volatile Organics in ug/kg DW										
Trichloroethene	inadequate data									
Tetrachloroethene	inadequate data									
Ethylbenzene	inadequate data									
Total Xylene	inadequate data									
Pesticides and PCBs in ug/kg DW										
4,4'-DDE	-0.033	0.023	0.170	0.721	0.810	0.432	0.122	-7.403		-
4,4'-DDD	-0.064	0.024	0.016	1.576	0.830	0.465	0.150	-13.778		-
4,4'-DDT	-0.035	0.014	0.021	0.900	0.497	0.203	0.060	-7.760		-
Lindane	inadequate data									
Heptachlor	inadequate data									
Aldrin	inadequate data									
Dieldrin	inadequate data									
alpha Chlordane	inadequate data									
Aroclor-1016	inadequate data									

Per Chemical Results:	Slope		P-Value	Intercept		sigma	SE(sigma)	Slope as % change/year	Outlier	Slope Direction
	beta	SE(beta)		alpha	SE(alpha)					
Aroclor-1242	inadequate data									
Aroclor-1248	inadequate data									
Aroclor-1254	inadequate data									
Aroclor-1260	inadequate data									
Aroclor-1221	inadequate data									
Aroclor-1232	inadequate data									

Notes:
"Not calculated" is shown for percent gravel, because the reporting of 0% gravel caused errors in the calculation of log-scale trends.
"inadequate data" is shown when the minimum data requirements of at least three observations in total, with at least two values above detection, are not met.
"excluded" is shown when the detected values do not span more than one year.
P-Value < 0.05

Table 5-5. Chemical tracking system output for Commencement Bay station CBP11

Per Chemical Results:	Slope			Intercept				Slope as %		Slope
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	change/year	Outlier	Direction
Conventionals										
Total Organic Carbon (% DW)	-0.008	0.002	0.001	0.381	0.070	0.072	0.011	-1.882		-
Total Sulfides (mg/kg DW)	0.036	0.024	0.137	-0.578	0.818	0.788	0.150	8.746		+
Ammonia (mg-N/kg DW)	0.002	0.006	0.677	0.754	0.201	0.184	0.028	0.569		+
TVS (mg/kg DW)	-0.004	0.002	0.032	0.773	0.058	0.060	0.009	-0.906		-
Total Solids (%)	0.003	0.001	0.006	1.573	0.035	0.036	0.005	0.709		+
Percent Gravel (□2.0 mm)	Not calculated									
Percent Sand (<2.0 mm - 0.06 mm)	-0.004	0.004	0.400	1.542	0.153	0.157	0.023	-0.883		-
Percent Silt (0.06 mm - 0.004 mm)	0.003	0.002	0.182	1.575	0.077	0.080	0.012	0.728		+
Percent Fines (<0.06 mm)	0.001	0.002	0.590	1.828	0.051	0.053	0.008	0.190		+
Percent Clay (<0.004 mm)	-0.003	0.002	0.118	1.468	0.064	0.066	0.010	-0.706		-
Metals in mg/kg DW										
Antimony	0.005	0.014	0.716	-0.722	0.471	0.470	0.080	1.172		+
Arsenic	-0.014	0.004	0.001	1.242	0.126	0.129	0.020	-3.270		-
Cadmium	0.009	0.006	0.113	-1.078	0.195	0.197	0.030	2.209		+
Copper	-0.011	0.002	0.000	1.871	0.057	0.059	0.009	-2.542		-
Lead	-0.035	0.007	0.000	2.358	0.241	0.248	0.037	-7.649		-
Mercury	-0.010	0.005	0.058	-0.764	0.175	0.180	0.027	-2.366		-
Nickel	-0.013	0.003	0.000	1.674	0.101	0.104	0.016	-3.030		-
Silver	-0.029	0.009	0.004	0.097	0.287	0.255	0.044	-6.352		-
Zinc	-0.016	0.003	0.000	2.219	0.114	0.118	0.018	-3.633		-
LPAH in ug/kg DW										
Naphthalene	0.005	0.011	0.660	0.757	0.389	0.353	0.060	1.128		+
Acenaphthylene	-0.032	0.004	0.000	1.525	0.126	0.057	0.025	-7.146		-
Acenaphthene	-0.002	0.017	0.903	0.570	0.613	0.456	0.107	-0.469		-
Fluorene	0.006	0.013	0.631	0.425	0.493	0.360	0.086	1.467		+

