Duwamish/Diagonal Sediment Remediation Project
Final 2010 Monitoring Report

Elliott Bay/Duwamish Restoration Program Panel

Prepared for:

Wastewater Treatment Division,
King County Department of Natural Resources and Parks
Elliott Bay/Duwamish Restoration Program

Prepared by:

Water and Land Resources Division,
King County Department of Natural Resources and Parks

Panel Publication 43

Elliott Bay/Duwamish Restoration Program
NOAA Damage Assessment and Restoration Center Northwest
7600 Sand Point Way Northeast
Seattle, Washington 98115-0070

206-526-6029
FAX: 206-526-6665

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Individuals and organizations needing further information about the Elliot Bay/ Duwamish Restoration Program should contact the Administrative Director at the following address and telephone number:

John Kern, Administrative Director
Elliot Bay/Duwamish Restoration Program
NOAA Damage Assessment and Restoration Center Northwest
7600 Sand Point Way NE
Seattle, WA 98115-0070
206-526-6029 FAX: 206-526-6665

The Panel of Managers holds regularly scheduled meetings that are open to the public. Technical Working Group and committee meetings are scheduled on an as-needed basis, and are also open to the public. Meetings are generally held at the National Oceanic and Atmospheric Administration, National Marine Fisheries Service – Regional Directorate Conference Room, Building 1, 7600 Sand Point Way NE, Seattle. The Panel recommends that you contact the Administrative Director at the above phone number to confirm meeting schedules and locations. The panel also holds periodic special evening and weekend public information meetings and workshops.

General Schedule for Panel and Committee Meeting Dates

- Panel: quarterly, first Thursday of January, April, July, October, 9:30 A.M. – 12:30 P.M.
- Habitat Development Technical Working Group: third Thursday of every month, 9:30 A.M. – 12:30 P.M.
- Sediment Remediation Technical Working Group: scheduled as needed.
- Public Participation Committee: scheduled as needed.
- Budget Committee: scheduled as needed.

Environmental Review of Specific Products

Formal hearings and comment periods on appropriate environmental documents for proposed sediment remediation and habitat development projects will be observed. Please contact the Administrative Director for more information.

This information is available in accessible formats on request at 206-477-4800 (voice) and 711 (TTY relay).

Acknowledgements

Jeffrey Stern has been the King County Duwamish/Diagonal Sediment Remediation Project Manager and provided technical feedback and review. Jenée Colton has led the Duwamish/Diagonal long-term monitoring program and report writing since 2007. Debra Williston, Deborah Lester and the Elliott Bay/Duwamish Restoration Program Panel provided technical review. The King County Environmental Laboratory provided the field and chemistry analytical services for all monitoring samples.

Citation

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Acronyms

AETs	apparent effect thresholds
BBP	benzyl butyl phthalate
BCM	Bed Composition Model
BEHP	bis(2-ethylhexyl)phthalate
BMP	best management practice
CSL	cleanup screening levels
COC	chain of custody
CSO	combined sewer overflow
DGPS	differential global positioning system
DNBP	di-N-butyl phthalate
dw	dry weight
EBDRP	Elliott Bay/Duwamish Restoration Program
Ecology	Washington State Department of Ecology
ENR	enhanced natural recovery
EPA	United States Environmental Protection Agency
GC/ECD	gas chromatography with electron capture detection
KCEL	King County Environmental Laboratory
LIMS	Laboratory Information Management System
MDL	method detection limit
MLLW	Mean Lower Low Water

MNR	monitored natural recovery
OC	organic carbon
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PSEP	Puget Sound Estuary Program
QA/QC	quality assurance and quality control
RDL	reporting detection limit
SAP	sampling and analysis plan
SD	storm drain
SMS	Sediment Management Standards
SPI	sediment profile imaging
SQS	Sediment Quality Standards
STM	Sediment Transport Model
TOC	total organic carbon

Executive Summary

The Duwamish Diagonal site is one of the Early Action Cleanup sites on the Lower Duwamish Waterway (LDW). Between November 2003 and March 2004, the Elliott Bay/Duwamish Restoration Program (EBDRP) implemented the Duwamish/Diagonal Sediment Remediation Project in the vicinity of the Diagonal combined sewer overflow/storm drain (CSO/SD) and Duwamish CSO. Polychlorinated biphenyls (PCBs), phthalates, and mercury were the identified chemicals of concern at the site. The objective of this project was to remediate contaminated sediment within a 7-acre area immediately adjacent to the Diagonal CSO/SD, Duwamish CSO, and the old Duwamish Treatment Plant outfall (denoted in EBDRP 2005a as Areas A and B, respectively). The 2003/2004 project included removal of 68,000 cubic yards of contaminated sediments from 7 acres across Areas A and B (Figure ES-1) from November 2003 to January 2004 and placement of a multiple-layered, engineered cap during January-February 2004 (ES-2). The intention was to isolate remaining chemicals from the environment and return the site to approximately the preconstruction river bottom elevations. The long-term remediation monitoring plan included annual sediment chemistry sampling and periodic physical measurements on the two cap areas and in the adjacent perimeter.

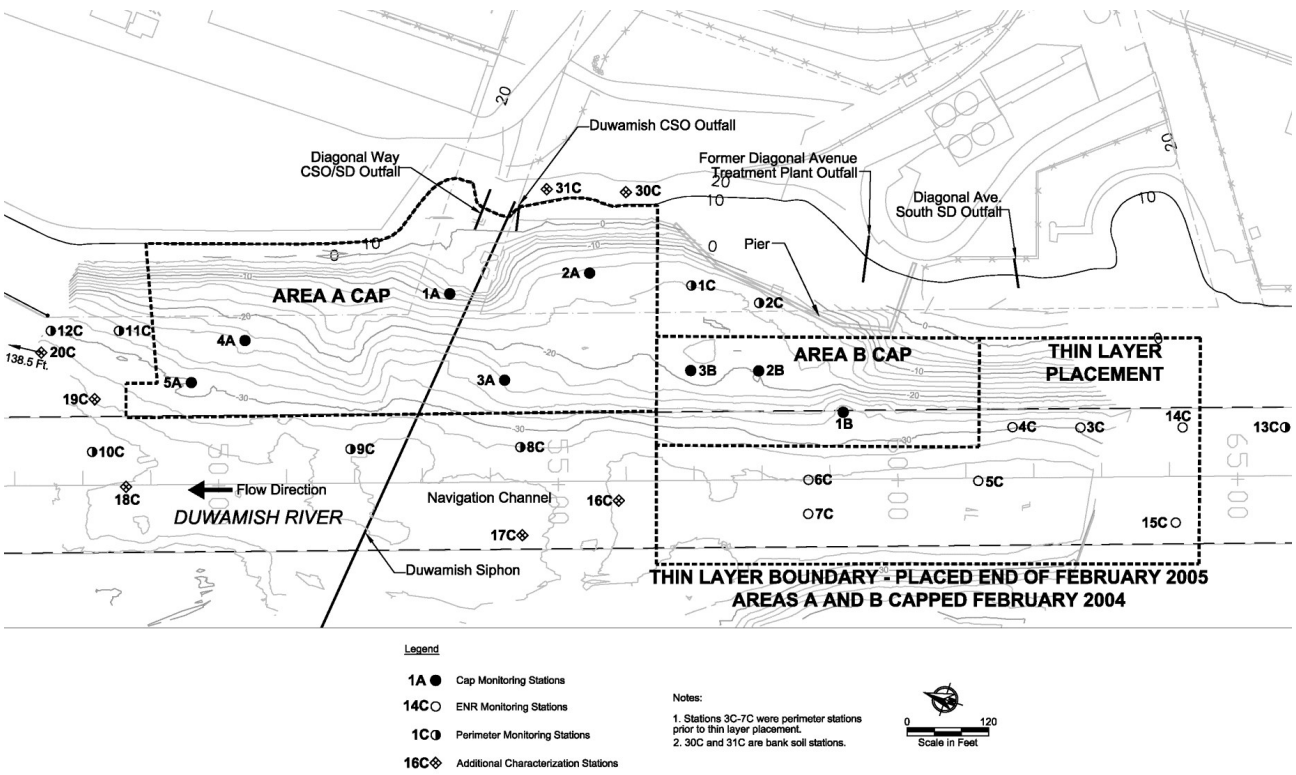

Figure ES-1. Duwamish Diagonal Cap, Thin Layer (ENR) and Perimeter Monitoring Stations

Post-cap 2004 sampling data from perimeter stations revealed that dredging activities had increased surface sediment concentrations of PCBs around the margin of Area B more than

those adjacent to Area A. This was consistent with the contractor's initial operations in this area that did not consistently apply required best management practices to minimize spread of dredging residuals. As a result, King County examined remedial actions to reduce elevated PCB levels caused by the dredging residuals. After consultation with Washington State Department of Ecology (Ecology) and the United States Environmental Protection Agency (EPA), King County selected the thin-layer placement remedy, also known as Enhanced Natural Recovery (ENR), as the best way to reduce the elevated PCB levels around Area B. The thin layer of sand was placed over 4 acres in February of 2005 on an area with the highest dredging residuals (Figure ES-1). This ENR area was subsequently monitored along with the two cap areas and the remaining perimeter area (Figure ES-2).

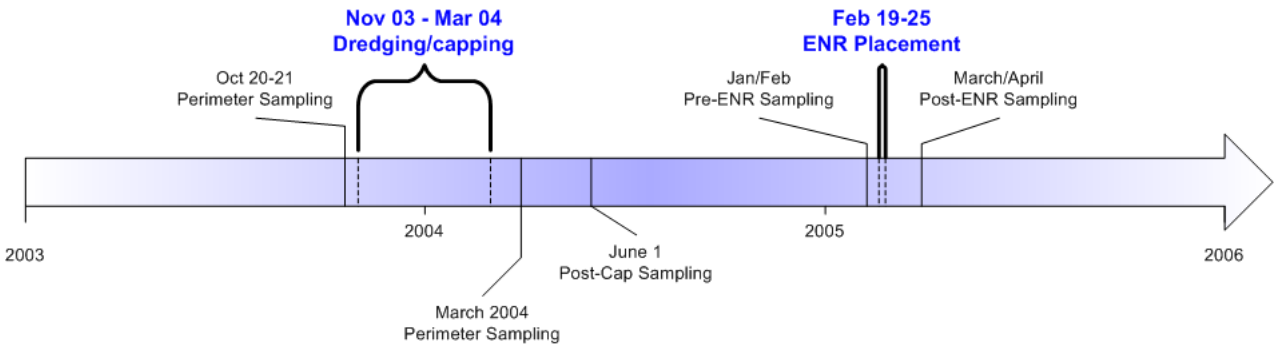

Figure ES-2. Duwamish Diagonal Project Timeline Through 2005

This report presents the results of both the 2010 annual monitoring event and a review of all monitoring activities[1] (2004-2010) for the Duwamish/Diagonal CSO/SD sediment remediation project. All monitoring activities to date have been conducted in accordance with the Ecology-approved monitoring program for this site. In addition to a review of the past seven years of monitoring activities (including pre-dredge conditions), this report evaluates fulfillment of long-term monitoring program objectives. There were two long-term objectives: one was to document any recontamination of the cap from CSOs or SDs; the other was to document cap stability.

The annual chemistry monitoring showed occasional and transient cap recontamination by chemicals, such as benzoic acid and dimethyl phthalate, typically at one station per year, and more persistent recontamination by certain phthalates. After an early recontamination event on the cap (associated with the CSO/SD outfall), PCB concentrations in Cap Area A decreased to below the Sediment Management Standard (SMS)'s sediment quality standard (SQS) [2]. In 2010, the cap data show the only SMS exceedances are for two phthalates and phenol. The monitoring program data has shown that bis(2-ethylhexyl)phthalate and benzyl butyl phthalate are the phthalates most commonly detected on Cap Areas A and B.

[1] 2010 monitoring results have not been previously reported. Monitoring data for 2003-2009 were presented by King County in previous reports to EBDRP.
[2] The SQS is now referred to as the benthic sediment cleanup objective in the 2013 SMS update.

Long-term monitoring conducted in the ENR area demonstrated the remedy of placing a thin layer of sand was successful in immediately reducing contaminant concentrations including PCBs from dredge residuals in the surface sediment and assisting in their long-term isolation. There have been no monitoring samples with concentrations exceeding SMS for PCBs since thin-layer placement. One phthalate exceeded SMS at one station in 2009 and phenol exceeded at one station in 2010.

The Perimeter Area long-term monitoring demonstrated contaminants have been declining over time, indicating natural recovery processes are occurring in this area. The monitoring showed greater frequency and magnitude in SMS exceedances with higher variability over space and time when compared to the other monitored areas. In 2010, the average PCBs concentration of the Perimeter Area continued to decline.

The long-term monitoring program met its objectives and demonstrated success of the remedial actions in reducing surface sediment contaminant concentrations and isolating remaining contamination under the cap. The long-term monitoring results indicate that PCBs and certain phthalates are the key chemicals to monitor for change at the site. The more recent monitoring events indicate average PCB concentrations in all monitoring areas except the Perimeter appear to be stabilizing. Analysis conducted for the LDW Feasibility Study examined background concentrations of PCBs in urban water bodies of western Washington and, based on this, concluded the expected range of anthropogenic/area[3] background for the Lower Duwamish Waterway is between 40 and 90 µg/kg dw (AECOM 2012). Natural background for Puget Sound, a measure of PCB concentrations that have not been influenced by localized human activity, is 2 ug/kg dw; this is the site-wide PCB cleanup level in the Lower Duwamish Waterway established by EPA (EPA 2014). In 2010, the mean PCB concentration across the remediated areas (i.e., the cap and ENR areas) was 60.8 µg/kg dw, which falls within this expected range of anthropogenic background but is above natural background. In addition, the average PCB concentration for each remediated area appears to be equilibrating around this value. Even the PCB concentrations in the Perimeter Area, which has only been subject to natural recovery processes (no active remediation), are decreasing toward the expected range of anthropogenic background.

Ongoing sources of phthalates are expected to continue to recontaminate the cap and possibly the ENR area in the future. Phthalates will be an ongoing source from the air-water-sediment pathway for decades with current source control and treatment options not expected to adequately control sources (Floyd|Snider 2007). Recurring site contamination by this type of contaminant can be expected. Based on the monitoring results, localized exceedances of SMS of phthalates will likely remain near the outfall with sporadic transient exceedances farther from the outfall.

The Duwamish Diagonal remediation was conducted with the awareness that phthalate recontamination was possible and likely, but that remediation was expected to address PCBs and mercury. PCB concentrations in Cap Areas A and B and the ENR Area appear to be

[3] Ecology then used the term "area background" in the SMS until it was updated in 2013. The term used now is regional background and the definition is similar to but slightly different from anthropogenic background.

stable, below the SQS, and within the range of anthropogenic background. The monitoring results showed mercury (the remaining chemical of concern for the site) did not exceed SMS post-remediation. Therefore, the objectives of chemical monitoring were met and further chemical monitoring is not expected to contribute new information. In addition, long-term monitoring demonstrated the cap and thin layer to be stable and resistant to existing disturbances. Sediment profile imaging surveys of the ENR Area also demonstrated benthic recolonization. Thus, the physical monitoring objectives were met and further monitoring under the original objectives is not recommended.

Monitoring of the ENR Area was planned to cease after five years (King County 2005). The project sampling and analysis plan discussed consideration of reducing the monitoring frequency on Cap Areas A and B after 5 years (King County 2003a). King County voluntarily conducted annual monitoring of all areas in 2011 and 2012 in order to extend the valuable time series on recovery and recontamination in this portion of the LDW[4]. Due to the consistency of the cap and ENR area monitoring data over time and the continued, steady decline in the Perimeter area monitoring data, King County believes the existing data are sufficient to evaluate the long-term status of recontamination potential from the four chemicals of concern and stability of the remedies. No further monitoring of Cap Areas A and B or the ENR Area is planned or recommended.

[4] 2011 and 2012 monitoring data will be reported under a separate cover when available.

1.0. INTRODUCTION

This report presents the results of both the 2010 annual monitoring event and a review of all monitoring activities through 2010 for the Duwamish/Diagonal Combined Sewer Overflow (CSO)/Storm Drain (SD) sediment remediation project. All monitoring activities to date have been conducted in accordance with the Ecology-approved monitoring program for this site. In addition to a review of the past seven years of monitoring activities (including pre-dredge) this report evaluates fulfillment of monitoring program objectives.

This section provides the project background and the station sampling history of the project. Section 2.0 summarizes 2010 sample collection and analytical methods, laboratory quality assurance and quality control (QA/QC) review, and deviations from the sediment Sampling and Analysis Plan (SAP)(King County 2003a). The results of the 2010 monitoring activities are also presented in Section 2.0. Section 3.0 reviews the original monitoring program objectives and the activities added for the thin-layer placement (enhanced natural recovery [ENR]) as laid out in the sediment and water SAPs (King County 2003a and King County 2003b) and the associated SAP addendum (King County 2005). The activities that have been conducted to meet the objectives of the monitoring program are reviewed in Section 4.0. Section 5.0 discusses if each monitoring objective was met and the need for any future monitoring activities. Section 6.0 is comprised of references followed by supporting appendices. Appendices to the report include the complete 2010 sediment chemistry results and quality assurance reviews of the chemistry data (Appendices A and C), data validation memos for all the long-term monitoring chemistry (Appendix B), the comparison of long-term monitoring data to marine benthic Washington State Sediment Management Standards[5] (SMS) (Appendix D), the 2006 sediment profile imaging (SPI) survey memo (Appendix E), and an appendix on additional long-term data analysis and modeling (Appendix F).

1.1 Project Background

Between November 2003 and March 2004, the Elliott Bay/Duwamish Restoration Program (EBDRP) implemented the Duwamish/Diagonal Sediment Remediation Project in the vicinity of the Diagonal CSO/SD and Duwamish CSO (Figure 1). The Closure Report (EBDRP 2005a) describes dredging, dredge material transport and disposal, and capping methods employed for the 2003/2004 project. The objective of this project was to remediate contaminated sediment within a 7-acre area immediately adjacent to the Diagonal CSO/SD, Duwamish CSO, and the old Duwamish Treatment Plant outfall (denoted in EBDRP 2005a as Areas A and B, respectively). The 2003/2004 project included removal of a minimum of three to an average of 5 feet of contaminated sediments from Areas A and B (Figure 1) from November 2003 to January 2004 and placement of a multiple-layered, engineered cap

[5] Ecology adopted new Sediment Management Standards that became effective in September, 2013. The SMS changed the term SQS to sediment cleanup objective (SCO) in Section 204-562 of the WAC, but still uses the term SQS in Section 204-320 of the WAC. Therefore, the term SQS has been retained for this report and is synonymous with "SCO based on protection of the benthic community" in the revised SMS.

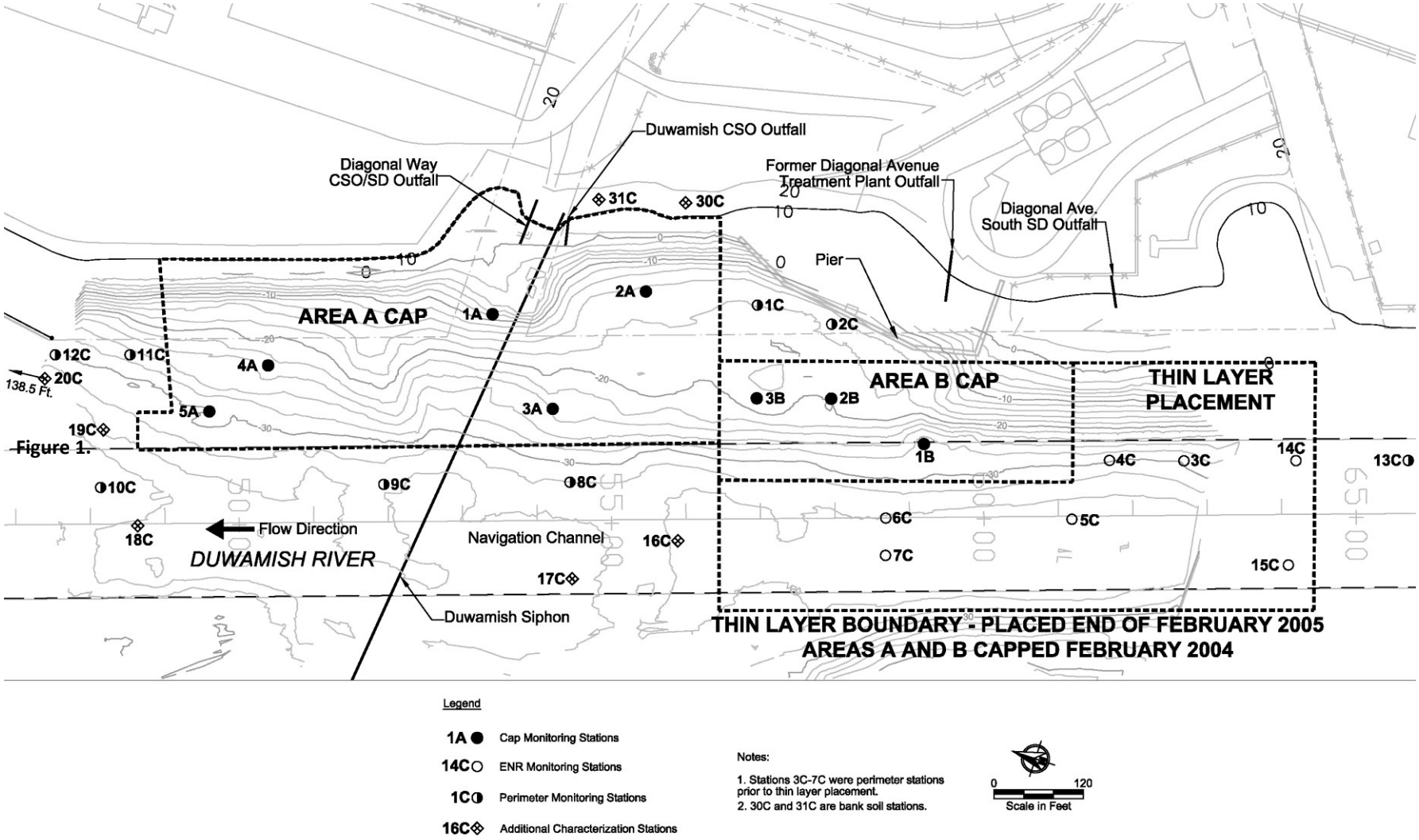

Figure 1. Duwamish Diagonal Site and Monitoring Station

during January-February 2004. The intention was to isolate remaining chemicals from the environment and return the site to approximately the preconstruction bottom elevations.

The engineered cap included areas with a layer of quarry spall and riprap to protect for erosion (See King County et al. 2003b for locations of quarry spall and riprap). In addition, habitat mix was applied as a surface layer at all elevations above -12 Mean Lower Low Water (MLLW) to improve salmonid habitat and in select deeper areas for erosion protection. Post-construction baseline sediment chemistry samples were collected from eight stations on the cap in Areas A and B in June 2004. These stations are shown on Figure 1 as 1A-5A and 1B-3B.

Dredging residuals are defined as contaminated sediments found at the post-dredging surface of the sediment profile, either within or around the dredging footprint (Bridges et al. 2008). Some form of dredging residuals could be expected to occur at most sediment cleanup sites; however, the magnitude of release varies widely between projects based on a range of site-specific and operational factors (Desrosiers et al. 2005, EPA 2005, NRC 2007). Both the Washington State Department of Ecology (Ecology) and the United States Environmental Protection Agency (EPA) required King County to monitor for movement of dredging residuals beyond the site boundary by measuring the preconstruction and post-construction sediment chemistry at 12 perimeter stations outside the 2003/2004 dredging/capping project boundary. The preconstruction sampling occurred in October 2003 prior to dredging followed by post-construction sampling in March 2004 (EBDRP 2005a). These stations are shown in Figure 1 as 1C-12C.

Analysis of the March 2004 sampling data from the perimeter stations revealed that 2003/2004 project dredging activities had increased surface sediment concentrations of polychlorinated biphenyls (PCBs) around the margin of Area B to a higher degree than dredging residuals adjacent to Area A (Figure 2). The occurrence of higher PCB concentrations from dredging residuals near Area B was consistent with the contractor's initial operations in this area that did not consistently apply required best management practices (BMPs) to minimize spread of dredging residuals. As a result, King County examined six prospective remedial actions to reduce elevated PCB levels caused by the dredging residuals. After consultation with Ecology and EPA, King County selected the thin-layer placement remedy, also known as Enhanced Natural Recovery (ENR), as the best way to reduce the elevated PCB levels within the 4-acre dredge residual area around Area B in the most expedient manner possible (see Anchor 2007).

The thin-layer placement remedy involved the placement of clean sand material to a minimum thickness of six inches over a 4-acre area (Figure 1) of dredging residuals to immediately reduce exposure to elevated PCB levels and accelerate the natural recovery timeframe in this area. The design called for placing 7,100 tons of sand, which would yield an average thickness of nine inches, to help ensure that the entire 4-acre ENR area would receive at least six inches of cover material. Over time, the natural process of bioturbation would be expected to mix clean sediment into underlying sediment

containing PCBs. Monitoring would continue for least five years to document the effectiveness of the thin-layer placement and bioturbation process and to compare the remediation strategy to natural recovery rates in the area surrounding Area A, which had significantly lower dredge residuals.