Per Chemical Results:	Slope			Intercept				Slope as % change/year	Outlier	Slope Direction
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)			
Phenanthrene	-0.015	0.011	0.194	1.785	0.375	0.384	0.058	-3.316		-
Anthracene	-0.017	0.014	0.233	1.357	0.496	0.471	0.097	-3.897		-
2-Methylnaphthalene	0.001	0.014	0.955	0.873	0.489	0.472	0.089	0.183		+
HPAH in ug/kg DW										
Fluoranthene	-0.018	0.011	0.100	2.001	0.361	0.370	0.058	-4.075		-
Pyrene	-0.015	0.011	0.184	1.887	0.376	0.379	0.060	-3.395		-
Benzo(a)anthracene	-0.019	0.011	0.097	1.740	0.377	0.368	0.062	-4.216		-
Chrysene	-0.015	0.010	0.145	1.802	0.341	0.341	0.055	-3.369		-
Total Benzofluoranthenes	-0.014	0.013	0.286	1.751	0.454	0.447	0.077	-3.239		-
Benzo(a)pyrene	-0.019	0.011	0.093	1.730	0.372	0.363	0.061	-4.222		-
Indeno(1,2,3-cd)pyrene	-0.018	0.009	0.070	1.536	0.324	0.311	0.053	-3.969		-
Dibenz(a,h)anthracene	-0.024	0.010	0.027	1.215	0.339	0.182	0.062	-5.480		-
Benzo(g,h,i)perylene	-0.011	0.010	0.293	1.317	0.368	0.352	0.062	-2.568		-
Chlorinated Aromatics in ug/kg DW										
1,3-Dichlorobenzene	inadequate data									
1,4-Dichlorobenzene	inadequate data									
1,2-Dichlorobenzene	inadequate data									
1,2,4-Trichlorobenzene	inadequate data									
Hexachlorobenzene	excluded									
Phthalate Esters in ug/kg DW										
Dimethylphthalate	inadequate data									
Diethylphthalate	0.077	0.011	0.000	-2.242	0.450	0.202	0.048	19.316	*	+
Di-n-Butylphthalate	0.053	0.021	0.019	-1.221	0.830	0.401	0.093	13.041		+
Butylbenzylphthalate	-0.019	0.017	0.276	1.007	0.625	0.326	0.102	-4.301		-
bis(2-Ethylhexyl)phthalate	-0.035	0.010	0.002	2.395	0.326	0.239	0.039	-7.837		-
Di-n-Octylphthalate	inadequate data									
Phenols in ug/kg DW										

Per Chemical Results:	Slope			Intercept				Slope as % change/year	Outlier	Slope Direction
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)			
Phenol	0.021	0.011	0.064	0.651	0.367	0.347	0.057	4.846		+
2-Methylphenol	inadequate data									
4-Methylphenol	0.025	0.012	0.046	-0.227	0.463	0.215	0.054	5.856		+
2,4-Dimethylphenol	inadequate data									
Pentachlorophenol	inadequate data									
Miscellaneous Extractables in ug/kg DW										
Benzyl Alcohol	excluded									
Benzoic Acid	excluded									
Dibenzofuran	-0.020	0.015	0.192	1.197	0.534	0.379	0.102	-4.455		-
Hexachloroethane	inadequate data									
Hexachlorobutadiene	0.012	0.014	0.401	-0.363	0.566	0.241	0.077	2.871		+
N-Nitrosodiphenylamine	inadequate data									
Volatile Organics in ug/kg DW										
Trichloroethene	inadequate data									
Tetrachloroethene	inadequate data									
Ethylbenzene	inadequate data									
Total Xylene	inadequate data									
Pesticides and PCBs in ug/kg DW										
4,4'-DDE	-0.055	0.013	0.001	1.492	0.443	0.206	0.063	-11.835		-
4,4'-DDD	-0.063	0.032	0.061	1.176	1.140	0.521	0.278	-13.540		-
4,4'-DDT	-0.040	0.012	0.003	1.097	0.412	0.180	0.046	-8.764		-
Lindane	inadequate data									
Heptachlor	inadequate data									
Aldrin	inadequate data									
Dieldrin	inadequate data									
alpha Chlordane	inadequate data									
Aroclor-1016	inadequate data									

Per Chemical Results:	Slope		P-Value	Intercept		sigma	SE(sigma)	Slope as % change/year	Outlier	Slope Direction
	beta	SE(beta)		alpha	SE(alpha)					
Aroclor-1242	inadequate data									
Aroclor-1248	inadequate data									
Aroclor-1254	excluded									
Aroclor-1260	excluded									
Aroclor-1221	inadequate data									
Aroclor-1232	inadequate data									

Notes:
"Not calculated" is shown for percent gravel, because the reporting of 0% gravel caused errors in the calculation of log-scale trends.
"inadequate data" is shown when the minimum data requirements of at least three observations in total, with at least two values above detection, are not met.
"excluded" is shown when the detected values do not span more than one year.
P-Value < 0.05

PAHs

The LPAH and HPAH groups did not show statistically significant trends at any of the perimeter stations. Six individual PAH compounds showed statistically significant decreases at Station CBP01 due to the elevated concentrations reported for this station in 1988 and again in 1995. Three individual PAHs had statistically significant decreasing trends at CBP07 and two at CBP11. None of the PAHs showed statistically significant trends at CBP03. PAH concentrations are currently reported at similar levels across all perimeter stations.

Chlorinated Aromatics

At least four individual compounds must have a calculable trend to be able to report the significance of the group mean trend. Detected results were insufficient to statistically interpret the chlorinated aromatic group trend at any of the perimeter stations. Of the individual chlorinated aromatic compounds that had sufficient detected data to allow the calculation of trends by station, hexachlorobenzene was the only one with a statistically significant trend at any of the stations (decreasing trend at CBP07).

Phthalates

The significance of the phthalate group mean trend was reportable for every station except CBP01; each group mean was non-significant ($p > 0.05$) with regard to trend. For individual chemicals, three of the four perimeter stations had a statistically significant positive slope reported for diethylphthalate, but all were flagged as outliers by the CTS software. These slopes were extreme due to the relatively high concentrations for this compound reported in 2017[7]. The concentration of diethylphthalate over time at the three perimeter stations is shown in Figures 5-1 and 5-2. All average diethylphthalate concentrations were below the SQS in 2017. As discussed in Section 4.2.4, the original diethylphthalate concentration from CBP01-A (134 mg/kg OC) exceeded the CSL of 110 mg/kg OC. However, the average concentration of diethylphthalate for station CBP01 (average of replicates A, B, and C) was 28.8 mg/kg OC, which did not exceed the SQS of 61 mg/kg OC.

Di-n-butylphthalate had significant positive slopes reported for stations CBP07 and CBP11. The slope for CBP07 was also flagged as an outlier. However, in both cases the di-n-butylphthalate concentrations were well below the SQS (Figure 5-2). Detected concentrations for this compound in 2017 averaged 14 µg/kg, two orders of magnitude below the DMMP SL of 1400 µg/kg DW.

Phenols

The significance of the phenol group mean trend was not reportable for any of the four Commencement Bay perimeter stations. 4-Methylphenol showed a statistically significant positive trend at station CBP11 ($p < 0.05$). However, the concentration of 4-methylphenol was well below the SQS (Figure 5-2).

Miscellaneous Extractables

The significance of the miscellaneous extractables group mean trend was not reportable for any of the four Commencement Bay perimeter stations. Individually, benzoic acid had a calculable slope at station CBP01 only, where the small positive trend was statistically significant ($p < 0.05$). The concentration of benzoic acid was well below the SQS (Figure 5-1).

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[7] Sample CBP01-A had an elevated diethylphthalate concentration and was reanalyzed for this sample only (see Section 4.2.4). Using the elevated original result or the non-detected reanalysis result, the trend for diethylphthalate was significantly positive in both cases.

Volatiles

Volatile organic compounds were not analyzed in 2017. Therefore, the trend results reported are the same as reported in 2007 but using the updated correlation-covariance matrix. The significance of the volatiles group mean trend was not reportable for any of the four perimeter stations. The trend of individual volatile compounds was only reportable at CBP01. None of the trends for the three volatile compounds reportable at CBP01 was statistically significant.

Pesticides and PCBs

The significance of the pesticides and PCBs group mean trend was not reportable for any of the four Commencement Bay perimeter stations. Individually, 4-4'-DDD had a statistically negative trend at CBP07; 4-4'-DDE had a statistically significant negative trend at CBP11; and 4-4'-DDT had statistically significant negative trends at both CBP07 and CBP11. There were no statistically significant trends for individual Aroclors, even when the original elevated concentration of Aroclor 1254 for sample CBP01-B was used in the calculations.