Placement of the ENR sand occurred between February 19 and 25, 2005. Samples were collected for Year 2005 monitoring in January, prior to placement, including samples at Perimeter stations 1C-12C. Additional stations were added to the January 2005 sampling event at EPA's request, to improve the general characterization of the area post remediation (13C-20C and bank stations

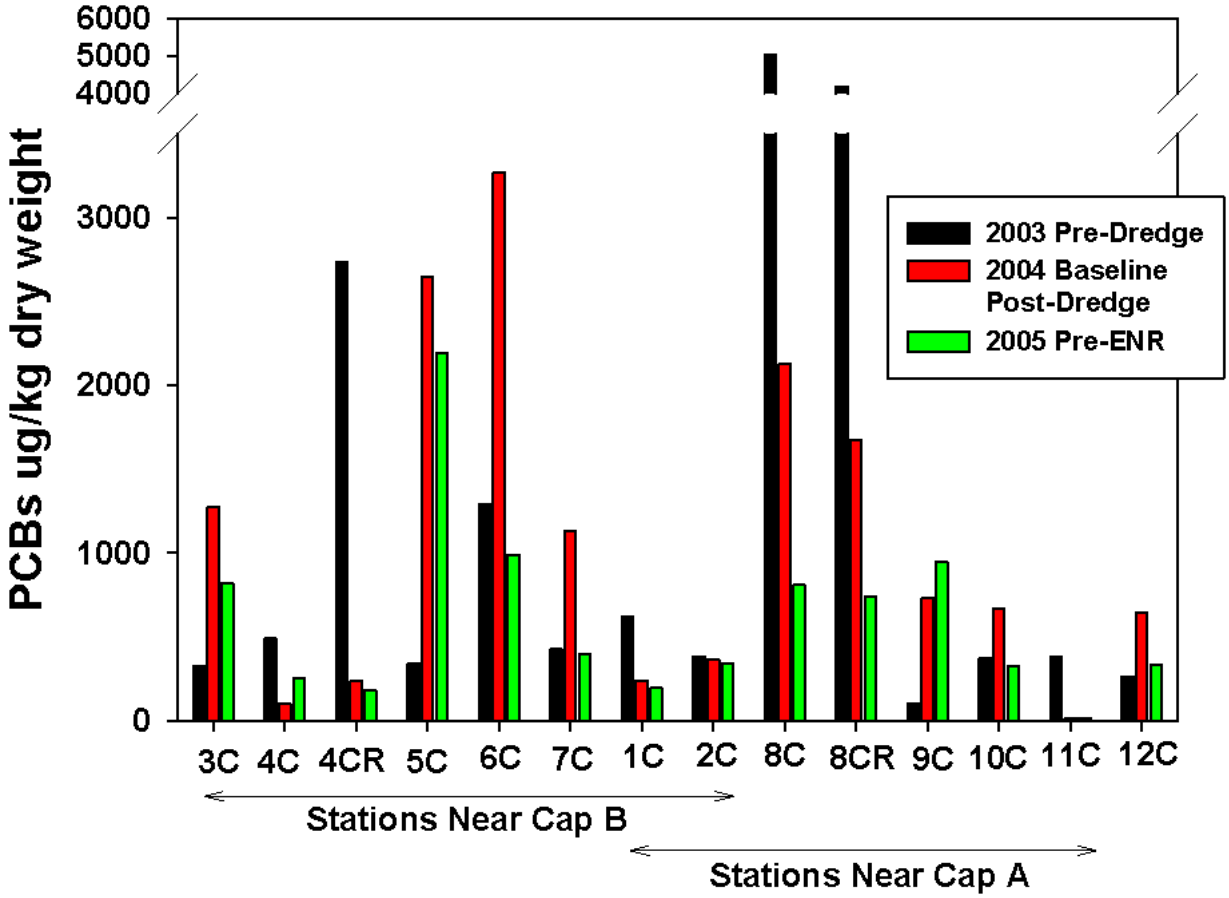

Figure 2. Changes in PCB Concentrations at Duwamish Diagonal Perimeter Stations (2003-2005)

30C-31C – see Figure 1). Post-ENR construction baseline sediment chemistry samples were then collected from seven stations within the ENR area in March 2005, five of which were the pre-existing stations 3C-7C and two of which were new stations added to increase spatial coverage (14C-15C). The major project events through 2005 are

presented on a timeline in Figure 3. Starting in 2006, annual surface sediment monitoring occurred each spring through 2010.

Sediment monitoring requirements for the Duwamish/Diagonal Sediment Remediation Project are described in the initial sediment SAP (King County 2003a) as well as the SAP addendum (King County 2005); the latter was prepared to cover monitoring activities for the ENR area. The baseline post-capping and post-ENR data were presented in the Duwamish/Diagonal CSO/SD Sediment Remediation Project Closure Report (EBDRP 2005a), the 2005 Monitoring Report (EBDRP 2007) and the 4-Acre Residuals Interim Action Closure Report (Anchor 2007).

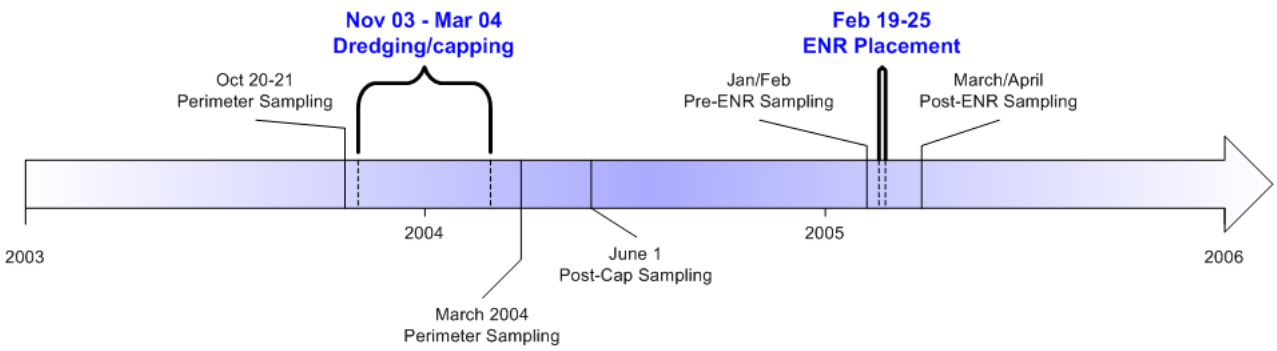

Figure 3. Duwamish Diagonal Project Timeline Through 2005

1.2 Stations Sampled During Program Monitoring Events

The annual monitoring events included sediment samples collected from a total of 23 stations in four monitoring areas at the Duwamish/Diagonal site: Cap Area A, Cap Area B, the thin-layer placement or ENR area, and from perimeter stations outside the areas of remediation and ENR. The last sampling event occurred at these sites on March 29 and 30, 2010. Figure 1 presents the locations of the 23 monitoring stations described in the following sections.

1.2.1 Sediment Cap Area A

Beginning in 2004, surface sediment samples were collected annually from five stations in Cap Area A. Table 1 provides a stations list and history of sample collection dates.

A baseline sediment sample was not collected from Station DUD_3A in 2004 because only coarse gravel was found during repeated attempts to sample this location; thus, precluding the ability to chemically analyze the substrate.

Table 1. Sample Dates for Sediment Cap Area A Stations

Station	2004 - Baseline	2005 – Year 1	2006 – Year 2	2007 – Year 3	2008 – Year 4	2009 – Year 5	2010 – Year 6[a]
DUD_1A	06/01/2004	04/27/2005	03/07/2006	04/03/2007	03/24/08	04/28/09	03/29/10
DUD_2A	06/01/2004	04/27/2005	03/07/2006	04/03/2007	03/24/08	04/28/09	03/29/10
DUD_3A	--	04/27/2005	03/07/2006	04/03/2007	03/24/08	04/28/09	03/29/10
DUD_4A	06/01/2004	04/27/2005	03/07/2006	04/03/2007	03/24/08	04/28/09	03/29/10
DUD_5A	06/01/2004	04/27/2005	03/07/2006	04/03/2007	03/24/08	04/28/09	03/29/10

[a] Year 6 sampling was not required in the project SAP but was collected to facilitate comparisons with the ENR area.

1.2.2 Sediment Cap Area B

Beginning in 2004, surface sediment samples were collected annually from three stations in Sediment Cap Area B. Table 2 provides a stations list and history of sample collection dates.

Table 2. Sample Dates for Sediment Cap Area B Stations

Station	2004 - Baseline	2005 – Year 1	2006 – Year 2	2007 – Year 3	2008 – Year 4	2009 – Year 5	2010 – Year 6
DUD_1B	06/01/2004	04/27/2005	03/07/2006	04/03/2007	03/24/08	04/27/09	03/29/10
DUD_2B	06/01/2004	08/17/2005	03/07/2006	04/03/2007	03/24/08	04/27/09	03/29/10
DUD_3B	06/01/2004	--	03/07/2006	04/03/2007	03/24/08	04/27/09	03/29/10

[a] Year 6 sampling was not required in the project SAP but was collected to facilitate comparisons with the ENR area.

The presence of coarse gravel in Year One prevented successful collection of samples at Station DUD_3B even after repeated attempts; coarse gravel cannot be chemically analyzed in the laboratory. Station DUD_2B also required multiple sampling attempts due to coarse gravel; however, sample collection of analyzable substrate was successful at this station in August 2005.

1.2.3 Enhanced Natural Recovery (ENR) Area

Beginning in 2005, surface sediment samples were collected from seven stations in the ENR area. Table 3 provides a stations list and history of sample collection dates. Stations 3C-7C were also sampled pre-ENR placement in 2005 but were designated as Perimeter Stations at that time and their sampling dates are summarized in Section 1.2.4.

Table 3. Sample Dates for ENR Stations

Station	2005 – Baseline	2006 – Year 1	2007 – Year 2	2008 – Year 3	2009 – Year 4	2010 – Year 5
DUD_3C	03/16/2005	03/10/2006	04/03/2007	03/25/08	04/28/09	03/30/10
DUD_4C	03/16/2005	03/10/2006	04/03/2007	03/25/08	04/28/09	03/30/10
DUD_5C	03/24/2005	03/10/2006	04/03/2007	03/25/08	04/28/09	03/30/10
DUD_6C	03/24/2005	03/10/2006	04/03/2007	03/25/08	04/28/09	03/30/10
DUD_7C	03/24/2005	03/10/2006	04/04/2007	03/25/08	04/28/09	03/30/10
DUD_14C	03/16/2005	03/10/2006	04/04/2007	03/25/08	04/28/09	03/30/10
DUD_15C	03/16/2005	03/10/2006	04/04/2007	03/25/08	04/28/09	03/30/10

1.2.4 Perimeter Stations

Surface sediment samples were collected from eight perimeter stations, all located outside of the cap and ENR areas. Table 4 provides a stations list and history of sample collection dates. Unlike the Cap and ENR monitoring stations, monitoring dates beginning prior to the remedial action are included in this table. Station DUD_13C was added to the monitoring program in 2005 to represent conditions upstream of the ENR area.

Table 4. Sample Dates for Perimeter Stations

Station	2003 – Pre-Construction	2004 - Baseline	2005 – Year 1	2006 – Year 2	2007 – Year 3	2008 – Year 4	2009 – Year 5	2010 – Year 6
DUD_1C	10/20/2003	03/29/2004	02/01/2005	03/08/2006	04/02/2007	03/24/08	04/27/09	03/29/10
DUD_2C	10/20/2003	03/29/2004	01/31/2005	03/08/2006	04/02/2007	03/24/08	04/27/09	03/29/10
DUD_3C	10/20/2003	03/29/2004	01/31/2005	--	--	--	--	--
DUD_4C	10/20/2003	03/29/2004	01/31/2005	--	--	--	--	--
DUD_5C	10/20/2003	03/29/2004	01/31/2005	--	--	--	--	--
DUD_6C	10/20/2003	03/30/2004	01/31/2005	--	--	--	--	--
DUD_7C	10/20/2003	03/30/2004	01/31/2005	--	--	--	--	--
DUD_8C	10/21/2003	03/30/2004	02/01/2005	03/08/2006	04/02/2007	03/24/08	04/28/09	03/29/10
DUD_9C	10/21/2003	03/30/2004	01/31/2005	03/08/2006	04/02/2007	03/24/08	04/29/09	03/29/10
DUD_10C	10/21/2003	03/30/2004	02/01/2005	03/08/2006	04/02/2007	03/24/08	04/29/09	03/29/10
DUD_11C	10/21/2003	03/30/2004	02/01/2005	03/09/2006	04/02/2007	03/25/08	04/29/09	03/29/10
DUD_12C	10/21/2003	03/30/2004	02/02/2005	03/09/2006	04/02/2007	03/25/08	04/29/09	03/29/10
DUD_13C	--	--	02/02/2005	03/09/2006	04/04/2007	03/25/08	04/29/09	03/29/10

Note: Stations 3C-7C were initially Perimeter Stations but following thin layer placement, these locations became ENR monitoring stations. Therefore, only sample dates between 2003 and 2005 are included in this table. In 2005, stations 3C-7C were sampled initially as Perimeter stations, and again post-ENR as Baseline ENR stations.

2.0. 2010 MONITORING AND RESULTS

This section describes the 2010 sediment monitoring activities and discusses laboratory QA/QC review and deviations from the project sediment SAP (King County 2003a) and SAP Addendum (King County 2005). The analytical results are also summarized in this section.

2.1 Sample Collection

In 2010, 26 surface sediment samples (including three field replicates) were collected from 23 stations located in Sediment Cap Areas A and B, the ENR area, and the perimeter stations. One field replicate sample was collected from each of the three monitoring areas. All sample collection followed protocols outlined in the Puget Sound Estuary Program's (PSEP) Puget Sound Protocols (PSEP 1997, 1998) and sediment SAP. This section summarizes the sample collection and handling methods and additional details can be found in the sediment SAP (King County 2003a).

2.1.1 Station Positioning

Surface sediment grab samples were collected from King County's research vessel (RV) *Liberty*, which is equipped with a differential global positioning system (DGPS). Field coordinates were recorded using DGPS for each sediment grab as the sampler contacted the sediment bed. Coordinates for each grab deployment are shown in Appendix A and are compared to the prescribed study coordinates.

2.1.2 Sample Collection and Handling

Composite surface sediment samples were obtained using two modified, stainless steel, 0.1 m^2 Van Veen grab samplers deployed in tandem from RV *Liberty*. A single deployment of the tandem Van Veen grab samplers was considered "two grabs" when both of the samplers returned an acceptable sample. The number of grabs composited into a sample varied depending on the area sampled. Beginning in 2010, a change was made to the number of grabs per composite sample collected in the perimeter area. To reduce the potential for oversampling[6] during collection of 10 grabs per composite, King County reduced the number of grabs per composite sample to 3 at all perimeter stations in 2010 (see further discussion in Section 2.4). A summary of the number of grabs obtained at each station is provided in Appendix A. The details of sample collection are summarized below and described in greater detail in Appendix A.

Sediment chemistry samples targeted the top 10 cm of sediment and required a minimum grab penetration depth of 11 cm to ensure that sediment touching the sides of the sampler was not collected. This was not always possible given the substrate in the sediment cap and ENR areas. When penetration depth was less than 10 cm, sediment was collected to a depth of 1 cm from the bottom of the grab. Penetration depth was

[6] Oversampling is defined as removing a volume of sediment from the same location such that subsurface and potentially more contaminated sediments are exposed.

determined by measuring the depth of sediment within each grab by sliding a ruler vertically along the inside of the sampler's side wall after each successful cast.

Undisturbed sediments in the grab were collected with a stainless steel spoon and then placed in a stainless steel bowl and stored covered with aluminum foil between grab deployments. Homogenization occurred in the bowl after sediment was collected from the three successful grabs. After thorough homogenization, sediment aliquots were transferred to appropriate laboratory containers.

Head space was left in all sediment chemistry sample containers to allow further mixing at the laboratory and for expansion should the containers be stored frozen. All sample containers were stored in insulated, ice-filled coolers while in the field.

The grab samplers were decontaminated between sampling stations by scrubbing with a brush and Detergent 8 (a phosphate-free soap) followed by a thorough *in situ* rinsing. A separate pre-cleaned stainless steel bowl and spoon were dedicated to each sampling station, precluding the need for decontamination of this equipment in the field.

While in the field, all samples were under direct possession and control of King County field staff. For chain of custody (COC) purposes, the RV Liberty was considered a "controlled area." Each day, all sample information was recorded on a COC form. This form was completed in the field and accompanied all samples during transport and delivery to the laboratory each day. Upon arrival at the King County Environmental Laboratory (KCEL), sample delivery staff relinquished all samples to sample login staff. The date and time of sample delivery was recorded and both parties then signed off in the appropriate sections on the COC form. Once completed, original COC forms were archived in the project file. Copies of all completed COC forms are included in Appendix A.

2.2 Laboratory Analyses

Sediment chemistry analyses were selected to allow comparison of numerical data to the SMS chemical criteria found in Tables 1 and 3 of Chapter 173-204 WAC (Ecology 1995). Other chemicals of interest (chlorinated pesticides and additional metals), total organic carbon (TOC), total solids and sediment grain size were analyzed as well. A complete list of all parameters analyzed along with their respective detection limits is included in Appendix A. All laboratory analyses were performed by the KCEL. The following subsections summarize the chemical analyses performed as well as QA/QC analyses.

2.2.1 Conventionals

Conventional analyses included percent total solids, TOC, and grain size. Percent total solids and TOC analyses were performed to provide data necessary to normalize sediment data to dry weight and organic carbon, respectively. Percent total solids analysis was performed according to Standard Method 2540-G (APHA 1997), which is a

gravimetric determination. TOC analysis was performed following EPA Method 9060 (EPA 2007), high-temperature combustion with infrared spectroscopy. Grain size analysis was performed according to ASTM Method D422 (ASTM 2002), which is a combination of sieve and hydrometer analyses.

2.2.2 Metals

Metal analytes included aluminum, antimony, arsenic, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, and zinc. With the exception of mercury, all metal analyses were performed following EPA Method 3050B/6010C (EPA 2007); strong-acid digestion with inductively coupled plasma optical emission spectroscopy (ICP-OES). Mercury was analyzed according to EPA Method 7471B (EPA 2007), cold vapor atomic absorption spectroscopy.

2.2.3 Trace Organics

Trace organic analytes included base/neutral/acid extractable semivolatile compounds (BNAs), chlorinated pesticides, and PCBs as Aroclors. BNA analysis was performed following EPA Method 8270 (EPA 2007), gas chromatography with mass spectroscopy (GC/MS). Chlorinated pesticides were analyzed by EPA Method 3550B/8081B (EPA 2007), gas chromatography with electron capture detection (GC/ECD). PCBs were analyzed by EPA Method 3550B/8082A (EPA 2007), GC/ECD.

2.2.4 Laboratory Quality Assurance/Quality Control (QA/QC)

Analytical QC samples included method blanks, laboratory duplicates, standard reference materials, matrix spikes and matrix spike duplicates. Chemistry data were reviewed following QA1 guidelines (Ecology 1989) and flagged with laboratory data qualifiers where appropriate. KCEL modified their data flags in early 2009 to make them closer to those used in the state Environmental Information Management (EIM) system database at Ecology[7]. Data flags applied to 2010 sediment results are presented in Table 5.

A QA issue discussed in Appendix A which warrants clarification is related to the overlap of Aroclor components (congeners) observed from the GC/ECD analysis. This is a common issue in the analysis of Aroclors. Aroclors 1248, 1254 and 1260 share some congeners with Aroclors 1016, 1232 and 1242, the lower chlorinated Aroclors. When the more prominent Aroclors 1248, 1254, and 1260 are present, identification of some or all of Aroclors 1016, 1232, and 1242 is not possible for all samples because of the overlapping congeners. To account for this, and to acknowledge the uncertainty in the potential presence of these lower chlorinated Aroclors, detection limit (both the method detection limit [MDL] and reporting detection limit [RDL]) values are elevated. In the "Organic Chemistry" section of each QA review in Appendix A, the impacted Aroclors for each sample are presented. The quantitation of the Aroclors 1248, 1254 and 1260 is not affected by the peaks that overlap the three lower chlorinated Aroclors. The total PCB

[7] When King County actually submits data to EIM, the laboratory data flags are manually changed to conform to the EIM system.

sum (sum of all detected Aroclors) should not be significantly impacted by the issue of elevated MDLs for 1016, 1232 and 1242 because the predominantly detected Aroclors are 1248, 1254 and 1260.

Table 5. King County Laboratory Data Qualifier Flags for 2010

Condition to Qualify	Flag
Less than the reporting detection limit (RDL)	<RDL
Less than the method detection limit (MDL)	<MDL
At the reporting detection limit (RDL)	RDL
An estimated value when the measured response was outside the expected accuracy of the method.	J
The reported value is estimated with low bias	JG
The reported value is estimated with high bias	TA
A parameter in associated method blank was detected and sample result is within 5X of blank.	B
A common lab contaminant[8] in associated method blank was detected and the sample result is > 5 and ≤ 10X the blank.	B2

2.3 Quality Assurance/Quality Control Review

King County's Science Section in the Water and Land Resources Division conducted an EPA Level Stage 2a (EPA 2009) data validation review using guidance found in USEPA Contract Laboratory Program National Functional Guidelines for Low Concentration Organic Data Review (EPA 2001) and USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review (EPA 2004). Materials reviewed included Batch Reports and Analytical Quality Control (QC) Reports downloaded from King County's Laboratory Information System (LIMS) database. The QC parameters reviewed during this data validation include holding time, method blanks, spike blanks, matrix spikes, matrix spike duplicates, laboratory control samples, standard reference materials, laboratory replicates, and surrogates. A data validation memorandum can be found in Appendix B.

The majority of the data did not require qualification. All of the antimony results were qualified as estimated with a "J" with low bias, due to a matrix interference. A matrix interference for antimony is inherent in marine sediments processed with the EPA method used. Laboratory data qualifiers were changed to conform to Functional Guidelines, i.e., "<RDL" was changed to "J," "<MDL" was changed to "U." In addition, some "B" qualifiers were changed as described below. All data are of acceptable quality. The remainder of this section summarizes the blank contamination ("B" flag) evaluation.

[8] Common lab contaminants are acetone, 2-butanone, methylene chloride, bis(2-ethylhexyl)phthalate, benzyl butyl phthalate, and di-N-butylphthalate.

Method blanks were contaminated with Bis(2-ethylhexyl)phthalate (BEHP) and Di-N-butyl phthalate (DNBP). Phthalates are a common laboratory contaminant due to the abundance of plastic ware and plastic piping in laboratories, as well as laboratory hood ventilation systems. BEHP and DNBP were detected in several method blanks. Thus, several sample results for these phthalate compounds detected in associated method blanks were flagged "B" or "B2." "B" and "B2" flags were applied when the sample result was within 5X or between 5X and 10X of the method blank result, respectively. Thus, any B or B2 flags were changed to nondetect or "U" at the result value in accordance with National Functional Guidelines (EPA 2001). Table 6 shows the stations that were impacted by blank contamination.

Table 6. 2010 Stations Where Sample Results Were Qualified as Nondetect Following Blank Contamination Evaluation

Area	BEHP	DNBP
Cap A	5A	1A-5A
Cap B	1B-3B	1B-3B
ENR	4C-7C, 14C, 15C	3C-7C, 14C, 15C
Perimeter	10C, 13C	1C, 2C, 8C–13C

BEHP – Bis(2-ethylhexyl)phthalate
DNBP – Di-N-butylphthalate

2.4 Deviations from Sampling Plan

There was one deviation to the sediment SAP and addendum (King County 2003a, King County 2005) in 2010. The number of replicate grabs in a composite was changed from ten to three for each Perimeter Area station. This change was made because 2009 chemistry results at Station 8C indicated that repeated collection of 10 replicate grabs may be removing enough surface material that underlying, more contaminated sediments were becoming exposed. This was of particular concern when collecting a field duplicate sample which doubles the number of grabs. The number of replicate grabs was reduced to three to be consistent with sampling in the main cap areas.

Average penetration depths (see Appendix A) indicate that the minimum required depth (0-10 cm) was not recovered for all. Less than 10 cm penetration depth was recovered for some samples at several stations in the ENR and Perimeter Areas and one in Cap A area. Multiple attempts to achieve maximum sampler penetration were attempted but at some stations, such as 5A, the underlying gravel mix prohibited penetration beyond the overlying soft fines.

2.5 2010 Surface Sediment Analytical Results

This section summarizes analytical chemistry results for 2010 monitoring samples collected in cap Areas A and B (Year 6 post-cap), the perimeter area (Year 6 post-cap) and the ENR (Year 5 post thin-layer placement). The percent total organic carbon content for all 2010 samples is presented in Figure 4 and Appendix C. Relative grain size composition for all 2010 samples is presented in Figure 5 and Appendix C. Due to analytical variability, the exact sum of the four size category percentages (i.e., clay, silt,

sand and gravel) in Appendix C does not always equal 100%. The size category percentages were standardized to the sum of 100% for presentation in Figure 5. In addition, the analytical chemistry results for all SMS chemicals can be found in Table 7, at the end of this section. The results are normalized to dry weight (dw) or organic carbon (OC) as appropriate for comparison to SMS. The complete analytical results can be found in Appendix C. Results are first summarized for all analytes by area and compared to SMS standards. Field duplicate values were averaged before comparison to SMS. SMS (Ecology 1995) rules were followed in the calculation of sums (e.g., total PCBs and PAHs) and handling of undetected results. A comparison of 2010 results to SMS chemical criteria is shown in Table 7.