Dioxin/Furan Congeners

The dioxin/furan group was not included in the CTS analysis spreadsheet when it was created in 1996. Since this group of compounds was only analyzed in one replicate during each of the 2007 and 2017 surveys, CTS trend analysis could not be conducted.

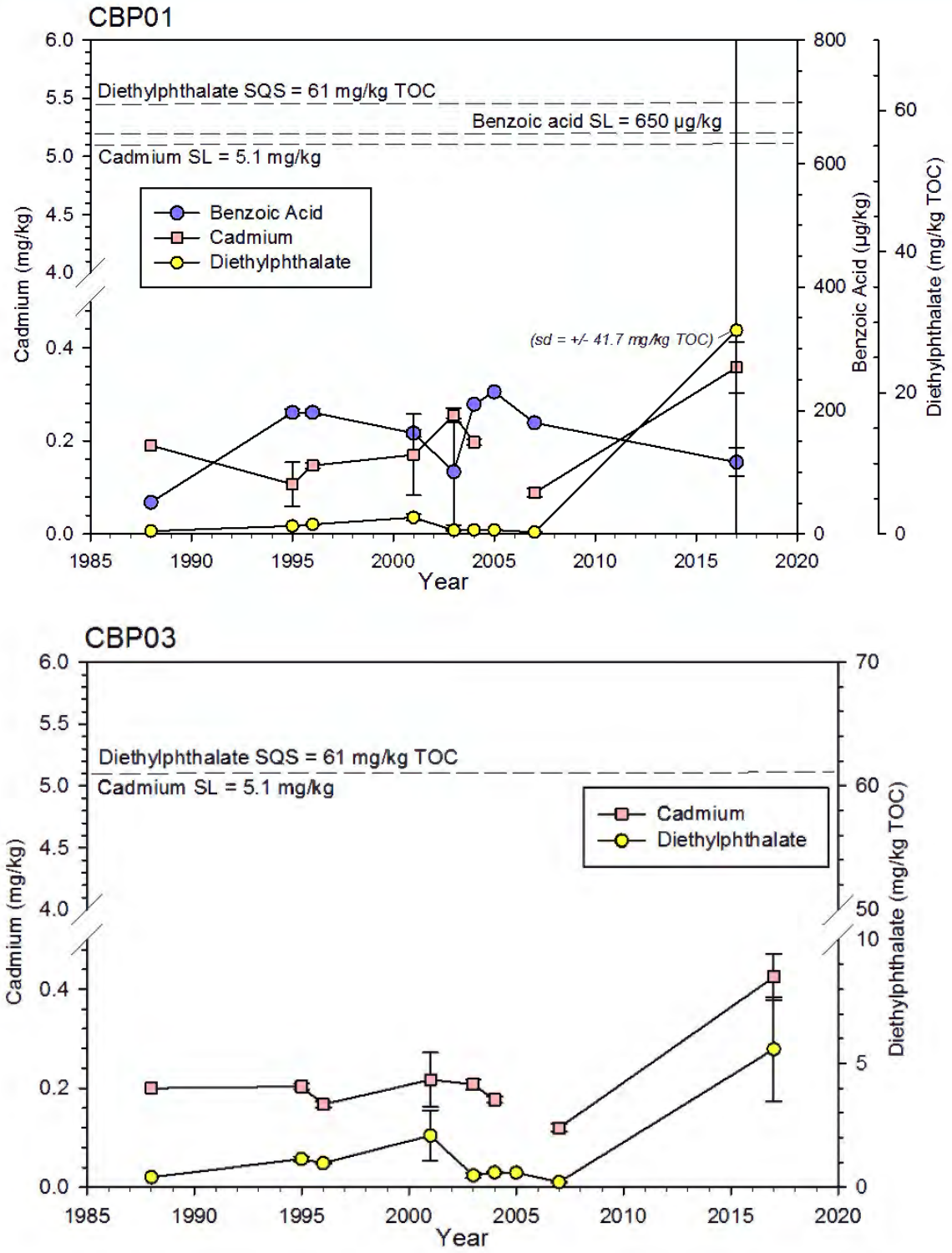

Figure 5-1. Average concentrations of chemicals showing statistically significant increases over time – CBP01 and CBP03. Cadmium was not analyzed for in 2005.