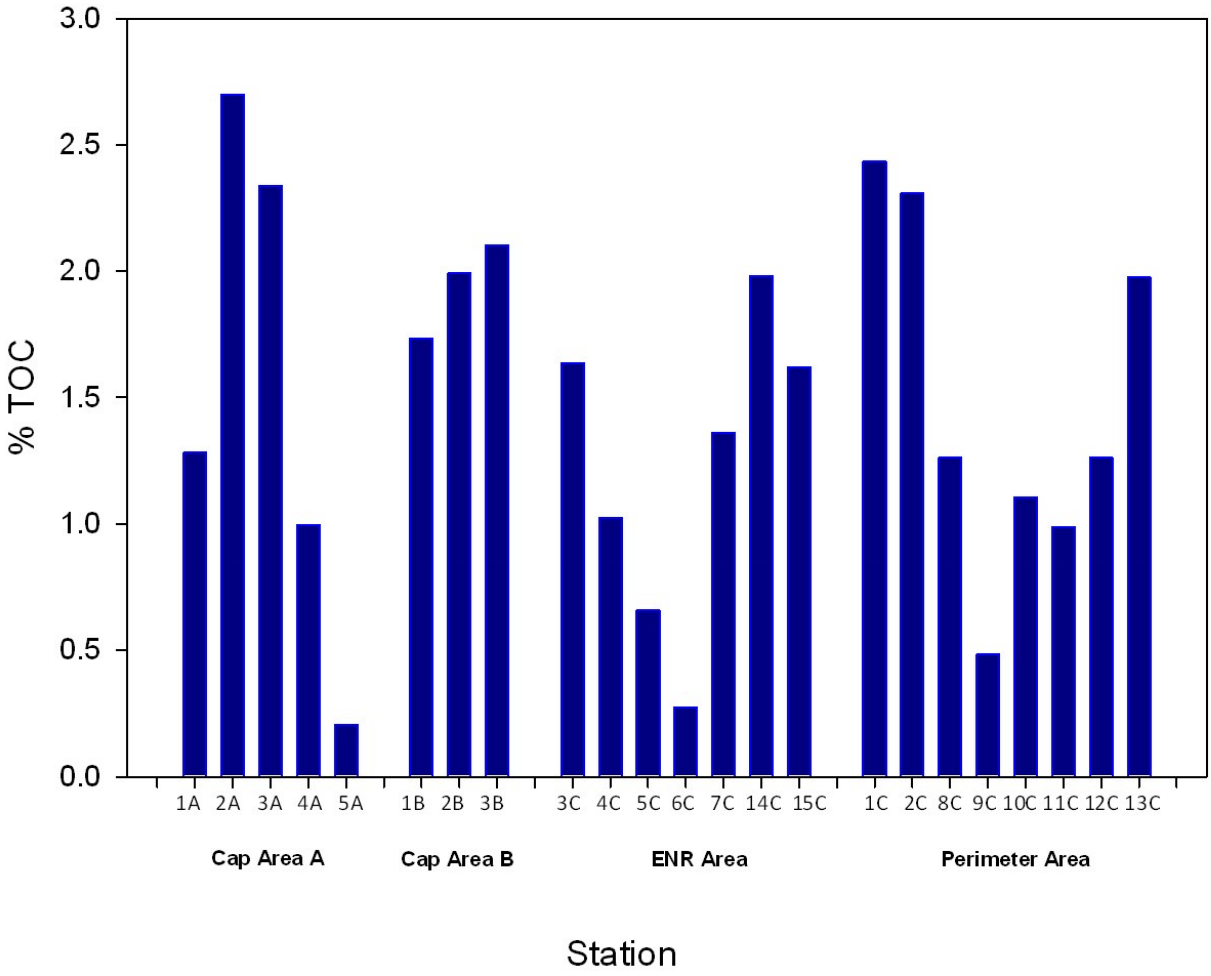

Figure 4. 2010 Percent Total Organic Carbon

2.5.1 Sediment Cap Area A Results

TOC content ranged from 0.21% to 2.7% in 2010 Cap Area A samples. TOC content at station 5A was outside the range for appropriate comparison to OC-normalized sediment quality standards (SQS) and cleanup screening levels (CSL) (0.5 – 4.0 %) and, thus, dw-normalized values were compared to dw-based apparent effect thresholds

(AETs) for regularly OC-normalized SMS chemicals. In Cap Area A, sand is the dominant size category in samples from stations 1A, 4A and 5A. In contrast, silt is the dominant size category in Cap Area A samples from stations 2A and 3A.

BEHP, BBP and phenol exceeded SMS in one or more samples in 2010. The OC-normalized concentrations of BEHP exceeded the SQS at station 4A and the CSL at station 1A. Similarly, the BBP concentrations at stations 1A and 4A exceeded the SQS. Phenol concentrations exceeded the SQS at station 3A and the CSL at station 2A.

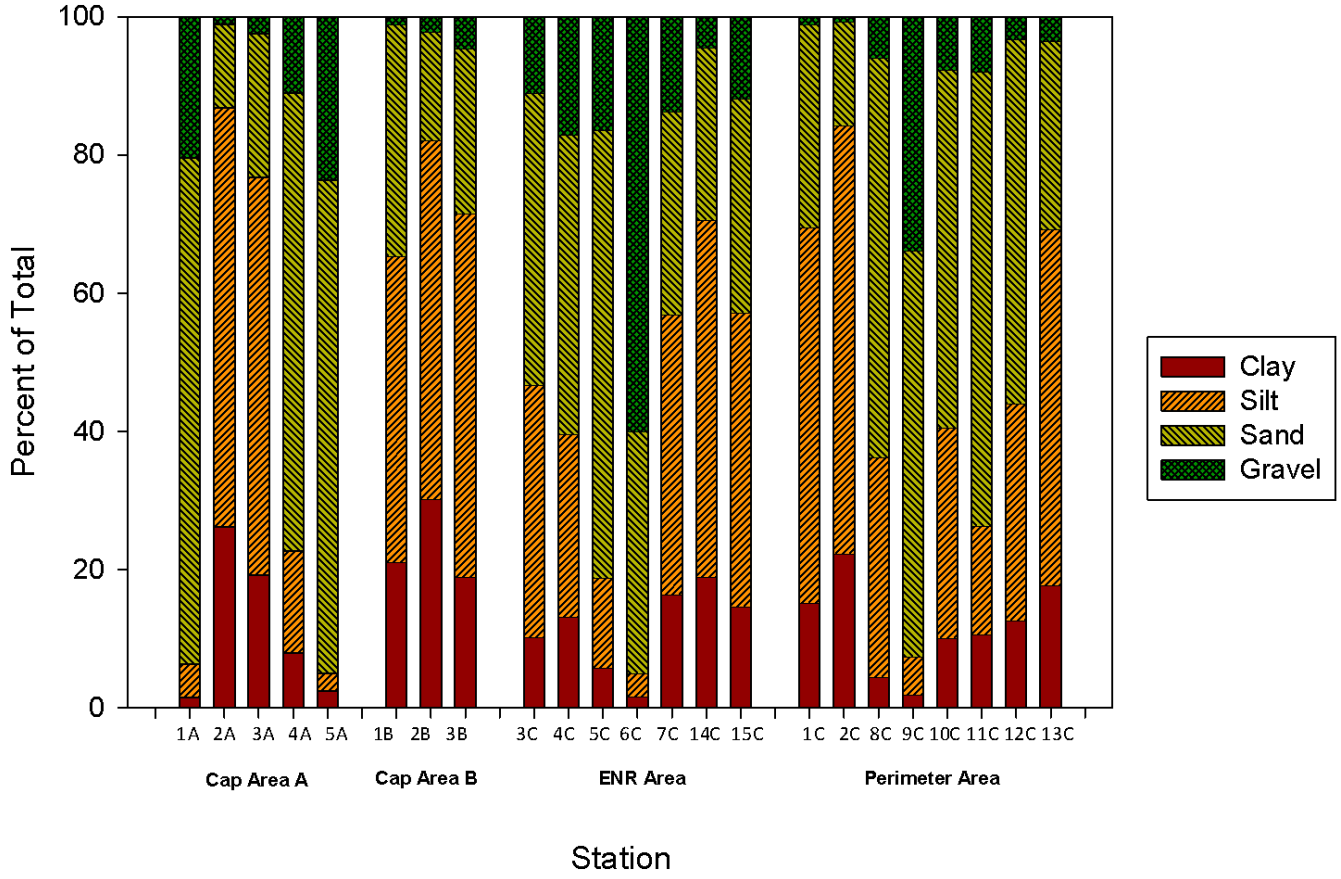

Figure 5. 2010 Percent Grain Size (Standardized to the Sum of 100%)

2.5.2 Sediment Cap Area B Results

TOC content ranged from 1.7% to 2.0% (Figure 4, Table 7) in 2010 Cap Area B samples. Silt was the largest grain size category in all Cap Area B samples (Figure 5, Table 7). Clay and sand also contribute substantially to these samples; however, very little gravel was present. Only one chemical exceeded SMS in 2010; phenol exceeded the SQS at stations 2B and 3B.

2.5.3 Enhanced Natural Recovery Area Results

TOC measurements in ENR area samples ranged from 0.27% to 2.0% (Figure 4, Table 7,) in 2010 ENR Area samples. Sand and silt comprise the majority of samples in the ENR area with the exception of Stations 5C and 6C. The majority of the sample at 5C was sand, and gravel accounts for over half of the sample at 6C (Figure 5, Table 7). TOC content in the sample from Station 6C was outside the range for comparison to OC-normalized SMS; thus, the chemistry results were compared to dw–normalized AETs. Only one chemical exceeded the SMS in 2010; phenol exceeded the SQS at station 3C.

2.5.4 Perimeter Area Results

TOC composition ranged from 0.48% to 2.4% in 2010 Perimeter Area samples (Table 7). Most samples in the Perimeter Area were comprised of mainly sand and silt grain sizes with some clay and very little gravel. Station 9C was different in that over 90% of the sample was comprised of gravel and sand.

In 2010, TOC content of the sample from Station 9C was outside the range for comparison to OC-normalized SMS values; thus, the chemistry results for this sample were compared to dw-normalized AETs. Three chemicals exceeded the SMS: PCBs, BBP and phenol. Concentrations of total PCBs exceeded the SQS at three stations: 8C, 10C, and 12C. BBP concentrations exceeded the SQS at Station 11C. Phenol concentrations exceeded the SQS at Stations 1C and 12C, and the CSL at Station 2C.

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Table 7. 2010 Sediment Chemistry Results – Comparison to SMS

			Cap Area A					Cap Area B			ENR Area							Perimeter Area							
Chemical	**SQS**	**CSL**	**1A**	**2A**	**3A**	**4A Avg**	**5A**	**1B**	**2B**	**3B**	**14C**	**15C**	**3C**	**4C**	**5C**	**6C Avg**	**7C**	**1C**	**2C**	**8C**	**9C**	**10C Avg**	**11C**	**12C**	**13C**
Conventionals (%)																									
Total Solids			75.6	44.1	47.1	69.5	64.9	51.2	45	46.3	47.8	55.9	55.4	81.3	74	86.7	58.1	44.8	44.6	66.5	75	62	69.2	63.4	48.7
Total Organic Carbon			1.28	2.70	2.34	1.00	*0.21*	1.73	1.99	2.10	1.98	1.62	1.64	1.02	0.66	*0.27*	1.36	2.43	2.31	1.26	*0.48*	1.10	0.99	1.26	1.98
Metals (mg/kg dw)																									
Arsenic	57	93	5.42 J	14.7	13.6 J	6.40 J	3.08 J	10.2 J	11.8 J	12.1 J	11.1 J	8.77 J	9.75 J	6.16 J	4.86 J	3.39 J	7.23 J	12.7 J	13.5 J	11.5	5.73 J	9.60 U	6.65 J	9.15 J	11.1 J
Cadmium	5.1	6.7	0.57 J	0.48 J	0.42 J	0.28 J	0.12 U	0.29 J	0.33 J	0.28 J	0.27 J	0.20 J	0.25 J	0.18 U	0.14 U	0.12 U	0.19 J	0.36 J	0.40 J	1.53	0.13 U	0.29 U	0.20 J	0.38 J	0.29 J
Chromium	260	270	29.8	32.9	32.7	24.8	19.2	27.9	32.2	31.3	30.1	26.1	25.8	24.7	18.6	14.7	25.1	31.5	32.1	46.5	18.0	27.7	25.3	24.9	29.6
Copper	390	390	57.7	77.8	82.8	60.5	42.2	62.1	66.2	72.1	59.4	53.8	66.2	44.2	34.6	32.9	49.4	72.8	74.4	61.5	44.8	53.5	51.7	59.3	63.9
Lead	450	530	37.0	32.7	41.4	23.8	7.4	25.4	24.7	26.6	24.1	22.2	28.2	14.5	10.2	4.5 J	17.6	31.5	30.5	49.8	12.0	31.7	23.4	46.2	26.5
Mercury	0.41	0.59	0.06 J	0.16 J	0.25 J	0.10 J	0.03 J	0.16 J	0.21 J	0.19 J	0.14 J	0.13 J	0.16 J	0.14 J	0.19 J	0.03 J	0.15 J	0.17 J	0.18 J	0.29 J	0.06 J	0.14 J	0.10 J	0.16 J	0.17 J
Silver	6.1	6.1	0.83 J	1.84 J	1.76 J	1.39	1.11 J	1.64 J	1.76 J	1.90 J	0.42 U	0.36 U	0.36 U	0.32 U	0.27 U	0.23 U	0.34 U	0.45 U	0.43 U	1.56	0.27 U	0.33 U	0.29 U	0.32 U	0.41 U
Zinc	410	960	210	149	138	97.8	43.1	104	115	121	102	87.3	98.7	66.1	52.2	35.9	78.7	139	135	124	52.3	94.0	82.1	107	106
PCBs (mg/Kg OC)																									
Total PCBs	12	65	5.25	2.46	3.88	4.64	*7.1*	5.13	3.69	3.50	3.26	4.43	7.02	5.64	4.59	*3.08*	3.16	2.58	3.15	54.8	*13.3*	15.8	5.52	14.4	6.81
LPAH (mg/Kg OC)																									
2-Methylnaphthalene	38	64	0.44	0.17 U	0.18 U	0.29 J	*1.20 U*	0.23 U	0.22 U	0.21 U	0.21 U	0.22 U	0.22 U	0.30 U	0.41 U	*0.91 U*	0.25 U	0.23 J	0.27 J	0.27 J	*0.63 J*	0.29 U	0.29 U	0.75	0.21 U
Acenaphthene	16	57	0.55 J	0.18 U	0.18 J	0.52 J	*1.20 U*	0.50 J	0.22 J	0.22 U	0.30 U	0.22 U	0.33 J	0.30 U	0.61 U	*0.91 U*	0.25 U	0.34 J	0.93	0.24 U	*0.55 U*	0.59 U	0.51 J	0.54 J	0.23 U
Acenaphthylene	66	66	0.27	0.17 J	0.23 U	0.32 U	*1.20 U*	0.23	0.25 U	0.21 J	0.21 J	0.22 U	0.23 J	0.30 U	0.41 J	*0.91 U*	0.25 U	0.26 J	0.46	0.24 U	*1.85*	0.29	0.34 J	0.31	0.21 J
Anthracene	220	1200	1.58	0.93	1.11	2.72	*4.20*	1.51	1.28	1.24	1.64	1.10	1.46	1.13	2.07	*1.64*	0.78	1.27	2.73	1.22	*8.29*	2.16	2.68	3.65	1.22
Fluorene	23	79	0.71	0.34	0.29 J	0.89	*1.20 U*	0.56	0.38 J	0.38 J	0.56	0.36 J	0.50	0.30 J	0.76 J	*0.93 J*	0.25 U	0.52	1.09	0.35 J	*2.38*	0.91	0.94	1.25	0.41 J
Naphthalene	99	170	1.37	0.45	0.18 U	0.42	*1.20 U*	0.23 U	0.22 U	0.21 U	0.21 U	0.48	0.22 U	0.30 U	0.41 U	*0.91 U*	0.25 U	0.38	0.41	0.33 J	*1.38*	0.31 J	0.32 J	2.37	0.21 U
Phenanthrene	100	480	8.43	2.27	2.85	8.76	*12.0*	3.52	3.65	2.32	3.51	2.37	3.61	1.97	5.12	*2.85*	1.82	4.06	9.48	2.04	*17.2*	5.75	9.21	8.06	2.42
Total LPAHs	370	780	13.1	4.17	4.25	13.4	*16.2*	6.09	5.31	4.16	6.00	4.31	5.84	3.40	8.57	*4.30*	2.60	6.79	14.9	4.21	*31*	9.6	13.4	16.6	4.27
HPAH (mg/Kg OC)																									
Benzo(a)anthracene	110	270	5.47	3.57	4.38	9.08	*16.0*	5.51	4.61	3.34	4.72	3.04	5.20	3.16	8.48	*5.01*	2.47	5.56	14.8	3.54	*13.55*	7.36	8.22	7.43	3.63
Benzo(a)pyrene	99	210	7.48	2.96	4.22	8.34	*14.4*	4.82	3.49	2.94	4.16	3.01	4.63	3.23	7.83	*4.55*	2.24	4.28	6.88	3.77	*13.09*	5.22	7.78	8.05	3.57
Benzo(g,h,i)perylene	31	78	6.64	1.93	2.68	5.40	*8.98*	2.84	2.19	1.75	2.21	1.87	2.88	2.08	4.61	*3.36*	1.49	3.22	3.67	2.16	*8.15*	3.15	5.10	5.13	2.33
Chrysene	110	460	6.90	4.56	6.02	10.9	*19.6*	7.85	6.70	5.20	6.31	4.53	7.43	5.46	11.8	*7.44*	3.19	7.83	15.2	4.47	*17.2*	8.97	11.8	9.49	5.34
Dibenzo(a,h)anthracene	12	33	2.54	0.60	0.95	1.90	*3.33*	1.14	0.91	0.83	0.81	0.73	1.00	0.73	2.07	*1.28*	0.55	1.10	1.42	0.83	*3.11*	1.33	1.86	1.90	0.90
Fluoranthene	160	1200	22.1	8.01	9.45	21.0	*39.5*	11.0	16.1	7.2	10.2	6.33	11.1	6.41	20.5	*10.3*	5.35	13.4	48.7	7.50	*33.6*	17.4	24.0	17.0	6.92
Indeno(1,2,3-Cd)Pyrene	34	88	5.25	1.69	2.43	4.61	*8.62*	2.71	2.00	1.74	2.20	1.82	2.69	1.92	4.55	*3.00*	1.45	2.88	3.82	1.95	*7.44*	3.04	4.72	4.82	2.16
Total Benzofluoranthenes	230	450	9.64	5.17	6.21	10.9	*33.2*	7.45	6.29	4.56	6.67	4.13	7.24	17.4	13.3	*13.4*	3.57	7.33	11.7	4.92	*30.5*	8.18	10.7	11.8	6.10
Pyrene	1000	1400	12.7	5.59	7.77	16.2	*26.9*	8.48	9.77	5.46	7.21	5.15	8.99	5.64	15.6	*8.25*	4.10	10.0	28.2	10.1	*26.9*	10.6	17.3	15.4	5.22
Total HPAHs	960	5300	72.1	32.7	43.0	85.1	*171*	50.3	51.4	32.2	43.2	29.9	49.8	32.6	88.1	*56.0*	23.7	53.8	135	38.5	*154*	64.4	89.5	77.0	34.6
Chlorobenzenes (mg/Kg OC)																									
1,2-Dichlorobenzene	2.3	2.3	0.02 U	0.02 U	0.02 U	0.03 U	*0.12 U*	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.03 U	0.04 U	*0.091 U*	0.03 U	0.02 U	0.02 U	0.02 U	*0.06 U*	0.03 U	0.03 U	0.02 U	0.02 U
1,2,4-Trichlorobenzene	0.81	1.8	0.01 U	0.01 U	0.01 U	0.01 U	*0.06 U*	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.02 U	0.02 U	*0.045 U*	0.01 U	0.01 U	0.01 U	0.01 U	*0.03 U*	0.01 U	0.01 U	0.01 U	0.01 U
1,4-Dichlorobenzene	3.1	9	0.60	0.02 U	0.02 U	0.03 U	*0.12 U*	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.03 U	0.04 U	*0.091 U*	0.03 U	0.02 U	0.02 U	0.02 U	*0.06 U*	0.03 U	0.03 U	0.02 U	0.02 U
Hexachlorobenzene	0.38	2.3	0.01 U	0.01 U	0.01 U	0.01 U	*0.06 U*	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.02 U	0.02 U	*0.045 U*	0.01 U	0.01 U	0.01 U	0.01 U	*0.03 U*	0.01 U	0.01 U	0.01 U	0.14 U
Phthalates (mg/Kg OC)																									
Bis(2-Ethylhexyl)Phthalate	47	78	81.0	20.2	22.0	53.8	*45.9 U*	11.1 U	12.2 U	11.5 U	10.4 U	6.87 U	40.4	12.5 U	22.7 U	*24.3 U*	6.0 U	29.4	22.2	36.4	*41.60*	23.0	34.8	25.5	7.91 U
Benzyl Butyl Phthalate	4.9	64	8.39	1.96	2.57	12.2	*8.44*	1.84	1.71	1.54	3.04	1.80	1.58	2.90	2.87	*2.50*	2.45	2.61	1.85	1.81	*3.86*	3.89	6.54	3.25	1.43
Diethylphthalate	61	110	0.41 U	0.34 U	0.36 U	0.58 U	*2.40 U*	0.45 U	0.45 U	0.41 U	0.42 U	0.44 U	0.44 U	0.60 U	0.82 U	*1.82 U*	0.51 U	0.37 U	0.39 U	0.48 U	*1.10 U*	0.59 U	0.58 U	0.50 U	0.42 U
Dimethylphthalate	53	53	0.58 J	0.34 U	0.36 U	0.58 U	*2.40 U*	0.45 U	0.45 U	0.41 U	0.42 U	0.44 U	0.44 U	0.60 U	0.82 U	*1.82 U*	0.51 U	0.37 J	0.39 U	0.48 U	*1.10 U*	0.59 U	0.58 U	0.50 U	0.42 U
Di-N-Butylphthalate	220	1700	2.53 U	1.48 U	1.79 U	2.57 U	*8.56 U*	1.85 U	1.74 U	1.74 U	1.59 U	1.63 U	2.70 U	2.47 U	3.01 U	*6.01 U*	1.73 U	1.56 U	1.59 U	2.24 U	*4.08 U*	2.21 U	2.79 U	2.60 U	1.57 U
Di-N-Octylphthalate	58	4500	0.41 U	0.34 U	0.36 U	0.58 U	*2.40 U*	0.45 U	0.45 U	0.41 U	0.42 U	0.44 U	0.44 U	0.60 U	0.82 U	*1.82 U*	0.51 U	0.37 U	0.39 U	0.48 U	*1.10 U*	0.59 U	0.58 U	0.50 U	0.42 U
Ionic Organics (mg/kg dw)																									
2-Methylphenol	63	63	2.65 U	4.54 U	4.25 U	2.88 U	2.46 U	3.91 U	4.44 U	4.32 U	4.18 U	3.58 U	3.61 U	3.08 U	2.70 U	2.31 U	3.44 U	4.46 U	4.48 U	3.01 U	2.67 U	3.23 U	2.89 U	3.15 U	4.11 U
4-Methylphenol	670	670	5.29 U	9.07 U	8.49 U	5.76 U	4.92 U	7.81 U	11.1 J	8.64 U	8.37 U	7.16 U	7.22 U	6.16 U	5.41 U	4.62 U	6.88 U	8.93 U	8.97 U	6.02 U	5.33 U	6.45 U	5.78 U	6.31 U	8.21 U
2,4-Dimethylphenol	29	29	1.32 U	2.27 U	2.12 U	1.44 U	1.23 U	1.95 U	2.22 U	2.16 U	2.09 U	1.79 U	1.81 U	1.54 U	1.35 U	1.15 U	1.72 U	2.23 U	2.24 U	1.50 U	1.33 U	1.61 U	1.45 U	1.58 U	2.05 U
Benzyl Alcohol	57	73	2.65 U	4.54 U	4.25 U	2.88 U	2.46 U	3.91 U	4.44 U	4.32 U	4.18 U	3.58 U	3.61 U	3.08 U	2.70 U	2.31 U	3.44 U	4.46 U	4.48 U	3.01 U	2.67 U	3.23 U	2.89 U	3.15 U	4.11 U
Benzoic Acid	650	650	208	133	130	87	62	68.0	66.4	55	129	96	87	92	85	50	67	469	276	134	107	122	109	127	97
Pentachlorophenol	360	690	13.2 U	22.7 U	21.2 U	14.4 U	12.3 U	19.5 U	22.2 U	21.6 U	20.9 U	17.9 U	18.1 U	15.4 U	13.5 U	11.5 U	17.2 U	22.3 U	22.4 U	15.0 U	13.3 U	16.1 U	14.5 U	15.8 U	20.5 U
Phenol	420	1200	86.4	1594	633	376	4.92 U	209	760	607	143	167	442	333	176	29.7	208	1069	1408	268	141	310	404	549	339
Miscellaneous (mg/Kg OC)																									
Dibenzofuran	15	58	0.40 J	0.19 J	0.18 U	0.36 J	*1.20 U*	0.41 J	0.22 U	0.21 U	0.25 J	0.22 U	0.22 J	0.30 U	0.43 J	*0.909 U*	0.25 U	0.32 J	0.70	0.24 U	*1.27*	0.45	0.54 J	0.46 J	0.21 J
Hexachlorobutadiene	3.9	6.2	0.05 U	0.04 U	0.05 U	0.07 U	*0.30 U*	0.06 U	0.06 U	0.05 U	0.05 U	0.06 U	0.06 U	0.08 U	0.10 U	*0.227 U*	0.06 U	0.05 U	0.05 U	0.06 U	*0.14 U*	0.07 U	0.07 U	0.06 U	0.05 U
N-Nitroso-di-phenylamine	11	11	0.41 U	0.34 U	0.36 U	0.58 U	*2.40 U*	0.45 U	0.45 U	0.41 U	0.42 U	0.44 U	0.44 U	0.60 U	0.82 U	*1.82 U*	0.51 U	0.37 U	0.39 U	0.48 U	*1.10 U*	0.59 U	0.58 U	0.50 U	0.42 U

Blue/Light Shading = Exceeds SQS

Orange/Dark Shading = Exceeds SQS and CSL

Bolded values were detected; unbolded values were not detected.

Bolded and *italicized* total organic carbon values are <0.5%; results in italics are dry-weight normalized and were compared to AETs; AETS are in Appendix D

A field duplicate was collected at one station in each area. The average of the two replicates is presented.

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3.0. MONITORING PROGRAM OBJECTIVES AND ACTIVITIES

This section reviews the monitoring program objectives and activities planned to meet those objectives as well as the long-term monitoring activities added in the SAP addendum. Monitoring activities described under Objectives 7 and 8 in the sediment SAP were designed to address the Cap Areas A and B only. After the thin-layer placement was completed to mitigate for dredge residuals, additional monitoring activities were added via the SAP addendum to address thin-layer placement stability (Objective 7) and sediment chemistry (Objective 8) objectives.

3.1 Original Program Objectives

The water and sediment SAPs included short- and long-term monitoring objectives and activities. Short-term monitoring objectives were related to confirmation that dredging and capping activities were conducted according to plan and water quality standards were not exceeded during construction. Objectives 1 through 6 are short-term objectives and were met as documented in the project Closure Report (EBDRP 2005a). Objectives 7 and 8 are long-term objectives and are described here along with their associated monitoring activities. The water SAP was designed to address short-term objectives, primarily Objective 1, which is considered complete. Thus, this document will discuss only objectives related to sediment monitoring and reference to the "project SAP" will only include the sediment monitoring SAP and addendum, not the water quality monitoring SAP.

3.1.1 Objective 7

Objective 7 in the project SAP is "to document potential future recontamination of the cap by continuing point source discharges of storm water and combined sewer overflow." This objective was intended to cover Cap Areas A and B. Identified point sources include the Diagonal SD, a separated stormwater basin which discharges an annual average of 316 metric tons of solids per year from storm water[9]; the Diagonal CSO, comprised of several combined sewer basins which discharge an annual average of 8.3 metric tons of solids from CSOs; and the Duwamish CSO (a.k.a. Duwamish Pump Station East) which discharges an annual average of 1 metric ton of solids per year[10] (AECOM 2012, QEA 2008). Other potential point sources are from the adjacent properties.

The project SAP required surface (0-10 cm) sediment sampling on the Duwamish/Diagonal cap (i.e., stations 1A-5A, 1B-3B) and sample analysis for SMS chemicals and associated conventional parameters, such as total organic carbon (TOC), total solids and grain size distribution. Three grab samples were to be composited at each site. The cap was to be

[9] The storm water solids estimate does not include storm water collected in the combined sewer system and discharged during CSOs.
[10] Storm water solids estimate from a runoff model based on precipitation data running simulations for the period 1986-2005. CSO solids estimate from monitored overflow data from 1999 through 2006.

sampled within 3 months of placement to document surface sediment conditions and annually for the first 5 years, after which a project monitoring review meeting with EPA and Ecology would be held to determine if future monitoring is needed and at what frequency. Chemistry results were to be dry weight- or organic carbon- (OC) normalized as appropriate for comparison to SMS criteria.

3.1.2 Objective 8

Objective 8 in the project SAP is "to document cap stability for isolating contaminated sediments over time." Monitoring of cap thickness was intended to accomplish this objective. The project SAP discussed three potential methods of monitoring cap thickness: installation and surveys of measuring stakes, detailed bottom surveys, and visual inspection by camera or diver survey. Concerns about stakes breaking from boat and anchor traffic, tribal nets snagging on the stakes and difficulty of installation in rock armored areas eliminated the first method. The latter two methods (bottom surveys and visual inspection) were selected as the best methods to examine the cap for sediment erosion. The frequency was specified as annual for the first five years.

3.2 Additional Activities in SAP Addendum to Meet Program Objectives

The SAP addendum added further monitoring activities on the thin-layer placement (ENR area) and the remaining area surrounding the cap referred to as the Perimeter Area. The monitoring activities completed to meet short-term objectives (Objectives 1-6) listed in the SAP Addendum were described in the 4-acre Residuals Interim Action Closure Report (Anchor 2007). Thus, all the short-term objectives added by the SAP Addendum have been previously met and documented. The long-term monitoring activities added by the SAP Addendum[11] were:

1) measuring baseline chemistry on the surface of the ENR area (added to Objective 7),
2) annual surface sediment chemistry monitoring (added to Objective 7), and
3) taking sediment profile images (SPI's) at 11 stations within the ENR boundary (added to Objective 8).

Measuring baseline chemistry on the surface of the ENR area (Activity 1 above) was comprised of resampling six surface sediment stations previously sampled as perimeter stations (3C-7C, 14C) located within the footprint of the ENR Area shortly after thin-layer placement. The purpose of this resampling was to "provide a Year 0 baseline for that area."

Annual surface sediment chemistry monitoring (Activity 2 above) was to include 14 stations (1C-14C) and begin after thin-layer placement. The purpose of monitoring was "to evaluate the effectiveness of the ENR remedy and the natural recovery of areas not treated

[11] Objectives for these activities were not specifically named in the SAP addendum but are attributed here to the objectives named in the SAP as seen in parentheses. Monitoring activities were grouped into one of two objectives based on surface sediment chemistry (Objective 7) or cap/thin-layer stability (Objective 8).

by ENR." The option to cease monitoring earlier than five years was provided if either the sediment concentrations reached pre-action levels or a final remedial action for the area was initiated, whichever occurs first.

For all chemistry monitoring, the same sediment sampling methods were to be used with the exception of the number of samples to be composited. Ten samples per station in the Perimeter Area were to be composited to maximize comparability. To prevent the sampler from eventually breaking through the thin–layer placement, the ENR Area was to have only one grab sample collected per station. Although not specified in the SAP addendum, it was assumed the sampling depth remained the same at 0-10 cm.

SPI imaging (Activity 3 above) was to be conducted at 7 chemistry stations (3C-7C, 14C-15C) and 4 non-chemistry stake locations (24C-SPI, 26C-SPI to28C-SPI) one year post-ENR. The purpose of SPI imaging was "to document benthic recolonization of the ENR" Area (King County 2005).

4.0. REVIEW OF LONG-TERM MONITORING ACTIVITIES

This section reviews all the long-term monitoring activities completed through 2010. Section 4.1 covers Objective 7 and, thus, reviews chemistry data validation findings and the comparison of chemistry data to SMS, highlighting changes in PCBs and BEHP for each area. Section 4.1 also reviews the TOC and grain size monitoring, temporal and spatial changes in area averages for PCBs and BEHP, and summarizes the Objective 7 monitoring results. Section 4.2 covers Objective 8 and, thus, reviews the bathymetry, SPI, and diver survey results for each area, as well as a summary of the Objective 8 monitoring results.

4.1 Recontamination Monitoring (Objective 7)

Sediment grab samples were collected in the perimeter areas (1C-12C; see Figure 1) for chemistry analyses in two events: the first event occurred before dredging, and the second event occurred after sediment caps were placed on Areas A and B (capping was in February 2004). In addition, post-cap sediment monitoring was conducted in Areas A and B (1A-5A, 1B-3B) (referred to as cap baseline; Table 8). This post-cap sampling occurred June 1, 2004, 82 days after the final cap confirmation survey[12] on March 11, 2004; thus, within the time specified in the project SAP. When the thin layer of sand (ENR area) was placed in 2005, perimeter stations located in that area became "ENR Area" stations (3C-7C; see Figure 1). In addition, two new monitoring stations were selected to enhance spatial coverage of the ENR Area (14C and 15C) and one monitoring station was added along the perimeter and upstream of the Duwamish/Diagonal site (13C). All ENR (3C-7C, 14C, 15C) and Perimeter stations (1C, 2C, 8C-13C) were monitored in early 2005 before the thin-layer placement was completed. After the thin layer was placed, the ENR stations were sampled again to provide baseline conditions for the ENR area (referred to as ENR baseline; Table 8). In addition, at the same time sediment monitoring was completed for Cap Areas A and B (referred to as 2005 annual sampling; Table 8). Thereafter, all of the Cap Area A, Cap Area B, ENR and Perimeter stations were monitored annually in spring from 2006 through 2010. The completed sediment chemistry monitoring is summarized in Table 8.

Because the ENR Area was not included in the project SAP, the 5-year timeline for monitoring this area was interpreted to start in 2005 when the thin layer of sand was placed, instead of 2004 when the main cap was placed. Thus, monitoring of the ENR and Perimeter Areas continued through 2010 and King County voluntarily expanded monitoring into a 6th year in Cap Areas A and B.

[12] A confirmation survey is a bottom survey used to determine if the design requirements of the dredging and capping project were met.

Table 8. Summary of Completed Sediment Chemistry Monitoring for Duwamish/Diagonal Dredging and Capping Project

		SAMPLING YEARS										
Chemistry Stations	**Station Position**	**2003**	**2004**	**2004**	**2005**	**2005**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
		Pre-Dredge	**Post-Cap**	**Cap Baseline**	**Pre-ENR**	**ENR Baseline**	**Annual**	**Annual**	**Annual**	**Annual**	**Annual**	**Annual**
DUD_1A	**On Cap**			X			X	X	X	X	X	X
DUD_2A	**On Cap**			X			X	X	X	X	X	X
DUD_3A	**On Cap**			X			X	X	X	X	X	X
DUD_4A	**On Cap**			X			X	X	X	X	X	X
DUD_5A	**On Cap**			X			X	X	X	X	X	X
DUD_1B	**On Cap**			X			X	X	X	X	X	X
DUD_2B	**On Cap**			X			X	X	X	X	X	X
DUD_3B	**On Cap**			X			X	X	X	X	X	X
DUD_3C	**Perimeter**	X	X			**THESE STATIONS BECAME ENR STATIONS IN 2005**						
DUD_4C	**Perimeter**	X	X									
DUD_5C	**Perimeter**	X	X									
DUD_6C	**Perimeter**	X	X									
DUD_7C	**Perimeter**	X	X									
DUD_14C	**Perimeter**											
DUD_15C	**Perimeter**											
DUD_3C	**ENR**				X	X		X	X	X	X	X
DUD_4C	**ENR**				X	X		X	X	X	X	X
DUD_5C	**ENR**				X	X		X	X	X	X	X
DUD_6C	**ENR**				X	X		X	X	X	X	X
DUD_7C	**ENR**				X	X		X	X	X	X	X
DUD_14C	**ENR**				X	X		X	X	X	X	X
DUD_15C	**ENR**				X	X		X	X	X	X	X
DUD_1C	**Perimeter**	X	X		X			X	X	X	X	X
DUD_2C	**Perimeter**	X	X		X			X	X	X	X	X
DUD_8C	**Perimeter**	X	X		X			X	X	X	X	X
DUD_9C	**Perimeter**	X	X		X			X	X	X	X	X
DUD_10C	**Perimeter**	X	X		X			X	X	X	X	X
DUD_11C	**Perimeter**	X	X		X			X	X	X	X	X
DUD_12C	**Perimeter**	X	X		X			X	X	X	X	X
DUD_13C	**Perimeter***				X			X	X	X	X	X
DUD_16C	**Off Cap***				X							
DUD_17C	**Off Cap***				X							
DUD_18C	**Off Cap***				X							
DUD_19C	**Off Cap***				X							
DUD_20C	**Off Cap***				X							
DUD_30C	**Bank***				X							
DUD_31C	**Bank***				X							

Notes:
Collection dates for each sampling event are presented in Tables 1-4.
Boxes are shaded when samples collection was not required.
*Eight additional sediment samples including 2 bank samples were requested by EPA for spatial characterization.

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4.1.1 Data Validation

KCEL reviewed each year of monitoring data following QA1 guidelines (Ecology 1989) and flagged data with laboratory qualifiers where appropriate. KCEL modified their data flags in early 2009 to adapt to changes in sediment data management at Ecology (see Section 2.2.4). Data flags applied to sediment data from 2003 to 2008 are presented in Table 9. Flags applied to sediment results from 2009 and later are presented in Table 10.

Table 9. King County Laboratory Data Qualifier Flags for 2008 and earlier

Condition to Qualify	Flag
High duplicate or triplicate relative percent difference	E
Less than the reporting detection limit (RDL)	<RDL
Less than the method detection limit (MDL)	<MDL
Contamination detected in method blank	B
Biased data, low surrogate, matrix spike, or SRM recoveries	G
Biased data, high surrogate, matrix spike, or SRM recoveries	L
A sample handling criterion (e.g., preservation, holding time) has not been met	H
Text available	TA
Extremely low bias – blank spike and/or matrix spike surrogate had <10% recovery.	X

Notes: The individual surrogate recovery is used for all organic analyses with the following exception – for BNA analysis, one surrogate recovery per fraction is allowed to be outside acceptance limits without causing the associated sample data to be flagged.
SRM – standard reference material

Table 10. King County Laboratory Data Qualifier Flags for 2009 and later

Condition to Qualify	Flag
Result is above the calibration range; unknown bias	E
Less than the reporting detection limit (RDL)	<RDL
Less than the method detection limit (MDL)	<MDL
An estimated value when the measured response was outside the expected accuracy of the method.	J
The reported value is estimated with low bias	JG
The reported value is estimated with high bias	JL
A parameter in associated method blank was detected and sample result is within 5X of blank.	B
A common lab contaminant in associated method blank was detected and the sample result is > 5 and ≤ 10X the blank.	B2
A sample handling criterion was not met prior to analysis	SH
A holding time criterion has not been met prior to analysis.	H
Text available	TA

Notes: Common lab contaminants include acetone, 2-butanone, methylene chloride, bis(2-ethylhexyl)phthalate, benzylbutylphthalate, di-n-butylphthalate.

King County's Science Section in the Water and Land Resources Division conducted an independent EPA Level Stage 2a data validation review (EPA 2009) using guidance found in USEPA Contract Laboratory Program National Functional Guidelines for Low Concentration Organic Data Review (EPA 2001) and USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review (EPA 2004). Materials reviewed included Batch Reports and Analytical Quality Control Reports downloaded from King County's Laboratory Information Management System (LIMS) database. The QC parameters reviewed during this data validation include holding time, method blanks, spike blanks, matrix spikes, matrix spike duplicates, laboratory control samples, standard reference materials, laboratory replicates, and surrogates. Data validation memoranda by year can be found in Appendix B.

The majority of the 2003-2009[13] data did not require qualification. A limited number of data (109 out of 30,925 results) were rejected because the spike blank recoveries were extremely low (0-1%) and the analyte was also not detected in the associated samples. Results were rejected in 2003, 2004, and 2009 for one or more of the following analytes: aniline, benzoic acid, chromium, endrin aldehyde and/or pentachlorophenol.

Antimony results for all years were qualified as estimates with a "J" with low bias, due to matrix interference. Matrix interference for antimony is inherent in marine sediments digested using EPA Method 3050B. Several other analytes in samples were occasionally qualified as estimates with a "J" typically because QC sample results (e.g., blank spikes, matrix spikes, laboratory duplicates) were outside of control limits. However, the J flags resulting from validation did not change how the data were analyzed in this report.

The other key validation issue in the 2003-2009 data was the requalification of some laboratory B-qualified results to nondetect flags or "U"s. In these cases, the sample result is considered nondetect and the result value becomes the new reporting limit for these samples. This occurred for results in 2005 through 2009. Affected analytes included di-n-butylphthalate (DNBP), BBP, BEHP, and benzoic acid. When the laboratory B flag was not changed to a "U," the laboratory B flag was removed as the validation flag. Final validation flags for all results can be viewed in Appendix C.

4.1.2 SMS Chemicals Monitoring

This section summarizes the comparison of sediment chemistry monitoring data to SMS over the monitoring period. When TOC content falls outside the range for appropriate comparison to OC-normalized SQS and CSL, (i.e., 0.5-4.0% TOC) (Michelsen 1992), dw-normalized values were compared to dw-based AETs. The results for each area are discussed separately and the quantitative comparison to SMS for all monitoring data can be found in Appendix D1. Comparisons to AETs can be found in Appendix D2 for samples where this was necessary. In 2003, the TOC for all samples was appropriate for comparison to OC-normalized SMS; thus, no comparison to AETs was necessary.

[13] The validation results for 2010 data were discussed previously in Section 2.3

Four chemicals of concern were originally selected as related to the Duwamish/Diagonal outfalls: mercury, PCBs, BEHP, and BBP (Ecology 2002). Phthalates were acknowledged to pose a risk of recontamination from ongoing stormwater and CSO discharges. PCBs, however, were not expected to recontaminate from ongoing sources because their sources were mainly historical and PCB concentrations in ongoing sources were believed to be low. Of the four chemicals of concern, only mercury has not exceeded the SQS at any time. BEHP and PCBs had the greatest SMS exceedance ratios and highest frequency of exceedances at the Duwamish/Diagonal site. Because of this, changes in PCBs and BEHP concentrations over time are highlighted in this section; other chemicals that exceed the SMS are also noted. Data for all chemicals are presented in Appendix C.

4.1.2.1 Cap Areas A and B

Over the monitoring period, seven chemicals exceeded SMS at least once (Table 11) in the cap areas. BEHP exceeded the SQS most frequently: at one or more stations every year during the monitoring period. Also, the total PCBs SQS was exceeded at one or more monitoring stations in 2005 and 2006 and the BBP SQS was exceeded each year except 2004 and 2009. Total PCBs have not exceeded the CSL in any of the monitoring years. BEHP have had periods where the CSL was exceeded, but not consistently (Table 11). Additional chemicals that exceeded the SQS were benzoic acid, dimethylphthalate, fluoranthene and phenol. Fluoranthene and dimethylphthalate most likely came from the Diagonal Way CSO/SD based on the location of the highest concentrations: 1A. Concentrations of benzoic acid, dimethylphthalate and fluoranthene were above SMS for only one monitoring event and phenol only exceeded SMS in two monitoring events.

When the spatial distribution for SMS exceedances is examined in Area A, Station 1A has the greatest number of both SQS and CSL exceedances. Second in this ranking is Station 2A, followed by 4A, 3A, and 5A. Sample results at station 5A have never exceeded SMS. There are only three years where a chemical exceeded the SQS in Area B: 1B exceeded the PCB SQS in 2005, 2B sample results exceeded the phenol SQS in 2008 and 2010, and 3B sample results exceeded the phenol SQS in 2010. Cap Area B has not experienced any exceedances of the CSL during the monitoring period.

Table 11. Chemicals Exceeding SMS at Cap Area A and B Stations

Year Sampled[2]	Chemical	Station Exceeding SMS[1]	
		>SQS	>CSL
2004	Bis(2-Ethylhexyl)Phthalate	2A	None
2005	Benzyl Butyl Phthalate	2A, 3A	None
	Bis(2-Ethylhexyl)Phthalate	1A-3A	2A
	Fluoranthene	1A	None
	Total PCBs	1A, 1B	None
2006	Benzoic Acid	1A	1A
	Benzyl Butyl Phthalate	1A, 2A	None
	Bis(2-Ethylhexyl)Phthalate	1A, 2A, 4A	1A, 4A
	Total PCBs	1A, 4A	None
2007	Benzyl Butyl Phthalate	1A	None
	Bis(2-Ethylhexyl)Phthalate	1A, 2A, 4A	1A
2008	Benzyl Butyl Phthalate	1A, 4A	None
	Bis(2-Ethylhexyl)Phthalate	2A-4A	None
	Dimethylphthalate	1A	1A
	Phenol	2B	None
2009	Bis(2-Ethylhexyl)Phthalate	1A	None
2010	Benzyl Butyl Phthalate	1A, 4A	None
	Bis(2-Ethylhexyl)Phthalate	1A, 4A	1A
	Phenol	2A, 3A, 2B, 3B	2A

[1] When the TOC was <0.5% or > 4%, the chemical concentration was compared to the LAET, the SQS dry weight equivalent, and the 2LAET, the CSL dry weight equivalent, for the OC-normalized SMS values.
[2] All monitoring occurred after dredging and capping was completed.

Changes in Total PCBs

Changes in sediment total PCB dry weight concentrations by year are presented for Cap Areas A and B stations in Figures 6 and 7, respectively. PCB concentrations in the Cap Area A samples increased in 2005 and 2006 compared to cap baseline conditions measured in 2004, particularly at stations 1A, 2A and 3A. This increase in PCB concentrations is likely due to discharges from the Diagonal CSO/SD and Duwamish CSO. The City of Seattle cleaned approximately 6,200 linear feet of pipe in the lower portion of the Diagonal CSO/SD drainage system during a period from 2002 to 2004 (Windward 2010). The main trunk line was cleaned in 2003 and 2004. Any residual solids mobilized following the cleaning (i.e., material not completely removed and then scoured) would have been flushed through the system during wet season high flows and likely passed through the outfall during CSO or stormwater discharges. This may have contributed more PCBs to the receiving surface sediments. Any impacts from the pipe cleaning would likely be reflected more in the 2005 and possibly 2006 monitoring data than from later years. After 2006, PCB

concentrations decreased at 1A, 2A, and 3A and approached concentrations similar to those measured at 4A.

The spatial pattern of total PCB concentrations at Cap Area A follows station number order through 2007, with 1A being the highest and 5A being the lowest concentration. After 2007, total PCB concentrations decreased at 1A and 2A and stayed relatively stable at 3A, 4A, and 5A (Figure 6). The changes in Cap Area A were most dramatic during the 2005 and 2006 monitoring periods at 1A, 2A, and 3A where a clear PCB signal can be seen. Overall in Cap Area A, total PCB concentrations at each station are trending toward a range between 50 and 100 µg/kg dw with the exception of 5A where concentrations have remained similar to baseline conditions (< 20 µg/kg dw). Total PCB concentrations have been consistently low at 5A throughout the monitoring program.

In Cap Area B, total PCB concentrations at 1B were generally higher each year than at 2B or 3B, and those at 3B were lowest (Figure 7). PCB concentrations tended to remain similar over the monitoring period at each station except in year 2008, when concentrations increased and 2009, when concentrations decreased below those measured in 2007. Overall, PCB concentrations remained more consistent in Area B compared to Area A over the monitoring program (ranged between 20 and 170 µg/kg dw) although Area B post-cap baseline concentrations were higher on average than Area A. However, both areas seem to be trending toward a range between 50 and 100 µg/kg dw.

Changes in BEHP

Changes in surface sediment BEHP dry weight concentrations by year are presented for Cap Area A and B stations in Figures 8 and 9, respectively. BEHP concentrations increased 3 to 10 fold in 2005 over cap baseline conditions in 2004 at 1A, 2A and 3A (Figure 8). This was most likely due to discharges from the Diagonal CSO/SD and Duwamish CSO. The 2003/2004 pipe cleaning in the Diagonal CSO/SD previously discussed may have resulted in elevated BEHP in Diagonal CSO/SD discharges. Stations 4A and 5A did not appear to be impacted. Since 2005, BEHP concentrations have declined at 1A, 2A and 3A into the 500 and 1000 µg/kg dw range. BEHP concentrations at 4A have slowly increased into the same 500 to 1000 µg/kg dw range. BEHP has not been detected at 5A over most of the monitoring period, which is similar to results for other chemicals at this station.

In contrast to Cap Area A, Cap Area B shows much lower concentrations of BEHP over the monitoring period. While concentrations have generally increased from baseline cap conditions, the concentrations have been variable without a notable increasing or decreasing trend (Figure 9). With the exception of 2008, BEHP have ranged from about 200 to 600 µg/kg dw.

BEHP is a ubiquitous, urban contaminant that has been found throughout the drainage basin in stormwater solids samples (Windward 2010, Floyd|Snider 2007). In addition, recontamination modeling predicted recontamination of BEHP on the cap (EBDRP 2005b). Thus, it is not surprising that BEHP continues to be detected with variable magnitude from year to year and that it often exceeds SMS criteria at Cap Area A. Although BEHP may be

discharged from the Diagonal CSO/SD outfall, the spatial distribution of BEHP over the monitoring program does not suggest this is the only source of BEHP to the Duwamish Diagonal site.