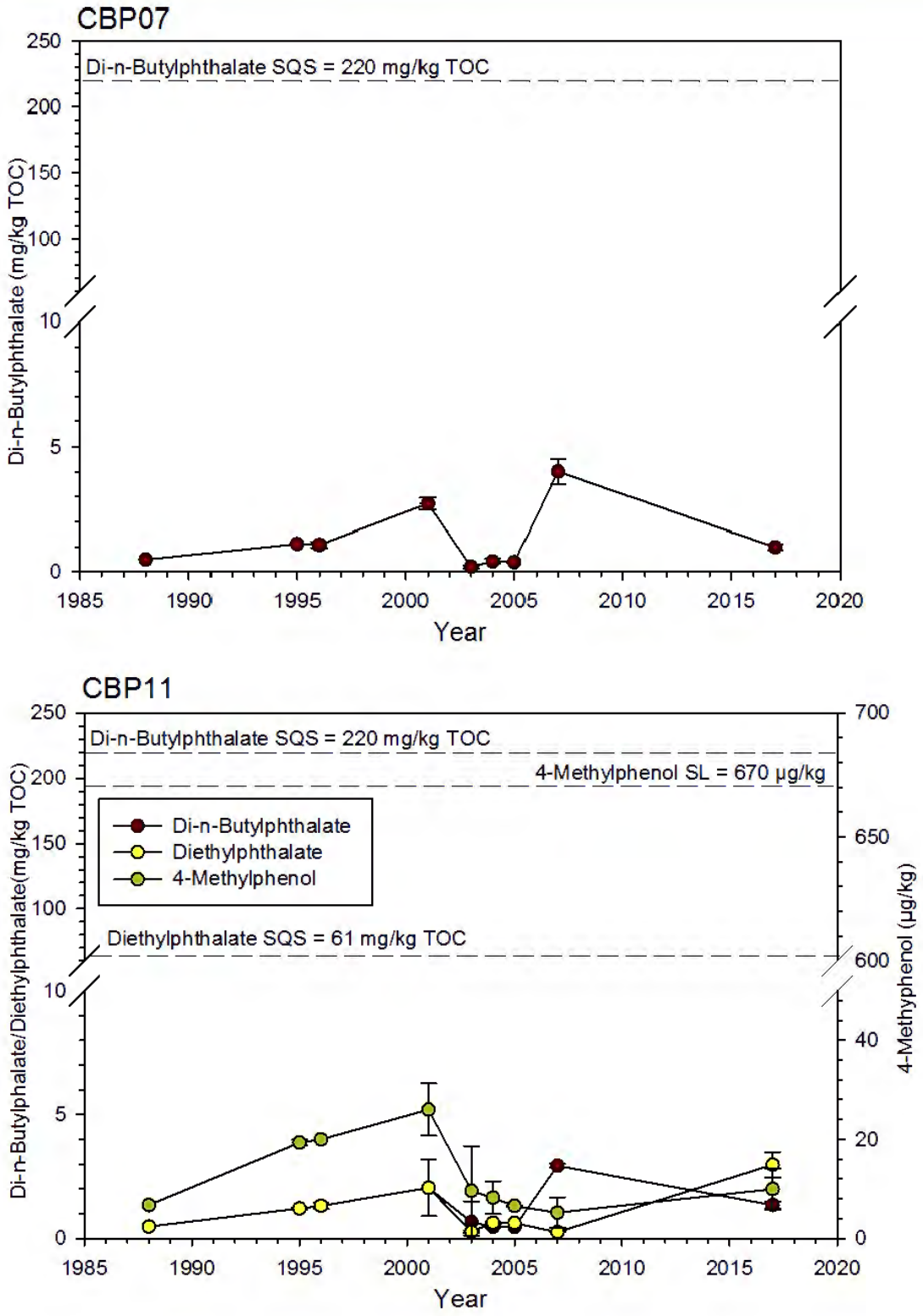

Figure 5-2. Average concentrations of chemicals showing statistically significant increases over time – CBP07 and CBP11

Summary of CTS Findings

The UEMP describes the use of SQS and CTS in addressing hypothesis 2 of the DMMP monitoring framework. CTS provides an "early warning" of temporal trends of increasing offsite concentrations before SQS values are exceeded. However, it is implied that comparisons to SQS provide the ultimate gauge of sediment quality at perimeter stations.