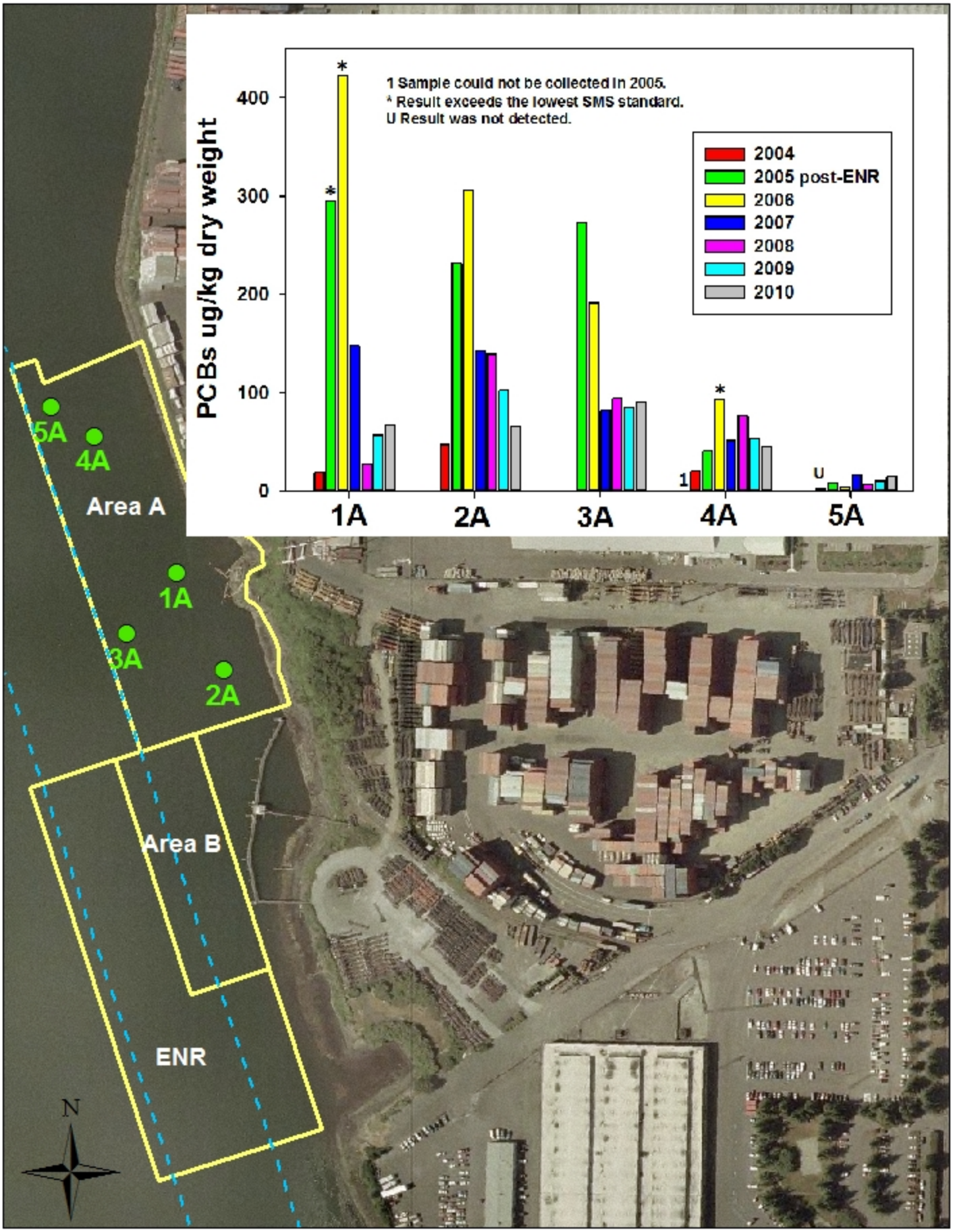

Figure 6. Changes in Total PCB Concentrations Over Time - Area A

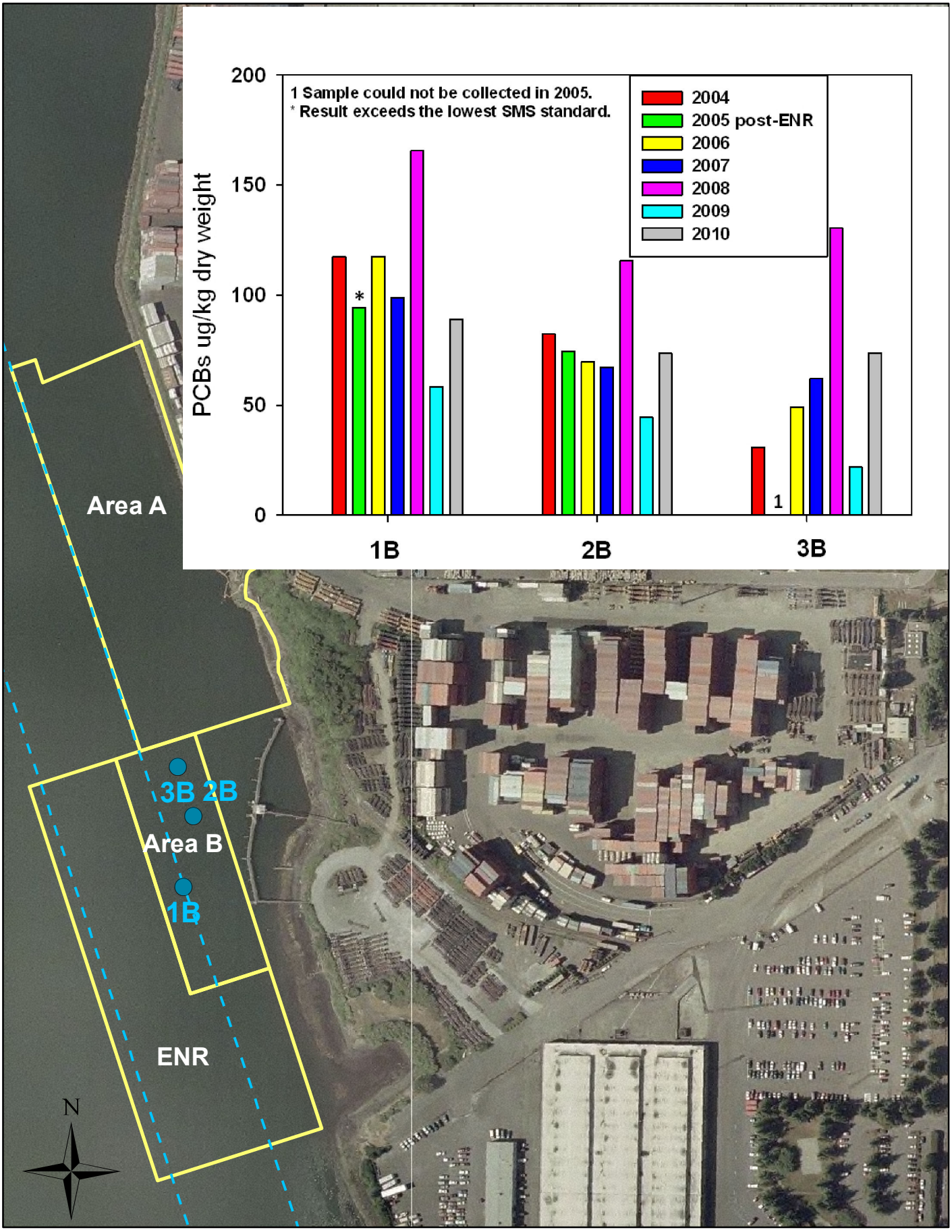

Figure 7. Changes in Total PCB Concentrations Over Time - Area B

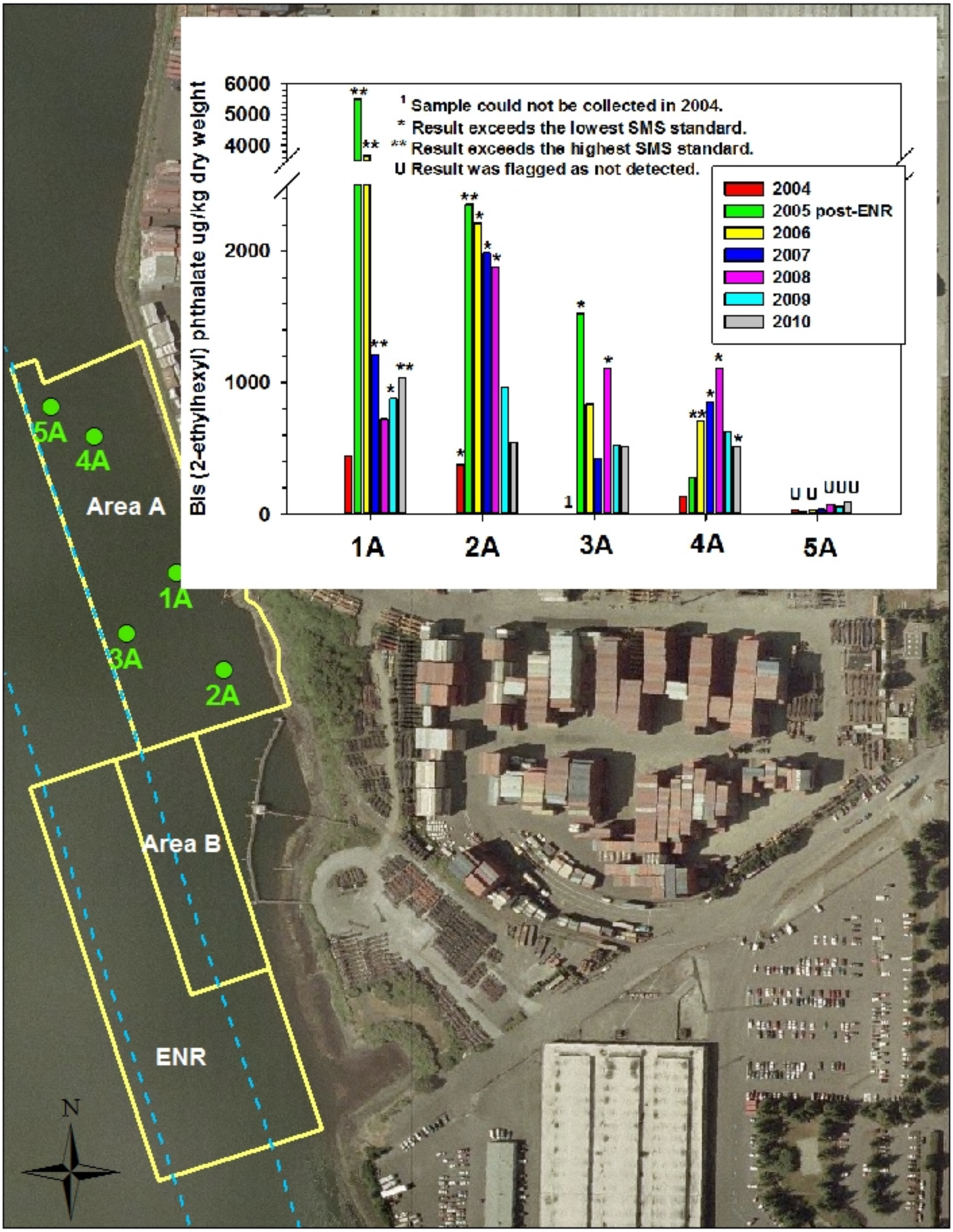

Figure 8. Changes in BEHP Concentrations Over Time - Area A

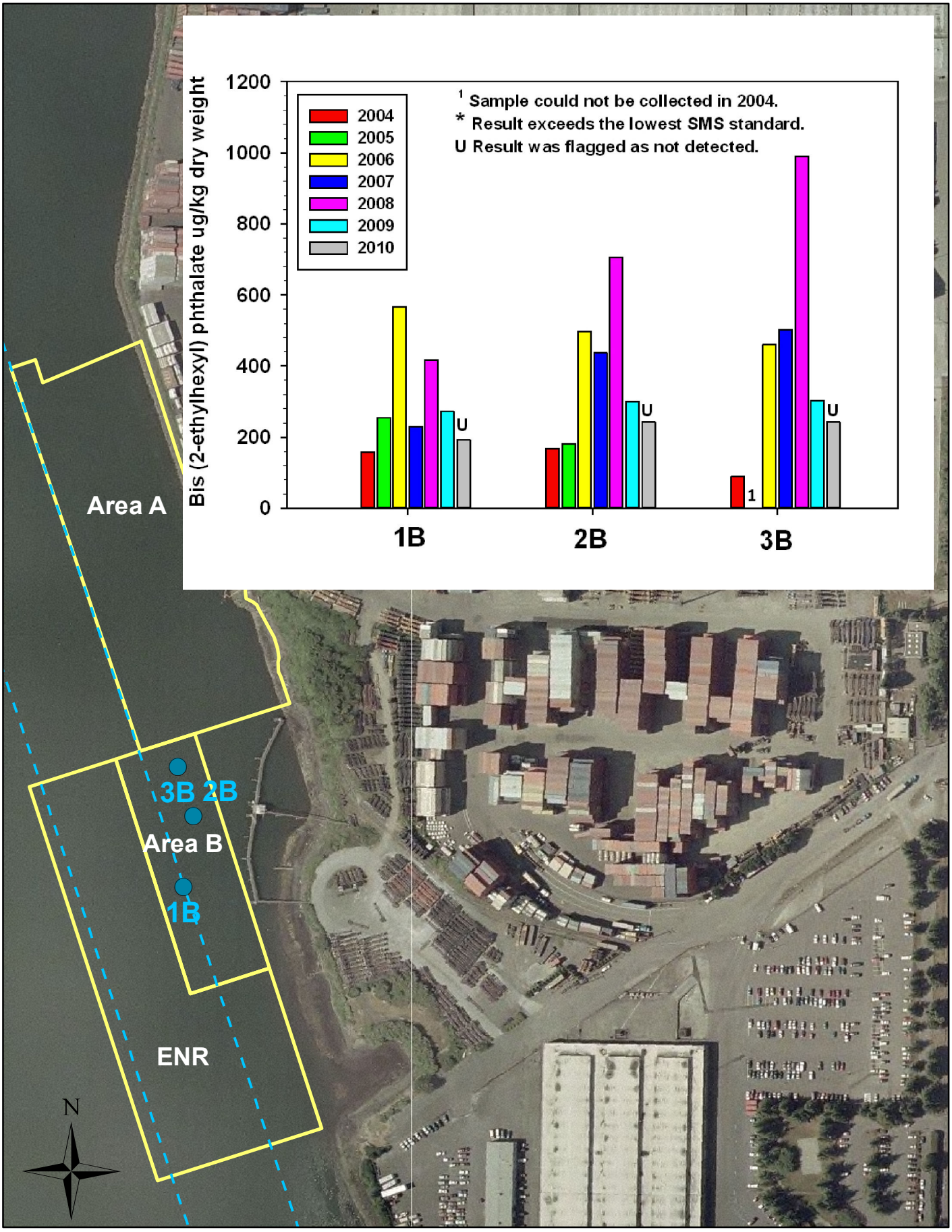

Figure 9. Changes in BEHP Concentrations Over Time - Area B

4.1.2.2 ENR Area

Prior to any remedial action, PCBs, mercury, BEHP and 1,4 dichlorobenzene exceeded the SQS/CSL at several stations (Table 12). Following the dredging and capping in Areas A and B, 1,4 dichlorobenzene no longer exceeded SMS, but BEHP and PCBs exceeded the CSL and BBP exceeded the SQS at several stations. This suggests this area was affected by dredge residuals. Within a year and just prior to thin-layer placement, the concentrations of all three chemicals were already receding, suggesting natural recovery of the residuals was occurring.

Prior to thin-layer placement, at least one sample result exceeded SMS for four chemicals: BEHP, BBP, mercury, and total PCBs (Table 12). The BEHP SQS was the most frequently exceeded (pre-ENR) of these four chemicals followed by PCBs SQS exceedances (pre-ENR, post-dredging). Before the thin layer was placed, SMS exceedances occurred in at least one sample at all stations that would become ENR stations. Following thin-layer placement, only two chemicals, ever exceeded the SMS; BEHP at 4C in 2009 and phenol at 3C in 2010. No other chemicals exceeded SMS over the monitoring period following thin-layer placement.

Table 12. Chemicals Exceeding SMS at ENR Area Stations

Year Sampled	Chemical	Station Exceeding SMS[1]	
		>SQS	>CSL
Prior to Dredging			
2003 October	Bis(2-Ethylhexyl)Phthalate	3C, 7C	None
	Total PCBs	3C - 7C	4C, 6C
	1,4 Dichlorobenzene	6C	6C
2003 December[2]	Mercury	4C	None
	Bis(2-Ethylhexyl)Phthalate	4C	4C
	Total PCBs	4C	None
Following Dredging and Capping			
2004	Benzyl Butyl Phthalate	3C, 6C, 7C	None
	Bis(2-Ethylhexyl)Phthalate	3C, 5C-7C	3C, 5C, 6C
	Total PCBs	3C-7C	3C, 5C-7C
2005 pre-ENR	Bis(2-Ethylhexyl)Phthalate	5C, 14C	None
	Total PCBs	3C-7C, 14C, 15C	3C, 5C, 6C
Following Thin-layer Placement			
2006-2008	None	None	None
2009	Bis(2-Ethylhexyl)Phthalate	4C	4C
2010	Phenol	3C	None

Notes: No chemicals exceeded SMS for years not presented in table.

[1] When the TOC was <0.5% or > 4%, the chemical concentration was compared to the LAET, the SQS dry weight equivalent, and the 2LAET, the CSL dry weight equivalent, for the OC-normalized SMS values.

[2] A second sample was collected at 4C two months after the regular sampling in 2003, mainly to assess divergent PCB results in field duplicates. This sample is presented separately.

Changes in Total PCBs

Changes in surface sediment PCB dry weight concentrations by year are presented in Figure 10. Following dredging and capping, surface sediment PCB concentrations substantially increased above 2003 levels in the area where the thin-layer placement occurred. As discussed in Section 1.1 Project Background, it was these increased PCB concentrations around the cap from dredge residuals that led to placing a thin layer of sand to the south and west of Cap B (Figure 10). The thin-layer placement immediately and substantially reduced surface sediment PCB concentrations at all stations in this area (3C-7C, 14C, 15C), as demonstrated by the 2006 PCB data (Figure 10). Since 2006, PCB concentrations have increased at 3C, 4C, 7C, 14C and 15C but never exceeded 150 µg/kg dw, and for some locations, it has rarely exceeded 50 µg/kg dw. PCB concentrations at 5C and 6C have remained consistently low (approximately 15-40 µg/kg dw).

Changes in BEHP

Changes in surface sediment BEHP dry weight concentration by year are presented in Figure 11. The impact of dredge residuals on BEHP concentrations was not as significant as it was for PCBs. This is consistent with the relatively lower concentrations in BEHP subsurface concentrations in the dredged material compared to PCBs (EBDRP 2005b). Overall, dredge residuals increases were most evident at stations 5C and 6C and to some extent 7C (Figure 11). Similar to PCB concentrations, BEHP concentrations were immediately and substantially lowered by the thin-layer placement. BEHP concentrations have generally remained low over the monitoring period since thin-layer placement.

4.1.2.3 Perimeter Area

Prior to any remedial action, BEHP and PCBs exceeded the SQS or CSL at several stations in the Perimeter Area while cadmium, silver and mercury exceeded the SQS or SQS and CSL at one station (8C) (Table 13). Following the dredging and capping in Areas A and B, BEHP, BBP, and PCBs were elevated at several stations in the Perimeter Area, suggesting this area was affected by dredge residuals, although not to the same degree as the ENR area. Since the Perimeter Area was projected to naturally recover to pre-dredge levels within 1-2 years, it was decided not to place a thin layer of sand here (Anchor 2007; Appendix C). Within the first year post-dredge and capping, SMS exceedances were reduced and the concentrations BEHP, BBP and PCBs declined back to or below pre-dredge levels. This suggests natural recovery of those dredge residuals was occurring.

PCBs exceeded SQS at more Perimeter Area stations each year than any other chemical except phenol in 2010. PCB concentrations at two stations (i.e., 12C, 8C) exceeded SMS every year of the monitoring program. PCB concentrations at four stations exceeded SQS the majority of years sampled: 8C, 9C, 10C, and 12C. At 11C, PCB concentrations decreased to below SQS in 2004 and have remained below the SQS. The temporal patterns at 1C and 2C are similar with PCB concentrations exceeding the SQS through 2006, and then decreasing to below the SQS. PCB concentrations at 13C did not decrease to below the SQS until 2009.

BEHP concentrations were above SQS, and sometimes the CSL, at most stations over the majority of the monitoring program, although trending downward with time. Exceptions were that BEHP concentrations at 10C only exceeded the SQS in 2004 and 2006 while concentrations at 13C never exceeded the SQS. In recent years, concentrations were generally lower, with station 11C being the only one with an SMS exceedance for BEHP in 2009 and no exceedances at any station in 2010.

BBP exceeded SQS at one or more stations every year of the monitoring period. Mercury, phenol and benzoic acid exceeded SQS or SQS and CSL at only a few locations. Acenaphthene and fluoranthene were the only PAHs that exceeded SQS over the monitoring period, and this occurred only in 2006 at station 2C. Following dredging and capping, silver and cadmium never exceeded either SQS or CSL again.

SQS exceedances of BBP are common but appear spatially random; for example, occurring at a single station in one year and at five stations the next. The spatial pattern for BEHP through 2006 is more consistent than BBP but after 2006 the number of exceedances decline and the stations with SQS or CSL exceedances vary notably each year. These patterns likely reflect the ubiquitous characteristic of these phthalates. The stations with SQS or CSL exceedances for PCBs are relatively consistent with fewer stations exceeding SQS over time. Phenol only exceeded at one station in 2006 and then exceeded at three stations in 2010, reflective of its transient nature in sediments. Exceedance of SQS or CSL occurred for four other chemicals (mercury, benzoic acid, acenaphthene, and fluoranthene) at 1C, 2C, 8C, or 10C (Table 13).

Changes in Total PCBs

Changes in surface sediment total PCB dry weight concentrations by year are presented in Figure 12. Temporal changes were highly variable across stations. Temporal and spatial changes in PCB concentrations in the Perimeter Area reflect the industrial, highly active (from vessel traffic), and depositional nature of the Lower Duwamish Waterway at Duwamish/Diagonal. Each station shows a slightly different pattern of change over time but all stations indicate overall decreases in PCB surface sediment concentrations between 2003 and 2010 (Figure 12). The exception was at station 8C which had a significant increase in 2009 before decreasing in concentration again. There is also evidence of dredge residuals increasing PCB concentrations between 2003 (prior to dredging) and 2004 (following dredging and capping); this is most evident at stations 9C, 10C, and 12C. The lowest PCB concentrations at these three stations occurred in the last two years of monitoring (2009 and 2010).

Table 13. Chemicals Exceeding SMS at Perimeter Area Stations[1]

Year Sampled	Chemical	Station Exceeding SMS[2]	
		>SQS	>CSL
Prior to Dredging			
2003	Cadmium	8C	None
	Mercury	8C	8C
	Silver	8C	8C
	Benzyl Butyl Phthalate	11C	None
	Bis(2-Ethylhexyl)Phthalate	1C, 2C, 8C, 9C, 11C, 12C	1C, 2C, 8C, 11C
	Total PCBs	1C, 2C, 8C-12C	8C
Following Dredging and Capping			
2004	Mercury	10C	10C
	Benzyl Butyl Phthalate	1C, 2C, 8C, 9C, 12C	None
	Bis(2-Ethylhexyl)Phthalate	1C, 2C, 8C, 9C, 10C, 12C	1C, 2C, 8C, 9C, 12C
	Total PCBs	1C, 2C, 8C-10C, 12C	8C, 9C, 12C
2005	Benzyl Butyl Phthalate	2C[2]	None
	Bis(2-Ethylhexyl)Phthalate	1C, 2C, 8C, 9C, 12C	None
	Total PCBs	1C, 2C, 8C-10C, 12C, 13C	8C
2006	Mercury	10C	None
	Acenaphthene	2C	None
	Benzoic Acid	1C	1C
	Benzyl Butyl Phthalate	1C, 2C, 8C, 11C, 12C	None
	Bis(2-Ethylhexyl)Phthalate	1C, 2C, 8C, 10C-12C	1C, 2C, 11C, 12C
	Fluoranthene	2C	None
	Phenol	2C	2C
	Total PCBs	1C, 2C, 8C-10C, 12C, 13C	None
2007	Benzyl Butyl Phthalate	2C, 11C	None
	Bis(2-Ethylhexyl)Phthalate	1C, 12C	None
	Total PCBs	8C, 9C, 12C, 13C	None
2008	Benzoic Acid	2C	2C
	Benzyl Butyl Phthalate	1C	None
	Bis(2-Ethylhexyl)Phthalate	1C, 2C, 9C, 11C, 12C	1C, 11C
	Total PCBs	8C-10C, 12C, 13C	None
2009	Mercury	8C	8C
	Bis(2-Ethylhexyl)Phthalate	11C	11C
	Benzyl Butyl Phthalate	11C	None
	Total PCBs	8C-10C, 12C	8C
2010	Benzyl Butyl Phthalate	11C	None
	Phenol	1C, 2C, 12C	2C
	Total PCBs	8C, 10C, 12C	None

[1] Additional characterization stations (16C-20C, 30C and 31C) were sampled only once in 2005. These stations were not part of the long-term monitoring program. The chemistry results for these stations are presented in a previous report (EBDRP 2007).
[2]When the TOC was <0.5% or > 4%, the chemical concentration was compared to the LAET, the SQS dry weight equivalent, and the 2LAET, the CSL dry weight equivalent, for the OC-normalized SMS values.

Station 8C samples had the highest PCB concentrations in 2003 and 2004. During 2005 through 2008, PCB concentrations at 8C fell within the range of other Perimeter stations. In 2009, high sample and replicate PCB concentrations were observed at 8C and are believed to result from the large number of replicate grabs (10) in the sampling design, plus the collection of field replicates at this station in 2009 which doubled the total number of grabs. Collection of all these sediment grabs in the same area may have removed enough of the more recently deposited sediment in the top 10 cm to reach more contaminated sediments buried below the cleaner surface layer. Historical sediment core data, collected in 2003 to measure subsurface sediment concentrations, showed that the average PCB concentration in the top 1 foot at a core station (DUD255) close to 8C was 3,600 µg/kg dw (Windward 2010). By 2008, the surface sediment PCB concentration had fallen to 290 µg/kg dw. The 2009 PCB concentration at 8C was 3,000 µg/kg dw. The decision was made to reduce the number of grabs for compositing from 10 to 3 for the 2010 sampling; hence increasing the likelihood of sampling from adjacent surface sediments instead of the spot repeatedly disturbed in 2009. The three-fold decrease in PCB concentrations at 8C in 2010 supports the hypothesis that the unexpectedly high 2009 PCB concentrations were not representative of surface sediments in that area but of subsurface sediments exposed by repeated sampling. It is also possible that cleaner sediments from other locations including the Green River deposited in the location contributing to the lower PCB concentrations in 2010.