A comparison of the 2017 perimeter station chemistry to the Washington State SQS criteria found that all detected chemicals were below the SQS with the exception of Total PCBs in the original sample from CBP01-B and diethylphthalate in the original sample from CBP01-A, both of which were determined to be outliers[8]. As discussed in Section 4.2.4, reanalysis of these samples did not confirm the original results. Four subsequent reanalyses of the CBP01-B sample could not replicate the elevated concentration of Total PCBs, and reanalysis of the CBP01-A sample could not replicate the elevated concentration of diethylphthalate. The CTS time-trends analysis detected statistically significant increases in cadmium for CBP01 and CBP03, di-n-butylphthalate for CBP11, 4-methylphenol for CBP11, and benzoic acid for CBP01. However, all concentrations of these chemicals of concern were below the SQS. Every perimeter station had a positive slope reported for diethylphthalate, but they were flagged as outliers, as was the positive slope for di-n-butylphthalate for CBP07. The average concentrations for these chemicals were also below the SQS (see Figures 5-1 and 5-2).

Only two rounds of dioxin analyses have been completed at Commencement Bay. Thus, statistical time-trends analysis will not be possible until collection of additional data.

Hypothesis No. 2 Question 1 asks if chemical concentrations do not measurably increase over time at offsite stations due to dredged material disposal. The interpretive guidelines ask if chemicals are above SMS, and are there trends of increasing chemistry over time. With the exceptions noted above, the concentrations of chemicals of concern were below SQS at perimeter stations. This included those chemicals that exhibited statistically significant increases at the perimeter stations over time. Therefore, ***Hypothesis No. 2 is accepted*** (there are some increasing trends over time but all concentrations are below the SMS). Because chemicals were all below SMS, no additional actions were taken. However, future monitoring should pay close attention to the chemicals that exhibited statistically significant increasing trends.

[8] See Section 4.2.4 for a detailed description of the analytical results for these two samples.

5.2 Question 2: Has dredged material disposal caused the biological effects condition 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.

PSDDA Site Condition II is evaluated by comparing onsite chemical concentrations to the DMMP MLs. DMMP MLs are chemical concentrations above which adverse biological effects are expected to occur. Onsite chemistry results did not exceed the DMMP ML values. Therefore, ***Hypothesis No. 3 is accepted.***

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.

Bioassays were evaluated according to the DMMP evaluation guidelines for non-dispersive disposal sites (PSDDA 1989b, DMMP 2016). The three onsite stations passed the DMMP bioassay interpretive criteria for all toxicity tests. Therefore, ***Hypothesis No. 4 is accepted.***

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6.0 CONCLUSIONS

The conclusions to the 2017 tiered-full monitoring program at Commencement Bay are presented below. Table 6-1 summarizes the data within the context of the DMMP monitoring framework.

6.1 Does the Dredged Material Remain On Site?

Physical and chemical monitoring results from the 2017 Commencement Bay survey were used to test the two hypotheses established to answer this monitoring question. The 2017 SPI survey found only trace amounts of dredged material at the site perimeter, less than the 3-cm interpretive guideline established for this purpose. All perimeter chemistry concentrations were below the Washington State SQS criteria with the exception of Total PCBs at CBP01-B and diethylphthalate at CBP01-A. Reanalysis of these samples did not confirm the original results. Four subsequent reanalyses of the CBP01-B sample could not replicate the elevated concentration of Total PCBs, and reanalysis of the CBP01-A sample could not replicate the elevated concentration of diethylphthalate. The other replicate sample results for CBP01 also showed very low concentrations of Total PCBs and diethylphthalate. PCBs and diethylphthalate were either undetected or found in low concentrations at on-site stations, providing evidence that the source of the elevated offsite results was not recent dredged material. Further evidence was found in the analytical results for dredged material from the Port of Tacoma Pier 4 Reconfiguration project, which did not include elevated concentrations of these chemicals. Further, the SPI survey found no evidence of recent dredged material deposits at CBP01. The DMMP agencies concluded that the most plausible explanation for the elevated concentrations of PCBs and diethylphthalate in single replicates from CBP01 was the presence of a small PCB-containing paint chip and a small piece of plastic respectively, possibly associated with a former dredged material disposal site south of the current site. The elevated concentration of diethylphthalate could also have been from laboratory contamination. Future monitoring should pay close attention to PCB and phthalate concentrations at the perimeter stations.

The CTS time-trends analysis detected decreasing trends for most chemicals in Commencement Bay perimeter stations. Statistically significant increases were observed for cadmium for CBP01 and CBP03, di-n-butylphthalate for CBP11, 4-methylphenol for CBP11, and benzoic acid for CBP01. However, concentrations were lower than the SQS by an order of magnitude or more. In addition, all perimeter stations had statistically significant increases for diethylphthalate, but they were flagged as outliers by the CTS analysis, as was the statistically significant increase of di-n-butylphthalate for CBP07. However, the average concentrations for these chemicals were also lower than the SQS.

Dioxin/furan congener TEQs were higher at three of the four perimeter stations in 2017, compared to 2007, but the average offsite concentration was still less than the background-based DSMO. The concentrations of these chemicals were generally lower in onsite sediments than in the perimeter sediments, on average (see Tables 4-2, 4-4, and 4-7), suggesting that any increases seen at perimeter stations were likely attributable to sources other than the recently deposited dredged material. There is no SQS for dioxin/furan congeners. If the DMMP DSMO (4 ng/kg TEQ) is used for comparison, three of the four perimeter stations and the average dioxin/furan concentration at all of the perimeter stations (3.52 ng/kg TEQ; ND = 1/2 DL) all fall below this natural background-based guideline. Only CBP07-A marginally exceeded the DSMO, with a concentration that was slightly less than that found in 2007.

The DMMP agencies concluded that the increases shown at some perimeter stations for cadmium, di-n-butylphthalate, 4-methylphenol, benzoic acid and dioxin/furan congeners were not related to recent dredged material disposal. However, future monitoring should pay close attention to these chemicals.

6.2 Is Site Condition II Exceeded?

Chemistry results from three onsite stations were compared to the DMMP MLs. No onsite ML values were exceeded. Bioassay testing of the same onsite stations passed the DMMP bioassay interpretive criteria. Therefore, PSDDA Site Condition II chemical criteria were not exceeded.

6.3 Are unacceptable adverse effects due to dredged material disposal occurring to biological resources off site?

Based on the data collected to answer the first two questions in the DMMP monitoring framework, the DMMP agencies concluded that analysis of archived benthic infaunal and tissue samples was not warranted for this monitoring event, nor was analysis of samples from benchmark stations.

Table 6-1. Results of the 2017 Commencement Bay DMMP monitoring framework

Question	Hypothesis	Monitored Variable	Interpretive Guideline	Action Taken
No. 1 Does the deposited dredged material stay on site?	1. Dredged material remains within the site boundary.	Sediment Vertical Profiling System (SVPS) Onsite and Offsite	Dredged material layer is greater than 3 cm at the perimeter stations? **NO**	
	2. Chemical concentrations do not measurably increase over time at offsite stations due to dredged material disposal.	Sediment Chemistry Offsite	SQS exceeded? **YES (Total PCBs and diethylphthalate in single replicates at CBP01)** Temporal increases? **YES**	CBP01-A reanalyzed once for diethylphthalate and CBP01-B reanalyzed four times for Aroclors. Reanalysis results all below SQS. Onsite and Pier 4 chemistry compared to SQS and DMSO. Comparisons made to SQS for compounds with temporal increase. All results were below guideline values. Therefore, it was concluded that dredged material disposal was not the cause of temporal increases in COCs at offsite stations.
No. 2 Are the biological effects conditions for site management [PSDDA-defined Site Condition II] exceeded at the site due to dredged material disposal? (PSDDA 1988b)	3. Sediment chemical concentrations at the onsite monitoring stations do not exceed the chemical concentrations associated with PSDDA Site Condition II guidelines due to dredged material disposal.	Sediment Chemistry Onsite	Onsite chemical concentrations exceed DMMP maximum levels? **NO**	
	4. Sediment toxicity at the onsite stations does not exceed the PSDDA Site Condition II biological response guidelines due to dredged material disposal.	Sediment Bioassays Onsite	DMMP bioassays exceed guidelines? **NO**	

Question	Hypothesis	Monitored Variable	Interpretive Guideline	Action Taken
No. 3 Are unacceptable adverse effects due to dredged material disposal occurring to biological resources off site?	5. No significant increase due to dredged material disposal has occurred in the chemical body burden of benthic infauna species collected down current of the disposal site.	Tissue Chemistry Transect	Guideline tissue chemistry values exceeded? **Not addressed**	
	6. No significant decrease due to dredged material disposal has occurred in the abundance of dominant benthic infaunal species collected down current of the disposal site.	Infaunal Community Structure Transect	Abundance of major taxa < ½ baseline macrobenthic infauna abundances? **Not addressed**	

7.0 RECOMMENDATIONS

7.1 CTS Computational Platform

The current version of the CTS program in Microsoft Excel is only expected to accommodate one more monitoring event (assuming three replicates per year) for the Commencement Bay site. TerraStat has recommended a transfer of the CTS calculations and generation of summary outputs to R (R Development Core Team 2017; https://www.r-project.org/), a freeware statistical program with broad community support. A migration to R would also allow the flexibility to add new chemicals to the time-trends analysis (e.g., dioxin/furan congeners).