Changes in BEHP

Changes in surface sediment BEHP dry weight concentrations by year are presented in Figure 13. BEHP concentrations in the Perimeter Area were more temporally and spatially variable than PCB concentrations. As noted earlier, BEHP and other phthalates are ubiquitous in urban areas with multiple sources. These characteristics are reflected in the monitoring results (Figure 13). Temporal variability was highest at stations 1C and 2C while the greatest temporal stability in BEHP was at 9C, 10C, and 13C. Similar to PCBs, BEHP concentrations increased in 2009 at 8C and then decreased in 2010 towards 2007/2008 levels. Sediment core samples taken at 8C during the 2003 preconstruction monitoring showed subsurface sediment BEHP concentrations of 1,700 µg/kg dw at 0-1 foot interval and 1,200 µg/kg dw at 1-2.5 foot interval (Windward 2010). In 2009, BEHP at Station 8C increased to an average concentration just below 1000 µg/kg dw but in 2010 concentrations decreased to 692 µg/kg dw. Thus, these results further support the hypothesis that some subsurface sediments were collected in 2009 as part of the 20 grab samples (i.e., 10 grabs composited for the sample and 10 grabs composited for the replicate). Despite the spatial and temporal variability in BEHP concentrations, the overall trend appears downward supporting the hypothesis that natural recovery is occurring in this area.

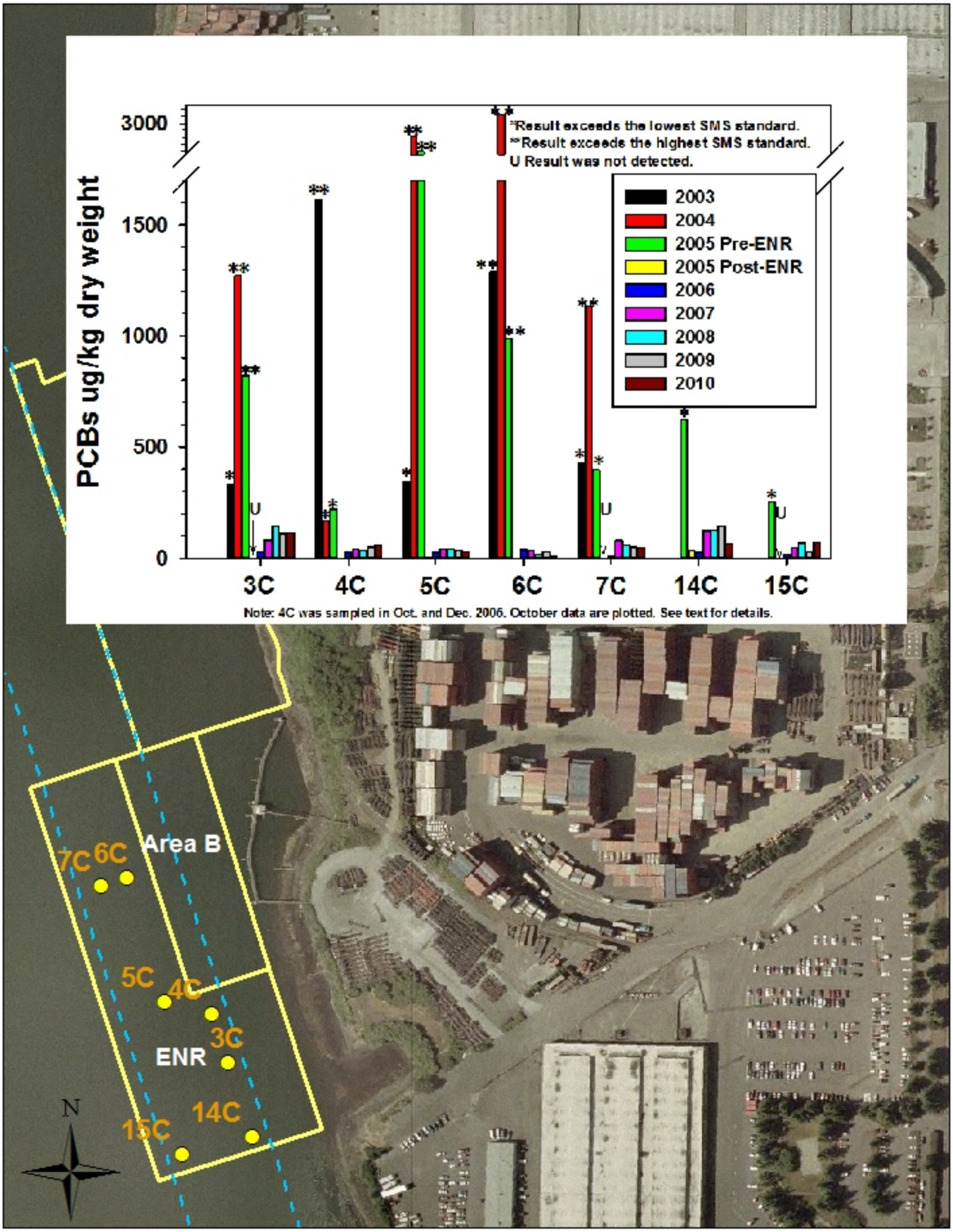

Figure 10. Changes in Total PCB Concentrations Over Time - ENR Area

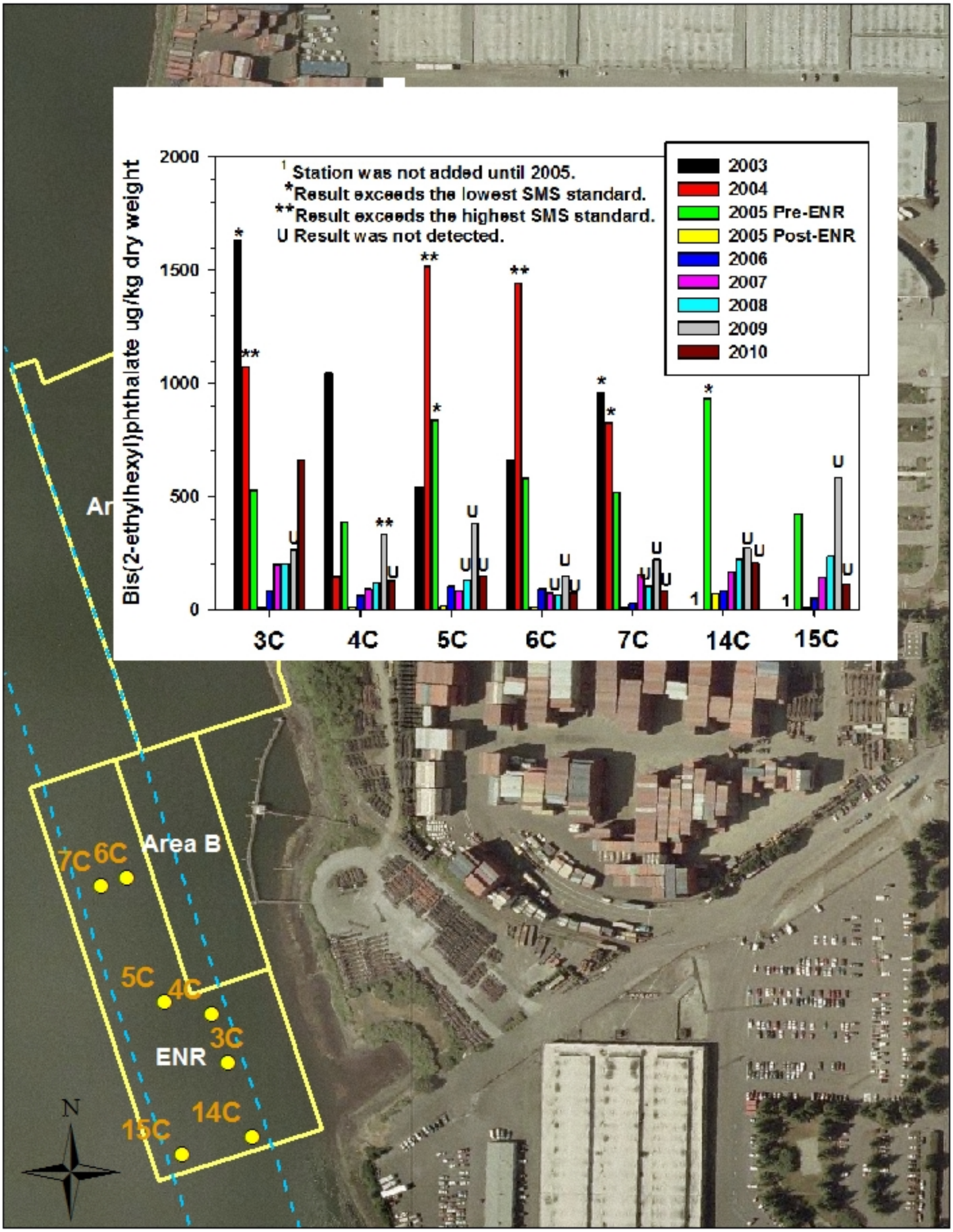

Figure 11. Changes in BEHP Concentrations Over Time - ENR Area

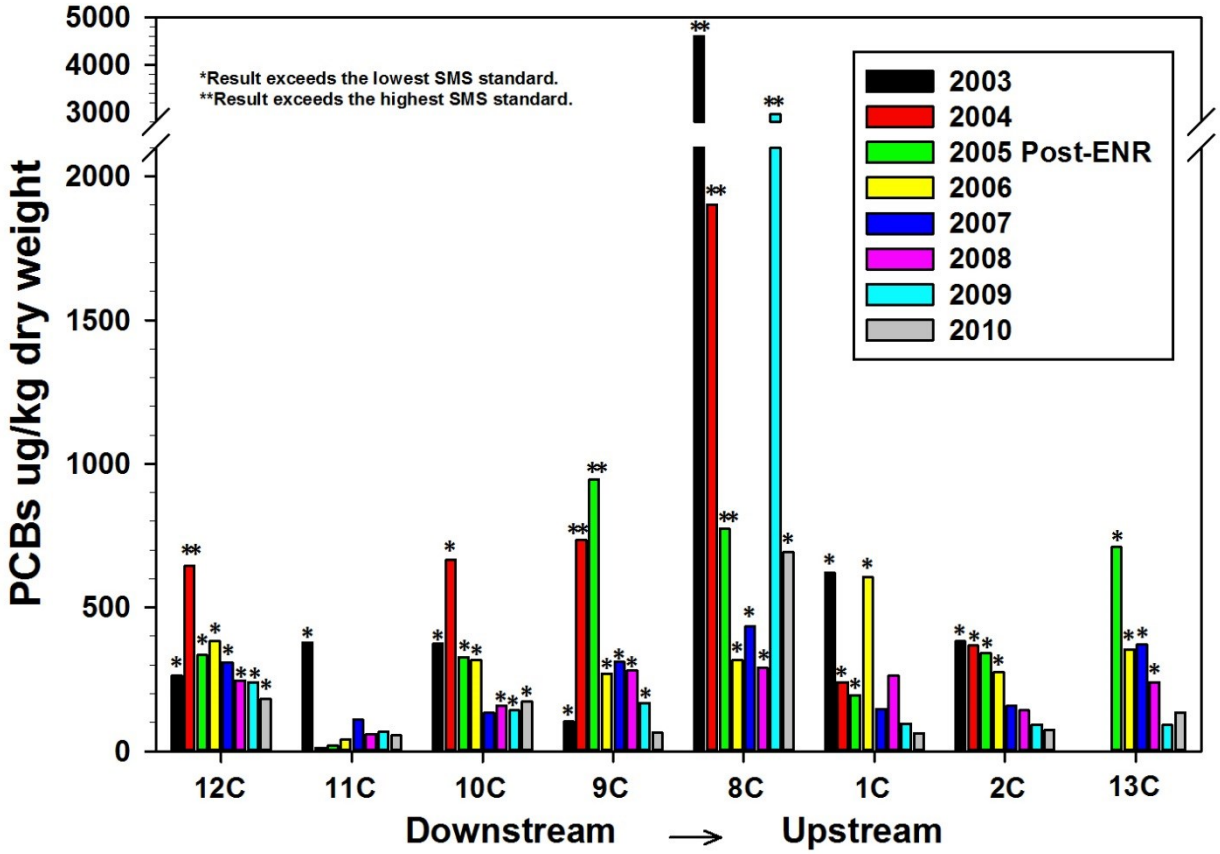

Figure 12. Changes in Total PCB Concentrations Over Time – Perimeter Area

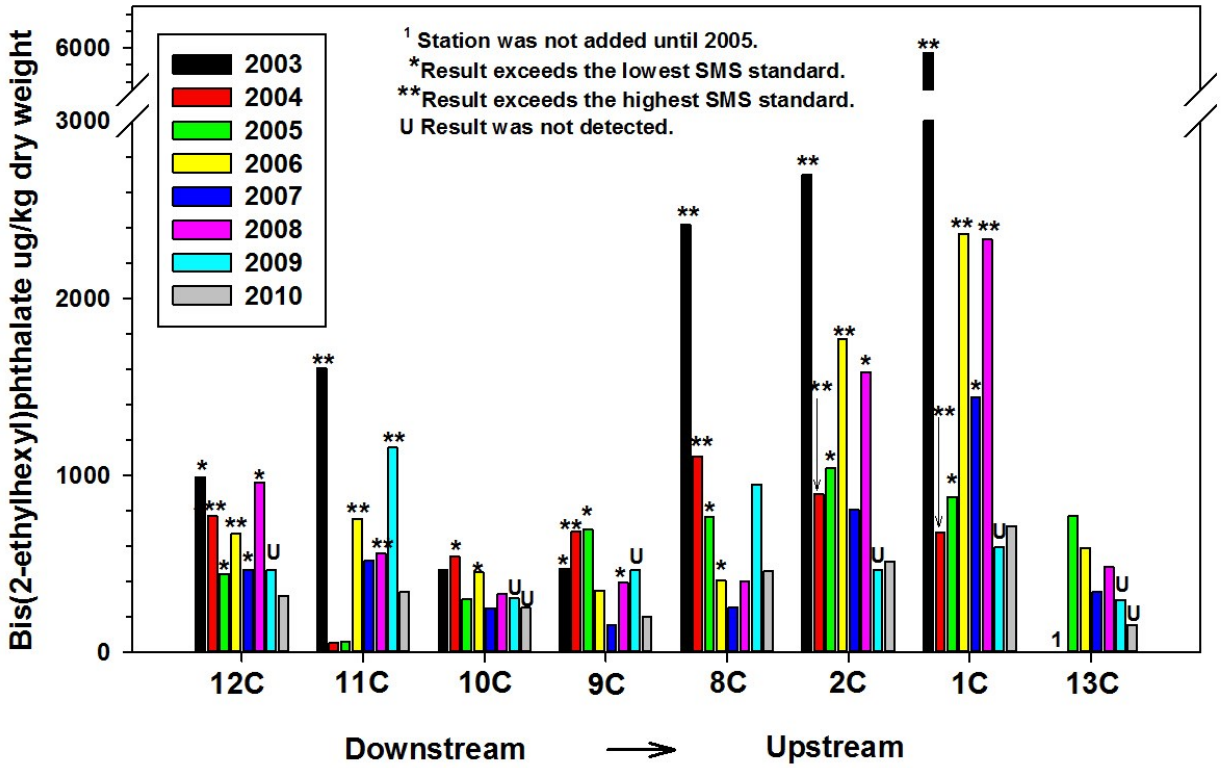

Figure 13. Changes in BEHP Concentrations Over Time – Perimeter Area

4.1.3 TOC and Grain Size Monitoring

4.1.3.1 Cap Areas A and B

Changes in TOC and percent fines over the monitoring period measured at Areas A and B stations are shown in Figures 14 - 17. At most of the Area A and B stations, percent fines started low post-cap (2004) at <20%, reflecting the new sand or habitat mix cap surface, and rapidly increased by 2-8 times within 3 years. Exceptions are at 1A and 5A. Station 1A is located offshore of the Diagonal Way CSO/SD outfall. Stormwater and CSO discharges from this outfall appear to contribute to deposition of higher fines content at station 1A (Figure 15), hence the consistent and high (>80%) fines composition at this station. In contrast, there appears to be some hydrodynamic conditions that are preventing the deposition or retention of fine material at 5A resulting in consistently low percent fines. More deposition appears to be occurring at 4A but not nearly as much as at 1A-3A or 1B-3B.

The relative amount of TOC has increased since baseline conditions (2004) at all stations in Cap Areas A and B. The temporal changes in TOC generally reflect corresponding changes in fines composition, although the percent TOC plateaus earlier than the corresponding percent fines. An exception is Station 1A where TOC is low at baseline, similar to other cap stations, but percent fines are high at baseline in contrast to other stations. Changes in TOC at 1A are more variable than other stations, presumably because of the direct influence from TOC content in Diagonal Way CSO/SD discharges. Station 1A also showed the most dramatic increase in TOC over baseline conditions; <0.5% to greater than 5.5% in one year. The TOC content at 5A has been consistently low (<0.5%), congruent with the low fines at this location.

4.1.3.2 ENR Area

Changes in TOC and percent fines over the monitoring period in the ENR Area stations are shown in Figures 18 and 19, respectively. The figures show conditions prior to dredging Cap Areas A and B (2003), following capping of Cap areas A and B and prior to (2005) and following (2006) thin-layer placement. As shown in the figures, the percent fines and TOC data at stations 3C and 4C appear to be influenced by the dredge and capping activities in 2003/2004 whereas stations 5C, 6C and 7C do not appear to have changed appreciably. TOC decreased by 50% or more at 3C and 4C after the dredging and capping activities. This may have been caused by upstream drift of the sandy cap material (low in organic carbon and fines content) from placement during flood tides. However, all the ENR area stations showed decreases in both TOC and fines content after thin-layer placement (see 2006 data) due to the characteristics of the imported clean sand. TOC and percent fines returned to pre-ENR area levels at most stations within four years of thin-layer placement (i.e., 2009).

Overall, TOC and percent fines in the ENR area appear to be moving toward the 1 to 2% and 50 to 80% ranges, respectively. These values are similar but slightly lower than those at Cap Area B. Ranges of TOC and fines appear lower at stations 4C, 5C, and 6C, ranging around 0.5 to 1.0% TOC and 10 to 30% fines. It is uncertain what is causing the difference in TOC and fines proportions at these stations.

4.1.3.3 Perimeter Area

Changes in TOC and percent fines content over the monitoring period in the Perimeter Area are shown in Figures 20 and 21, respectively. Temporal changes in relative TOC and fines content varied with location. At 13C, the most upstream station, and 10C, the most downstream station in the navigation channel and farthest removed from the remedial actions, relative TOC and fines content were the most stable over the monitoring period. Changes at 1C and 2C were similar with time reflecting their similar location between Cap Area B and the shoreline. Following capping activities in 2004, the TOC and percent fines dropped by half or more at 1C and 2C followed by annual increases until 2007 (for fines) and 2008 (for TOC).During the last three years of monitoring, TOC and fines content appear to be stabilizing at 1C and 2C. Although stations 11C and 12C are relatively close and at similar distance from shore, fines and TOC content differed over time. TOC and fines content at 12C were more stable than at 11C; this may be due to the proximity of 11C to Area A cap. The largest changes at 11C occurred after capping, when TOC and percent fines dropped by 80% or more, remained low through 2005, and then increased. The data suggest this location received some cap material from placements during ebb tides when the cap was placed in Area A. Station 12C may have also received a smaller amount of cap material. The chemistry data for total PCBs and BEHP support this idea (see Figures 12 and 13). Stations 8C and 9C which are located in the navigation channel have shown variable levels of TOC and fines over the monitoring period. As with the chemistry data, an increase in TOC and fines content at 8C was observed in 2009.

The most recent data indicate that percent fines at stations 8C-12C are generally heading toward 30 to 50%. Comparable data at 1C, 2C and 13C show fines are heading towards 70 to 85%. The same spatial relationship holds true for TOC with 8C-12C heading toward the 1 to 1.5%, and 1C, 2C and 13C heading toward 2 to 2.5%.

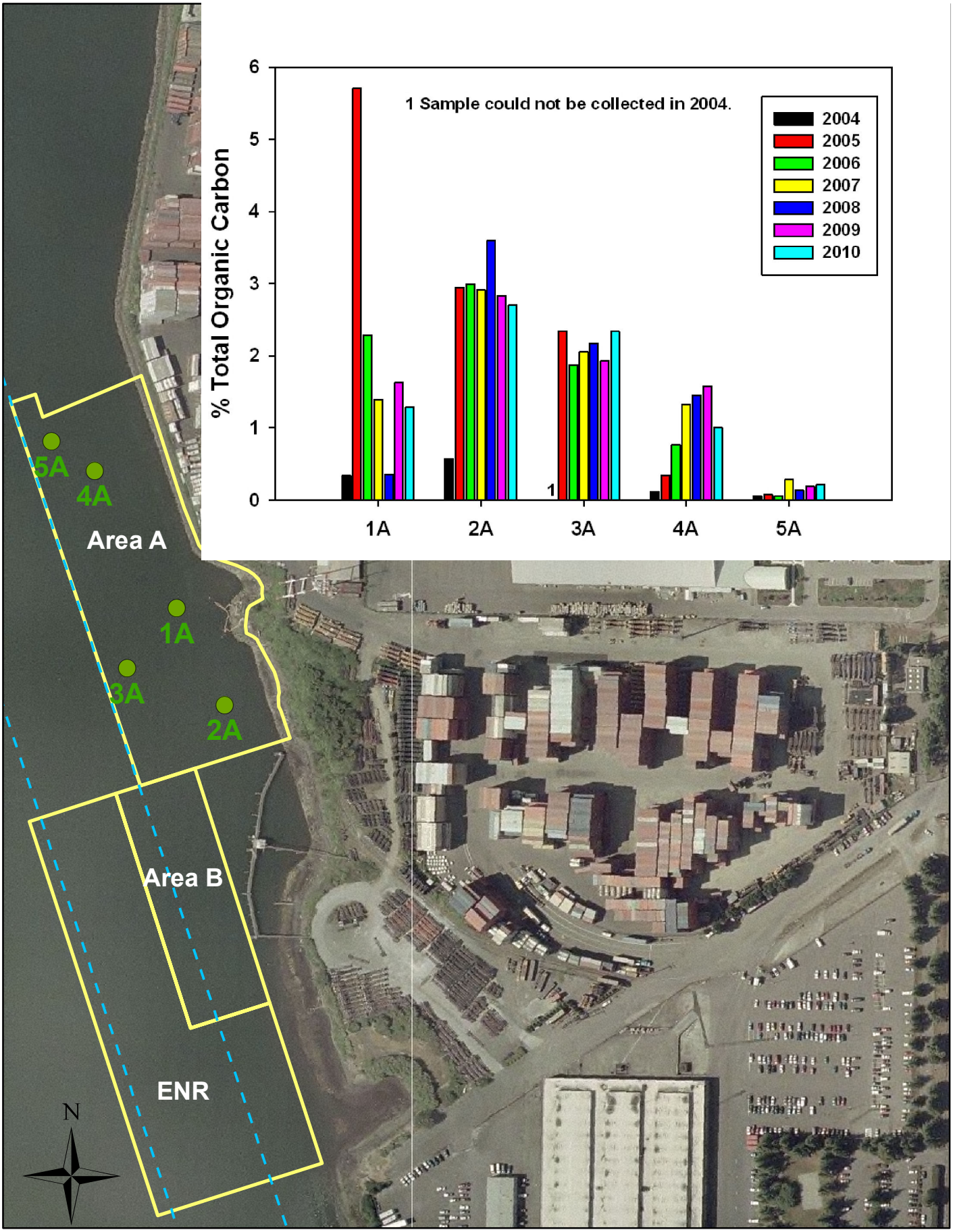

Figure 14. Changes in Relative TOC Over Time - Area A

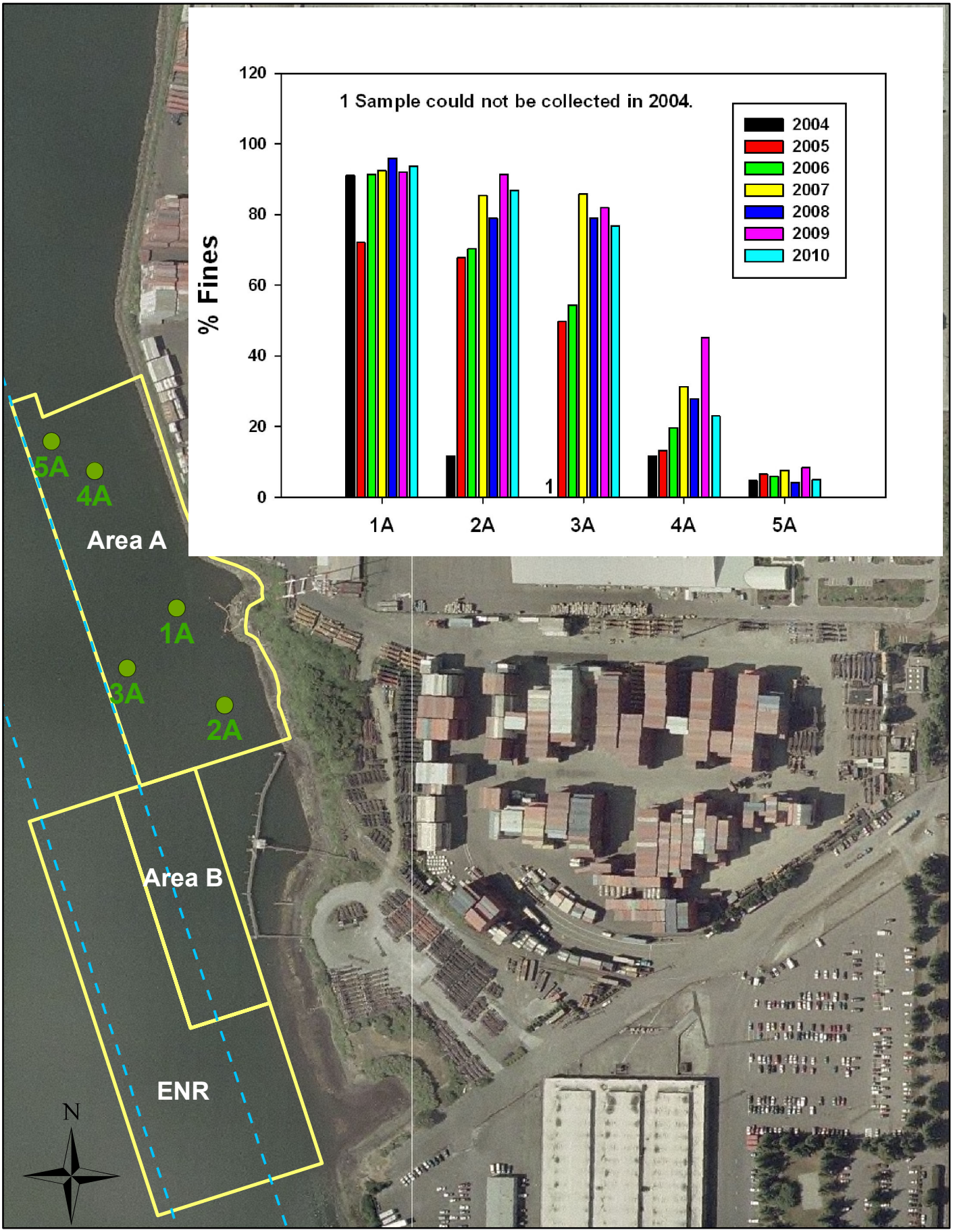

Figure 15. Changes in Relative Fines Over Time - Area A

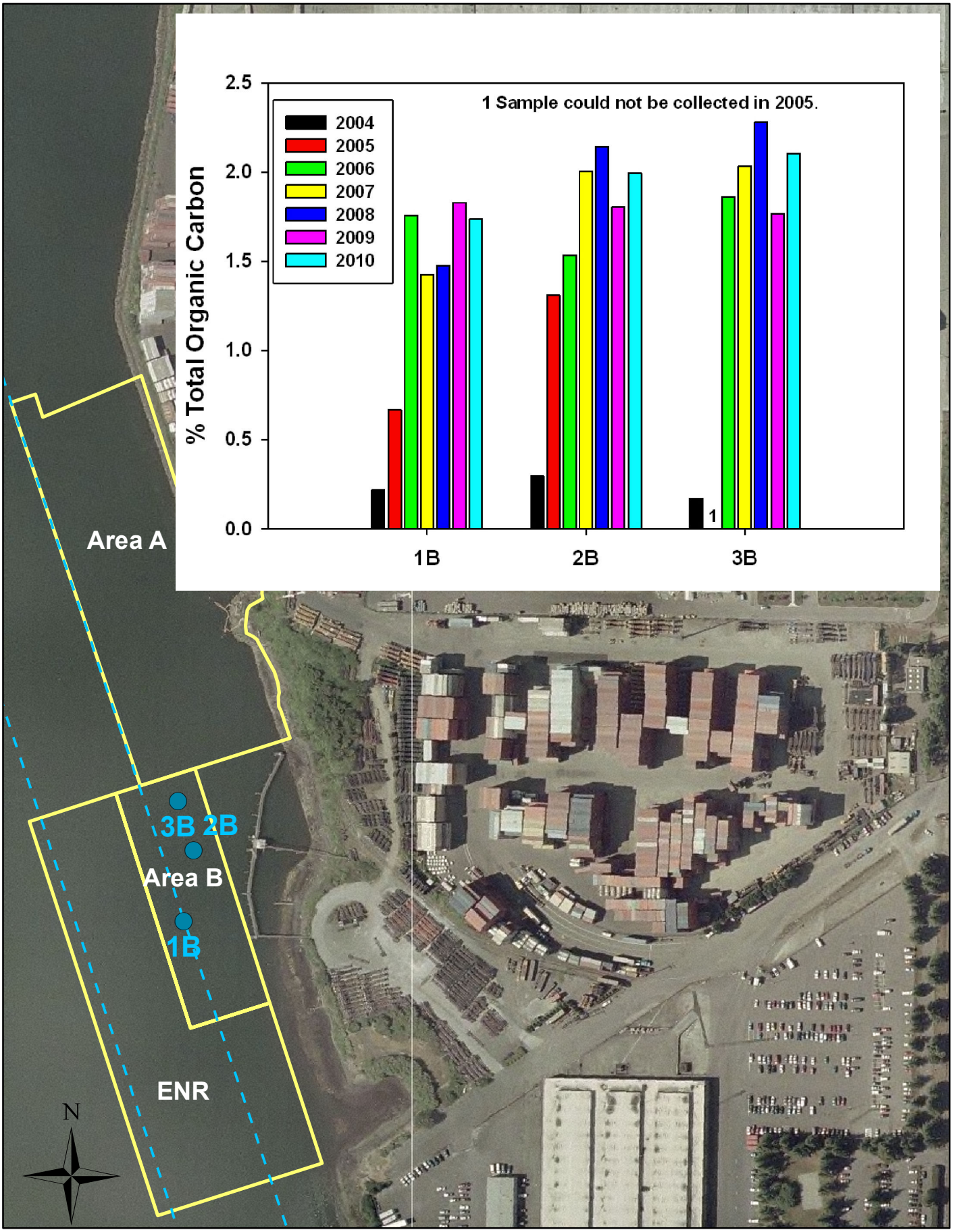

Figure 16. Changes in Relative TOC Over Time - Area B

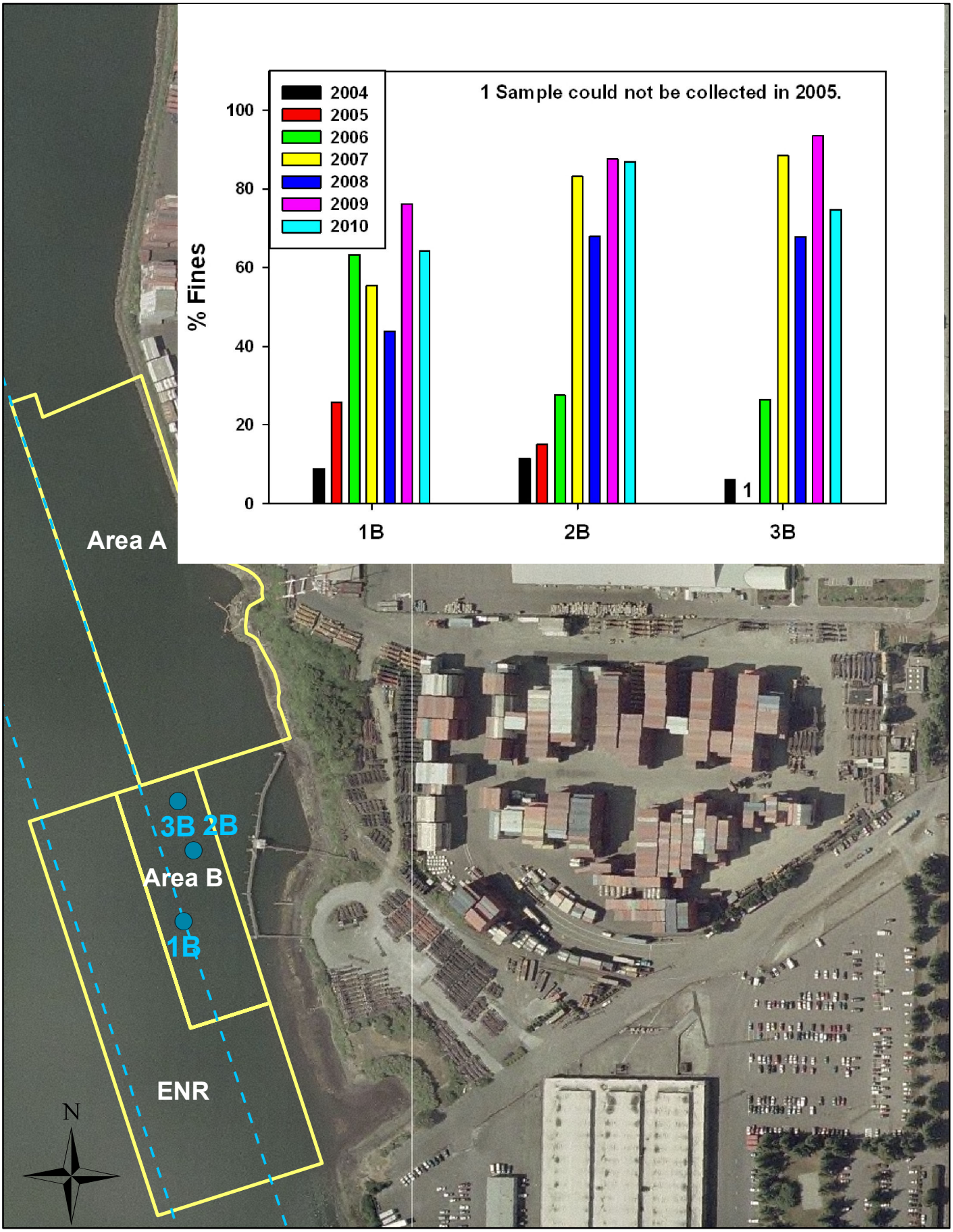

Figure 17. Changes in Relative Fines Over Time - Area B

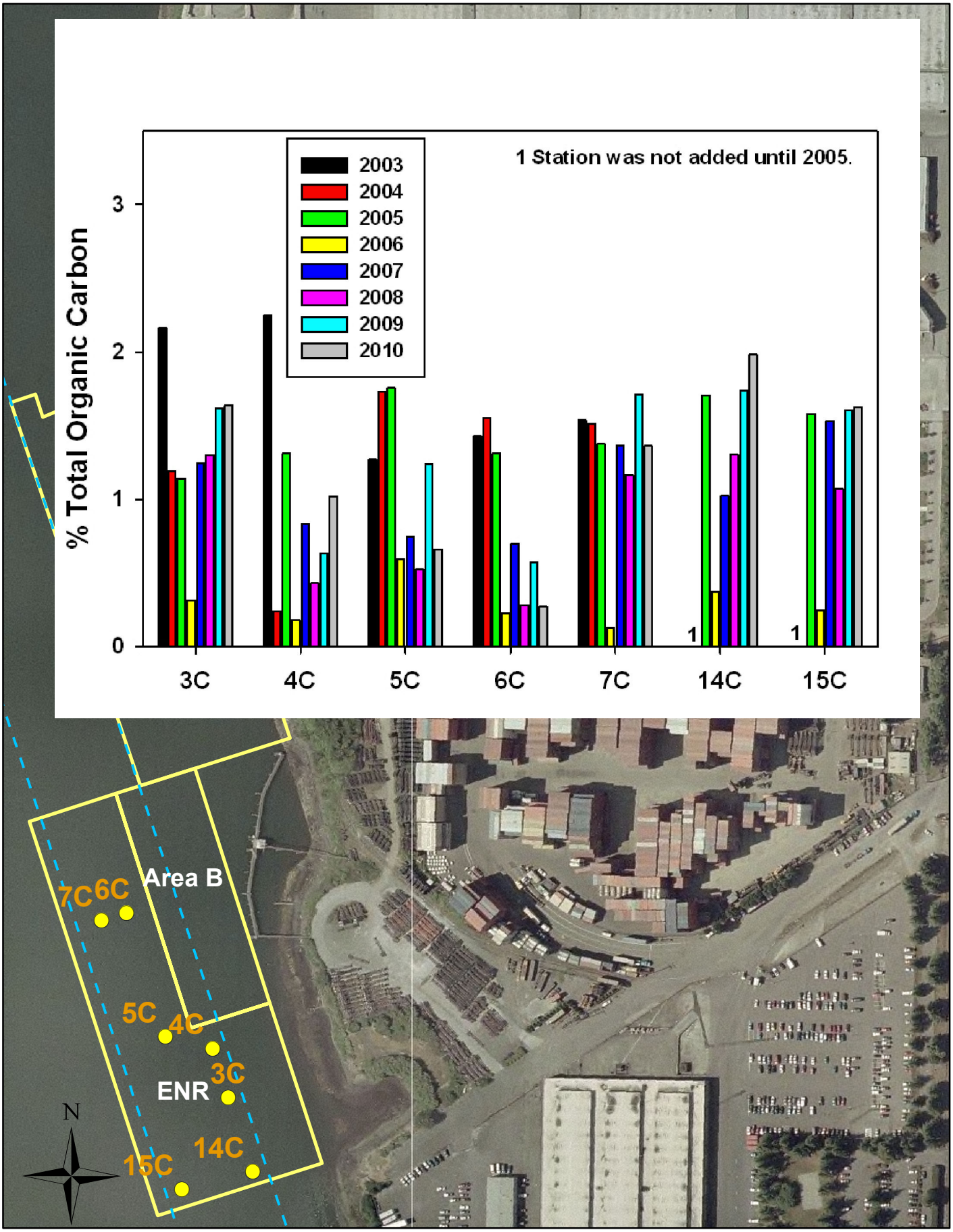

Figure 18. Changes in Relative TOC Over Time - ENR Area

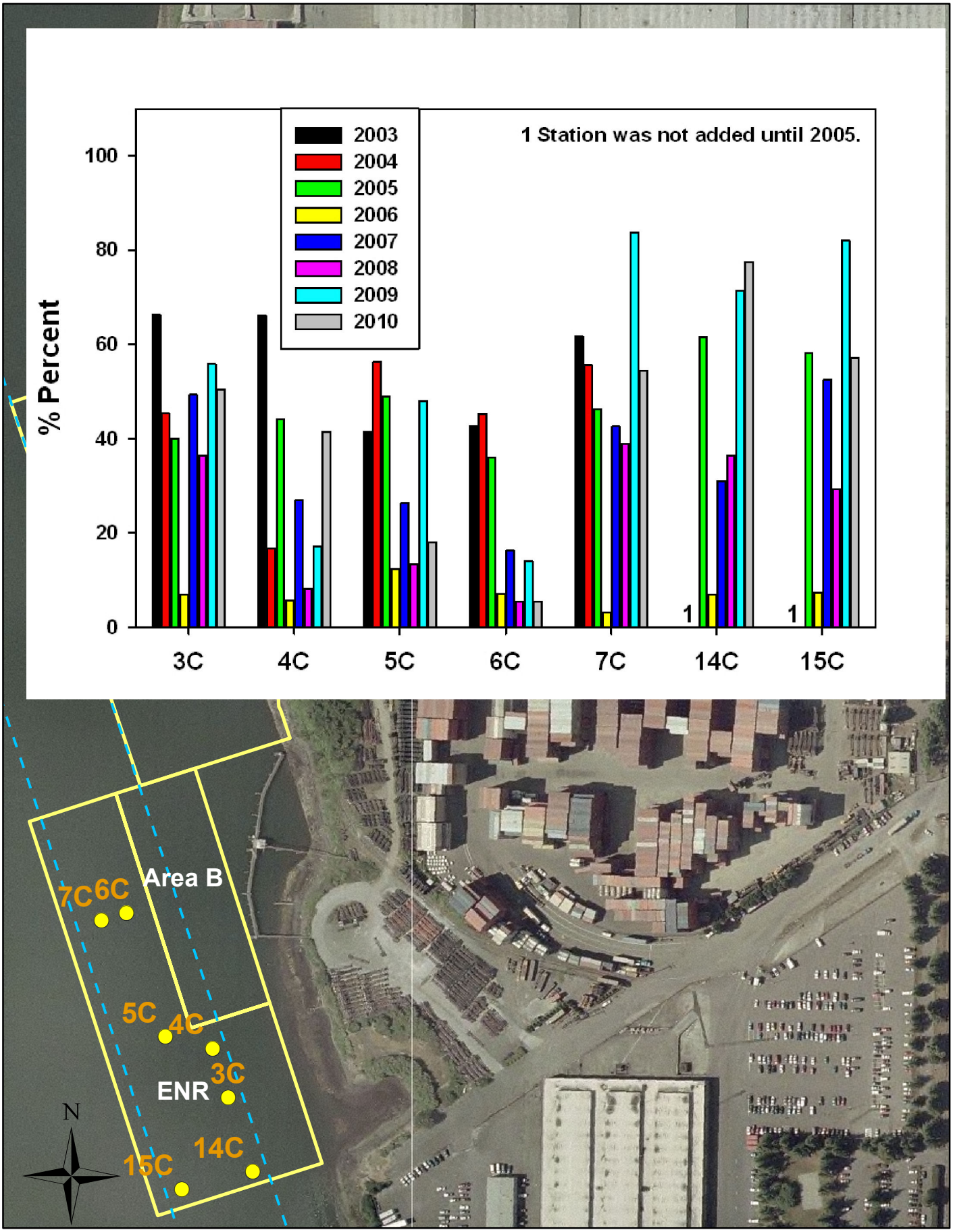

Figure 19. Changes in Relative Fines Over Time - ENR Area

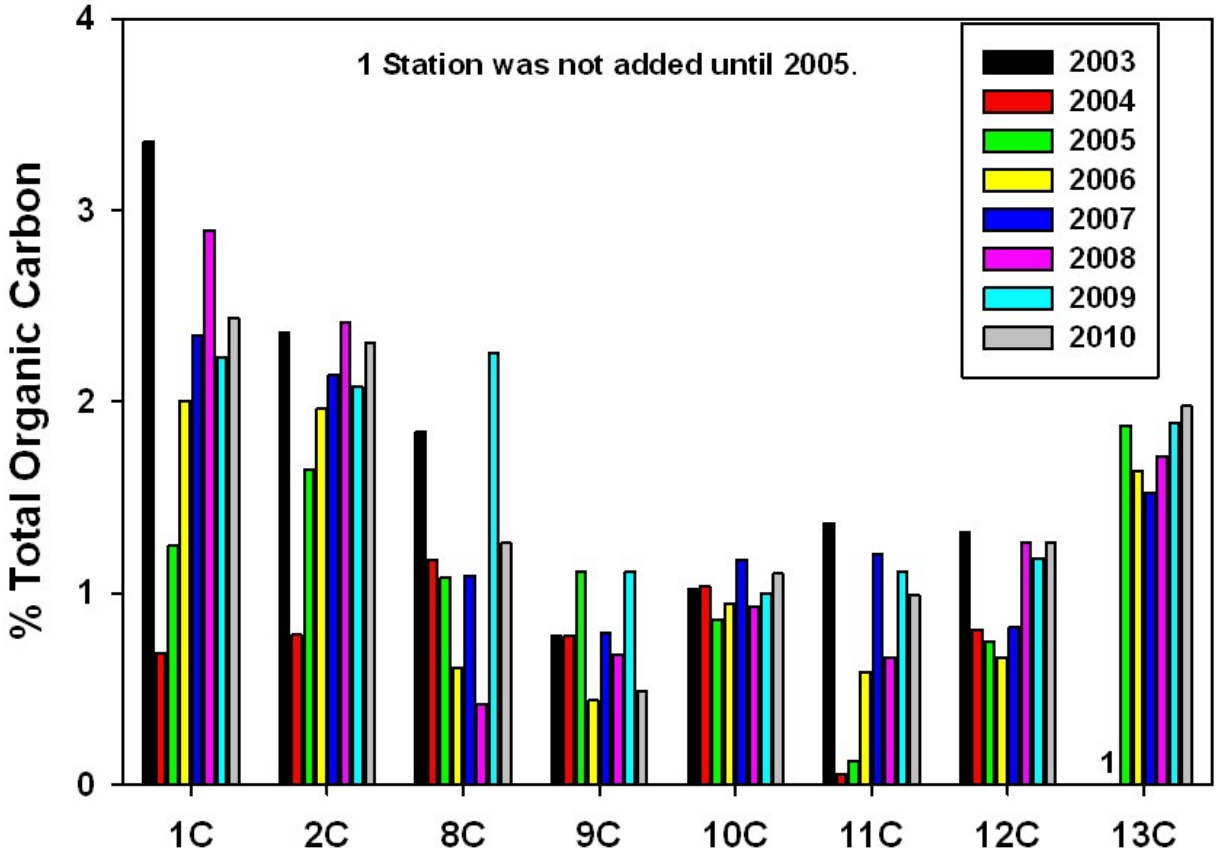

Figure 20. Changes in Relative TOC Over Time – Perimeter Area

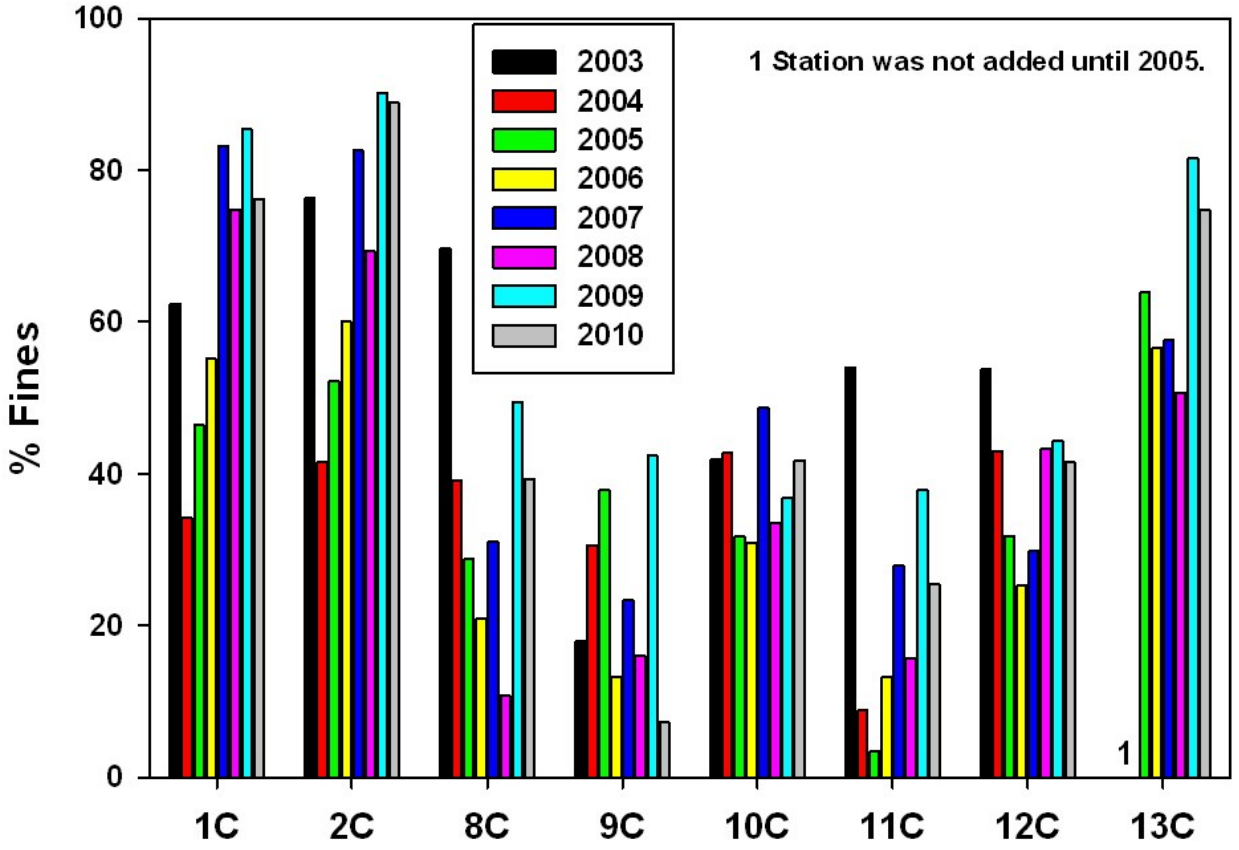

Figure 21. Changes in Relative Fines Over Time – Perimeter Area

4.1.4 Objective 7 Monitoring Summary

This section summarizes the objectives of the monitoring activities grouped under Objective 7 and discusses whether these objectives were met. Each area is discussed separately for clarity.

4.1.4.1 Cap Areas A and B

Objective 7 was intended to address future contamination on Cap Areas A and B due to continuing point sources. There is evidence of recontamination events in the monitoring data. For example, increases in PCBs and BEHP were observed at Stations 1A, 2A, and 3A in 2005 and 2006 after the Diagonal CSO/SD main line was cleaned. In addition to this one-time event, transient increases in various chemicals were seen over the monitoring period. This is likely due to the influence of the active Diagonal Way CSO/SD and Duwamish CSO discharges. The Diagonal Way SD is estimated to discharge an annual average of 316 metric tons of solids per year, while the Diagonal Way and Duwamish CSOs are estimated to discharge an annual average of 9.3 metric tons of solids per year (AECOM 2012, QEA 2008). Chemical concentrations measured at station 1A exceeded SMS more often than other Area A and B stations. This pattern is also indicative of contamination from active discharges at station 1A.

In contrast to other stations in Cap Area A, station 5A, the most downstream monitoring station, has never had any post-cap SMS exceedances. The TOC and grain size data indicate that 5A is subject to less sediment deposition than other cap stations. A steep bottom slope and faster bottom currents may prevent the deposition of sediments at 5A that occurs at 1A and other cap stations (Nairn 2011).

Overall, Cap Area B has had fewer SMS exceedances when compared to Cap Area A. The distance from the Diagonal Way CSO/SD outfall may reduce recontamination compared to Cap Area A. Cap Area B could be influenced to some degree by Diagonal South SD; however, this basin is relatively small draining just 12 acres of land (Windward 2010).

The results of monitoring at Cap Areas A and B have shown both the magnitude and spatial extent of recontamination events resulting from continuing point sources. Monitoring was sufficient to document the spatial and temporal scale of recontamination and, therefore, Objective 7 for the Cap Areas has been met.