R has the flexibility to accommodate very large datasets that can be imported from Microsoft Excel or Microsoft Access. Utilizing R would also increase the automation of conducting the preliminary correlation analysis. The analyst would have the opportunity to modify any of the decision points during the analysis (e.g., at least 75% of individual correlations within a group must be positive) and to review intermediate and summary correlation tables. R is a programming language that may not be as well known to practitioners who are familiar with Excel. However, with adequate comments and documentation, the analysis in R would run similarly to how it currently runs in Excel. Because the language is not proprietary, any statistically knowledgeable person could maintain the code, as needed.

7.2 Concurrent Analysis of Benchmark Stations

The 2017 Commencement Bay monitoring survey measured initial perimeter station concentrations of diethylphthalate and Total PCBs that exceeded the Washington State SQS criteria. As summarized in Section 6.1, the DMMP agencies concluded that the elevated concentrations were not attributable to recent dredged material based on sample reanalysis, consideration of onsite chemistry results, evaluation of analytical results for dredged material from the Port of Tacoma Pier 4 Reconfiguration project, and evaluation of the recent dredged material footprint using SPI.

To better understand area trends in environmental contaminants that may not be related to dredged material disposal, it is recommended that the DMMP agencies consider the analysis of benchmark sediment samples concurrently with the onsite and perimeter sediment samples during site monitoring studies. For example, future Commencement Bay monitoring studies should, at a minimum, consider benchmark station analysis of diethylphthalate, PCB Aroclors, and dioxin/furan congeners as part of the initial round of chemical analyses.

7.3 Onsite Tissue Collection for Bioaccumulation Studies

Under the DMMP monitoring framework, target organisms are collected at transect and benchmark stations to address Question No. 3: “Are unacceptable adverse effects due to dredged material disposal occurring to biological resources off site?” In Commencement Bay, the *Molpadia intermedia* sea cucumber is the target organism for tissue collection. Transect tissue samples (and potentially benchmark tissue samples) are chemically analyzed during a full monitoring program to assess whether chemical body burdens have been affected by dredged material disposal.

One question that has been asked is whether chemical body burdens could be determined for organisms that are present within the disposal site boundary. In general, it is expected that *Molpadia* densities within the disposal site would be lower compared to offsite areas, due to disturbance from dredged material disposal. However, during the 2017 Commencement Bay monitoring survey, it was noted that *Molpadia* were present at some of the onsite stations, although absent in areas near the site center where recent and thick

accumulations of dredged material were present (see Appendix C). In particular, some of the random onsite stations sampled for dioxin/furan congeners and TBT analysis showed the presence of *Molpadia*. For future monitoring surveys where random sampling is required, it is recommended that *Molpadia* specimens that are incidentally collected in the grab samples be retained. If enough organisms are present, one or more tissue sample composites could be collected to allow assessment of chemical body burdens in onsite areas.

7.4 Tissue Dissections

As discussed in the cruise report (Appendix C), *Molpadia* sea cucumbers collected for tissue samples during the 2017 monitoring survey were dissected aboard the R/V *Kittiwake* as the organisms were collected. This allowed confirmation of dissected sample weights needed for proposed analyses and minimized the collection of extra, unneeded sea cucumbers. This approach is helpful because the abundance of sea cucumbers can vary from location to location, and from year to year. The number of collected sea cucumbers is further reduced when specimens are caught in the jars of the grab sampler and are ruptured. Specimens ruptured in the field are not normally retained for tissue chemistry samples.

However, the 2017 monitoring survey evaluated whether ruptured specimens could be dissected and retained for tissue samples, since the dissections were conducted in the field shortly after collection. It was determined that fully ruptured specimens tended to retain sediments in the folds of the external tissue and the sediment could not be effectively removed through scraping or rinsing. Therefore, the ruptured specimens were discarded and it is recommended that they not be retained in future surveys.

Tissue dissections in the laboratory will continue to be acceptable, but tissue dissection in the field should be maintained as an option for future monitoring surveys. Under either approach, fully ruptured specimens should be discarded.

8.0 REFERENCES

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