4.1.4.2 ENR Area

Objective 7 for the ENR Area includes both measurement of baseline conditions (Year 0) and evaluation of the ENR remedy effectiveness. Baseline conditions were successfully characterized by monitoring immediately after thin-layer placement in early 2005. The thin-layer remedy was designed to quickly reduce exposure risk to aquatic life from elevated chemical concentrations in dredge residuals. It was also designed to allow for existing benthic invertebrates to resurface and mix the clean thin-layer sand with deeper contaminated sediment through bioturbation. In theory, this would result in chemical

concentrations increasing from baseline conditions in the ENR area but staying relatively low.

Surface sediment chemistry data for the ENR area shows an immediate and substantial reduction in PCBs and BEHP in the baseline monitoring event. Since then, PCB concentrations have increased but stayed below 150 µg/kg dw. BEHP concentrations have also increased. The changes in BEHP year-to-year are more variable than PCBs yet concentrations have stayed below 400 µg/kg dw except for one station (3C) where the 2010 BEHP concentration was 660 µg/kg dw. In the ENR Area, only phenol and BBP have been detected above SMS and these exceedances were not persistent but transient. Overall, the changes in PCBs and BEHP since the thin-layer placement have successfully documented that the ENR Area remedy was initially effective at reducing concentrations to below post-cap levels and remained effective over the monitoring period and, therefore, met Objective 7 for the ENR Area.

4.1.4.3 Perimeter Area

Objective 7 for the Perimeter Area was to document natural recovery processes through an evaluation of reductions in sediment chemistry. Overall, Perimeter Area samples over the monitoring period contained chemicals above SMS more frequently and widely than the other areas. This is expected because no active cleanup measures were taken in these areas. In 2003, Station 8C experienced SMS exceedances of high magnitude (i.e., >CSL) for several chemicals (i.e., cadmium, mercury, BBP, BEHP, PCBs). Since then, the chemicals with CSL exceedances at 8C have been limited to PCBs, BEHP and mercury with only PCBs exceeding the SQS in 2010. The Perimeter stations show an overall decrease in PCB concentrations. Although BEHP concentrations are highly variable, a downward trend is observed at most stations.

An exponential curve was fit to the average PCB concentrations across all Perimeter stations to determine the trend from natural recovery processes (Figure 22). The Perimeter Area averages included stations 1C - 12C in 2003 and 2004. For the purpose of reporting average concentrations, the Perimeter Area included stations 1C, 2C, 8C-13C from 2005 to 2010 (stations 3C-7C no longer included since they were covered by ENR) and the 2005 average was calculated using pre-ENR data. The curve fitting was begun in 2005 because the elevated PCB concentrations from dredge residuals seen in 2004 had returned to or were lower than the pre-dredge baseline concentrations and the 2005-2010 data set is a consistently sampled station group. However, the 2009 average concentration does not include Station 8C results because it is believed they represent subsurface sediments for the reasons discussed in Section 4.1.2.3. The trend indicates that despite observed variability between years, the concentrations of PCBs in the Perimeter Area are decreasing on average. Monitoring has successfully documented the occurrence and rate of natural recovery in the Perimeter Area and, therefore, has met Objective 7 for the Perimeter Area.

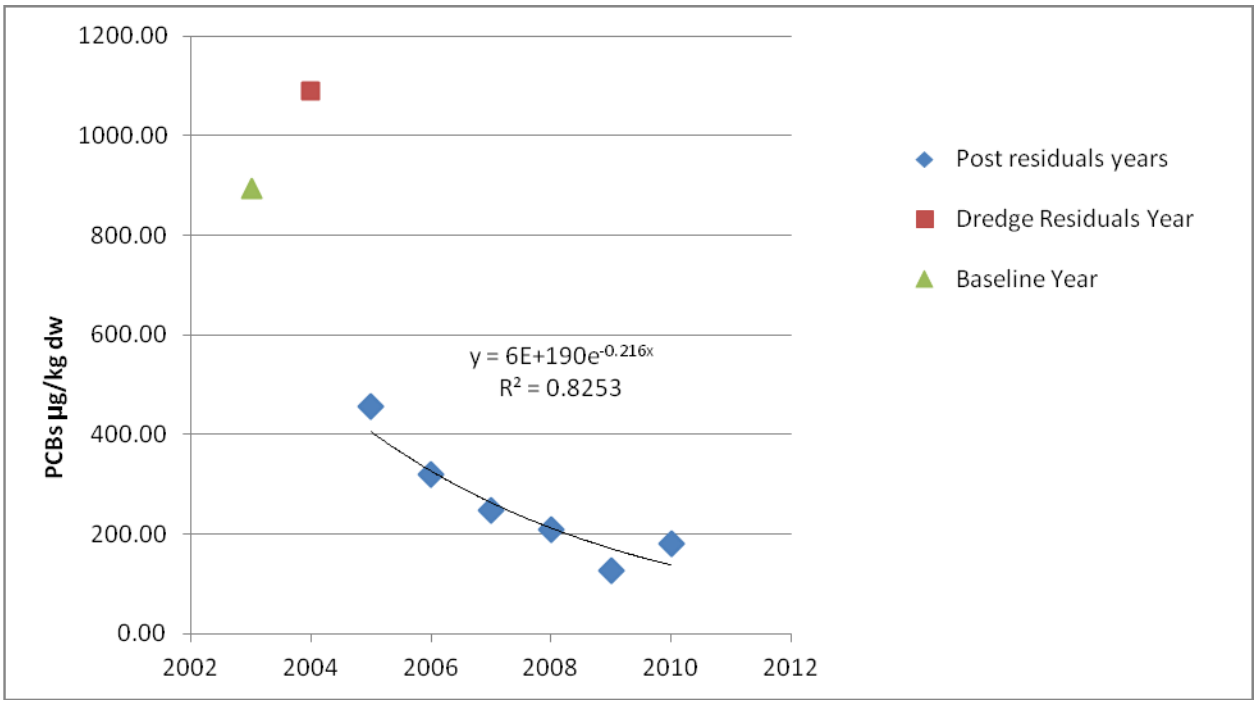

Figure 22. Average Total PCB Concentrations in Perimeter Area over Time (8C not included in 2009)

4.2 Cap and ENR Stability (Objective 8)

Physical measurements of the site were collected using several techniques: bathymetry, sediment profile imaging (SPI), and diver surveys. Several bathymetric surveys were completed before long-term monitoring began including a pre-dredge survey (10/23/2003), post-dredge survey (two days in January, 2004), post-cap survey (3/3/2004) and a final confirmation[14] survey (3/11/2004) (EBDRP 2005a). These surveys were conducted for Cap Areas A and B. Three SPI surveys were conducted: a pre-ENR survey in the entire Perimeter Area (2/8/2005), a post-ENR survey repeating stations located in the ENR Area (3/4/2005) (Anchor 2007), and a one-year post-ENR survey at the ENR stations (Germano and Associates 2006). In February 2005, sediment stakes were placed at 11 locations in the ENR area prior to thin-layer placement (Anchor 2007). Divers made initial physical measurements at the stakes following placement and a second diver survey was conducted to measure changes one year later in April, 2006 (EBDRP 2008). Substantial loss of stakes was discovered in the second diver survey: divers only found two of the eleven stakes. Therefore, stake measurements were eliminated in subsequent ENR area surveys.

Due to an oversight, additional bathymetry and diver surveys were not conducted until April 2009. A bathymetric survey and a diver survey of Cap Areas A and B, and the ENR

[14] Confirmation surveys were used to determine if the design elevations of the caps were met.

Area were completed in 2009. The findings of these various surveys were presented in the 2008/2009 annual report (EBDRP 2010) and are summarized below.

4.2.1 Cap Areas A and B

Based on the 2004 and 2009 bathymetric surveys, the majority of Cap Areas A and B has experienced net accretion after five years in the 0.5-1.5 foot range. In some areas, net accretion was greater than 3 feet. The largest area of accretion was near Station 1A and the Diagonal Way CSO/SD outfall. Within approximately 100 feet inshore of this depositional area is a series of erosional spots located in front of the Diagonal Way CSO/SD and the Duwamish CSO Outfall. The net erosion in this area was over 1 foot after five years. This pattern would follow the expected scouring from active discharges directly in front of the outfalls, and accretion nearby and downstream. A second erosional area is located in the southeast corner of Cap Area B. This may be due to scouring from boat activity at the pier. As the cap is armored (beneath 1.5 feet of habitat mix) in these erosional areas, the observed scouring does not represent a concern to cap integrity.

The video survey of Area B in 2006 showed that most of the area was depositional with a silty layer of several inches on the surface. Four transects across Area B were recorded by divers on video. The most downstream transect showed more exposed gravel on the surface than the other three transects located upstream. The slope cap material was identified as crushed rock and quarry spall with rip-rap. At this point in time, divers concluded that Cap Area B appeared stable. Other than the exposed gravel surface, divers noted no irregularities in the bottom were evident in this survey.

In 2009, divers performed video surveys across both cap areas and the ENR area using nine transects (see Section 4.2.2 for ENR discussion). Although all three areas showed evidence of silt deposition up to several inches in thickness, some differences were observed. For example, the inshore section of one transect (in Area B) that runs just downstream of 5C, was only dusted with silt and large gravel was visible. This section ended at the toe of the slope in the navigational channel where the recent depositional layer becomes thicker and is primarily silt. The steepness of the slope may result in instability and prevent substantial accumulation of silt similar to a steep mountainside. Physical irregularities along the bottom were not observed in the video survey.

In the 2009 survey, divers also manually probed with yardsticks two locations each on Cap Area A and B transects with the goal of approximating the depth of both the silt layer and the underlying sand layer. Locations were selected where divers had performed similar probes in 2006. At station 1A, divers measured 8 inches of silt over a 5-6 inch sand layer. The silt layer at station 2A was similar at 9 inches thick. The underlying cap material was too large to probe at station 2A. In Cap Area B, divers found 8 to 13 inches of silt near 1B and at a point between stations 2B and 3B. Large cap material precluded probing below the silt at both locations.

4.2.2 ENR Area

The March 3, 2004 bathymetric survey was conducted on the Cap Areas A and B and extended a bit beyond the design boundaries to encompass all potential cap material. The thin layer was placed in early 2005 and to gather supplementary information, the bathymetric survey in 2009 included the ENR Area in addition to the Cap Areas A and B. The bathymetry subcontractor, Blue Water Engineering, used the data from these two surveys to estimate changes in accretion/ erosion in the cap and ENR areas (Figure 23). They note that their 2009 estimates of accretion in the ENR area are biased high by approximately 6 inches (the post-placement survey measured ENR sand placement depths of 6 to12 inches at the stake locations) because of the thin layer placed in the ENR Area in between their two survey dates. The portion of the ENR area where changes could be estimated showed roughly 12-24 inches of accretion from 2004 to 2009, inclusive of the 6-12 inch thin-layer placement.

One baseline and two post-ENR SPI surveys were conducted in the ENR Area. The baseline survey was conducted on February 8, 2005 before thin layer placement and the first post-ENR survey was conducted on March 4, 2005. The results of these two surveys were presented and discussed in the 4-Acre Residuals Interim Action Closure Report (Anchor 2007). The third and last SPI survey was conducted one year later on March 14, 2006; 11 stations were surveyed (Germano and Associates 2006). Due to an oversight, the 2006 SPI results were not included in the 2006/2007 annual monitoring report (EBDRP 2008). A discussion and detailed results of the 2006 survey can be found in Appendix E of this report. A brief summary of the findings from the two post-ENR SPI surveys is included here. The first post-ENR SPI survey showed the newly deposited sandy sediments of the ENR at each station and evidence of deposit-feeding or burrowing infauna at only one station, which was measured at a bioturbation depth of 5.4 cm. The one-year comparison showed a substantial shift in grain size from primarily medium-grained sand to primarily fine-grained sand that were well-mixed at the SPI penetration depth. Evidence of bioturbation from benthic invertebrates was observed at all stations in 2006; the bioturbation depth in individual replicates ranged from 2.9 to 13.1 cm with an overall average of 7.1 cm. Repopulation of benthic invertebrates in the ENR Area sediment was indicated by these bioturbation results. Also, the bioturbation depth indicates absence of disturbance events deeper than the bioactive layer e.g., scour or high flow events.

During the 2006 diver survey, one to two inches of recently deposited silt was observed at all but two of eleven locations inspected (EBDRP 2008). Divers noted signs of furrows, especially at the channel side of the ENR area, and suspected these were caused by dragging barge harness chains or anchors. In addition, divers observed one spud hole near 14C while conducting the 2006 sediment sampling in the ENR Area. The size of the spud hole was visually estimated as 2 feet deep and 2 feet in diameter. In 2009, divers did not find this spud hole but did notice an old spud hole near 7C in the navigation channel. This one was filled with silt. Visibility was limited during the 2009 diver survey and no other disturbance observations were reported (EBDRP 2010).

4.2.3 Objective 8 Monitoring Summary

The survey data collected on Cap A, Cap B and ENR areas over the monitoring program has demonstrated that the majority of the Duwamish/Diagonal site is depositional. Bathymetry analysis indicates the total depth of sediment deposited across the majority of Cap Areas A and B and the ENR area between 2004 and 2009 ranged from 0.0-1.5 feet. Maximum accretion was above 3.0 feet in two main areas. A steep slope located in 20 to 30 feet below MLLW in northern Area B (See Figure 23) is several hundred feet in length and accumulates more silt than other areas. The accumulations appear to be located in small ravines which may act as silt collectors. A second area is located offshore of the Diagonal Way CSO/SD outfall. This area may represent the zone of highest deposition from the outfall. Within approximately 100 feet inshore of this depositional area near the active Diagonal Way CSO/SD outfall, signs of erosion were observed. Net erosion (approximately -1 foot) was measured in this area near the active Diagonal Way CSO/SD outfall as well as an area in southeast Area B near the pier. The erosion in these spots is believed to be due to regular scouring from outfall discharges and vessel operations, respectively, that prevents accretion of silt. These areas are relatively small in size (i.e., 25-40 feet in width) and the scouring does not threaten cap integrity because the cap is well armored in these locations; it was designed with minima of 1 foot habitat mix on top of 1.5 feet quarry spall over a minimum of 1.5 feet base cap material (King County et al. 2003).

Observations of physical disturbances to the sediment surface made during two diver surveys indicate there are occasional shallow disturbances possibly from barge chains, boat anchors or barge spuds. However, as detailed above, evidence of these disturbances was sparse. Divers did not observe exposed armoring of the cap or thin layer sand of the ENR in these disturbances. The high accretion of silt across the site will further increase cap/thin layer protection from future physical disturbances.

The SPI surveys added information in support of the grain size analysis results and diver surveys showing a shift in the surface conditions in the ENR Area from sand to fines after one year. Repopulation of benthic invertebrates in the ENR Area sediment was also indicated by the one year post-ENR SPI survey which also indicated no recent disturbance events at those sites.

Results of the surveys have demonstrated that the Cap Areas A and B appear stable and its integrity intact. The SPI survey results have documented benthic recolonization has occurred in the ENR Area. Additional survey results also demonstrate that the ENR Area thickness met design criteria and appears stable. Therefore, Objective 8 for the cap and ENR Areas has been met.

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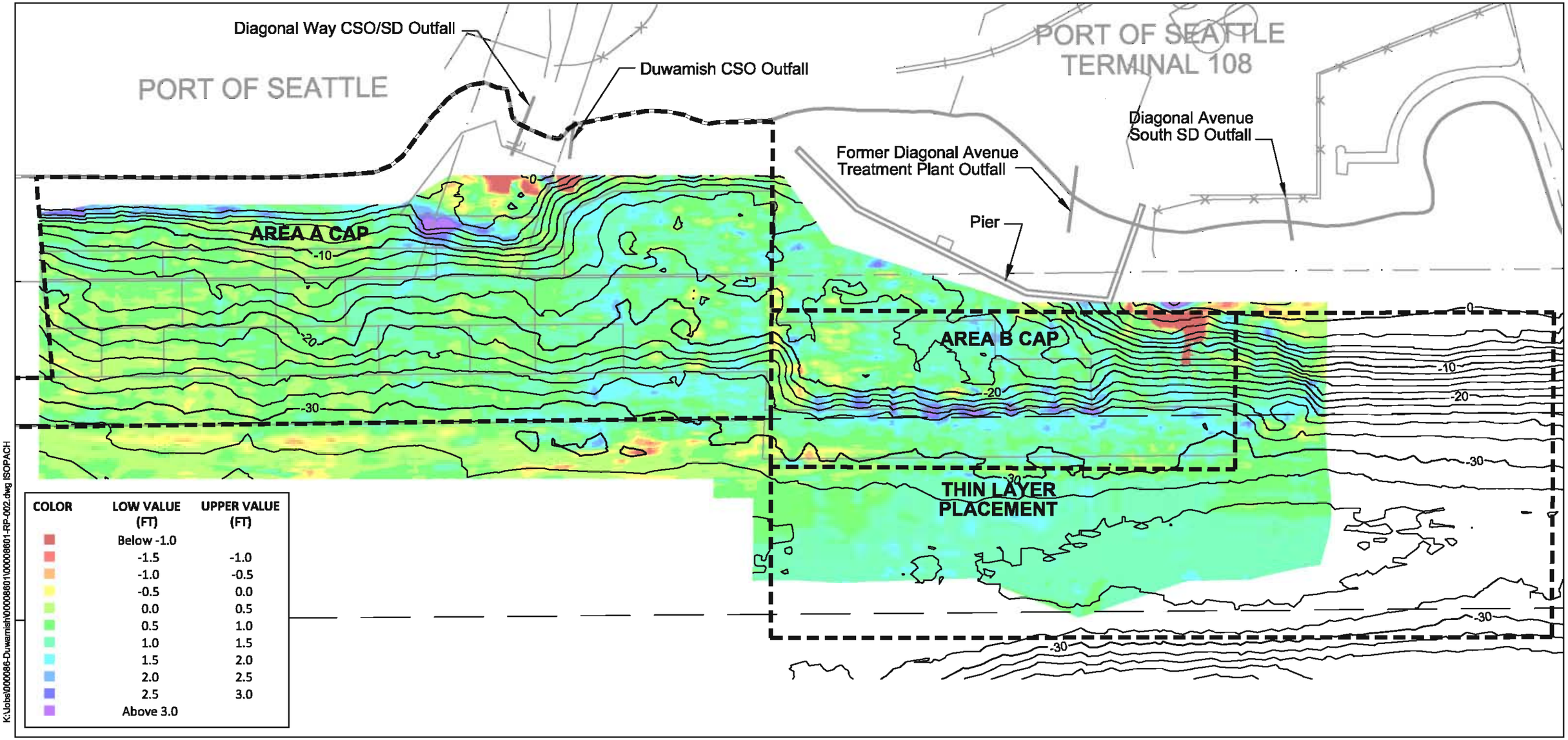

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Sep 03, 2009 1:54pm dholmer

SOURCE: Drawing based on surveys by Blue Water Engineering (BWE) dated March 3, 2004 and April 23, 2009.
HORIZONTAL DATUM: Washington State Plane North, NAD83 (US Survey Feet).
VERTICAL DATUM: Mean Lower Low Water (MLLW).

NOTES:
1. Bathymetric contours are from BWE survey dated April 23, 2009. Contour interval 2 feet.
2. The 2004 bathymetry was recorded prior to placement of the Thin Layer Cap in the ENR areas. Therefore accretion results from 2009 bathymetry comparisons are biased high.

ANCHOR QEA

0 100
Scale in Feet

Figure 23
Isopach Map of 2004 vs. 2009 Surveys
Duwamish Diagonal
Sediment Remediation Project

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5.0. DISCUSSION AND RECOMMENDATIONS

The long-term monitoring activities planned to meet Objectives 7 and 8 were completed according to the project SAP with the exception of two missed years of diver surveys. Despite this oversight, the objectives were met to document the level of chemical recontamination on the cap areas and the ENR area and to monitor for cap stability and ENR benthic recolonization. In this section, area averages for PCBs and BEHP are discussed, a summary of the monitoring information is presented and future monitoring recommendations are discussed.

5.1 Area Averages for PCBs and BEHP

For the purposes of evaluating the temporal trend for PCBs and BEHP over the monitoring period, the average dry weight concentrations across stations in each area were calculated and are presented in Figures 24 and 25, respectively. This calculation was straightforward for Areas A and B; however, the stations included in the ENR Area and the Perimeter Area varied according to site events. The ENR Area average includes stations 3C-7C, 14C and 15C and begins at the pre-ENR sampling event in 2005. The Perimeter Area averages included stations 1C - 12C in 2003 and 2004, and then 13C was added to this group for 2005 pre-ENR samples. From 2005 post-ENR to 2010, the Perimeter Area included only stations 1C, 2C, 8C-13C as stations 3C-7C were covered by the ENR.

While average PCB concentrations on Cap Area B have been fairly consistent over time, those on Cap Area A showed an increase from baseline conditions in 2005 and 2006 followed by decrease in 2007 (Figure 24). This increase is believed to be due to releases from the Diagonal Way CSO/SD outfall (see Section 4.1.2.1). Figure 23 shows a substantial reduction in average PCB concentration in the ENR Area after thin-layer placement (i.e., 2005 post-ENR). The average PCB concentration in the clean sand of the thin layer increased somewhat after placement as demonstrated by the small increases in 2006, 2007 and 2008 average concentrations. The average post-cap PCB concentration in Perimeter Area sediments (2004) was higher than the average pre-cap concentration reflecting the increase in surrounding sediment concentrations from dredge residuals. The average PCB concentration in the Perimeter Area is higher than the other areas but appears to be decreasing over time.[15] The most recent two years of monitoring data indicate that the three actively remediated areas, Cap Areas A and B, and the ENR Areas, are approaching a similar average PCB concentration.

The average BEHP concentration in Cap Area A showed a similar pattern to PCBs with increasing concentrations over baseline conditions, likely due to recontamination from the Diagonal Way CSO/SD outfall (Figure 25). However, since that time, BEHP concentrations

[15] Station 8C has a strong influence on the 2009 average PCB concentration in the Perimeter Area with the average PCB concentration decreasing from 455 to 128 µg/kg dw when the 8C sample concentration is excluded from the average.

have declined in Area A. In Cap Area B, average BEHP concentrations are highly variable over time. Average BEHP concentrations in the ENR Area declined after thin layer placement then increased from the post-ENR baseline conditions to a 2010 average concentration similar to Area B (about 200 µg/kg dw). The average BEHP concentration in the Perimeter Area varied between 2004 and 2009 but data for the last three years indicate a downward trend similar to PCBs. In general, BEHP concentrations exhibit more year to year variability than PCBs. Local sources may continue to affect variability, particularly at Cap Area A especially since BEHP has been shown to be ubiquitous in urban areas.

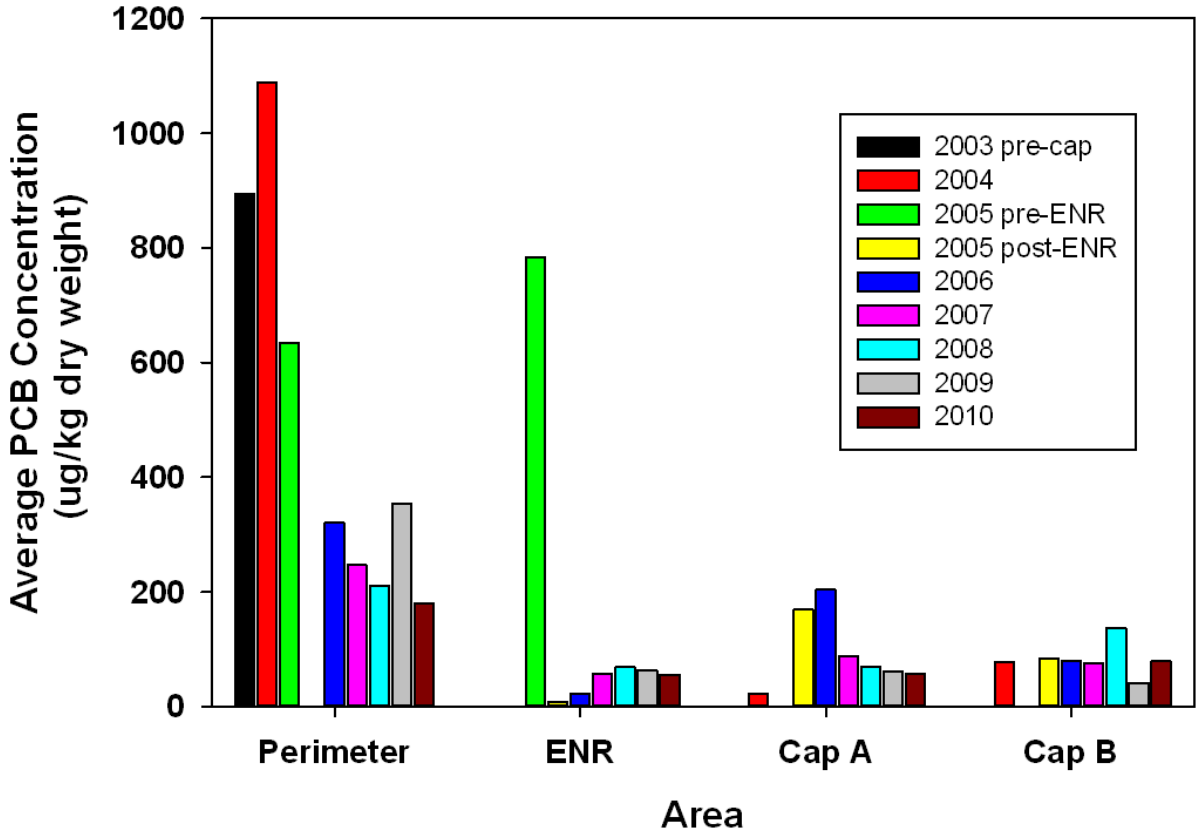

Figure 24. Annual Average Total PCB Concentrations in each Monitoring Area (dry weight-normalized).

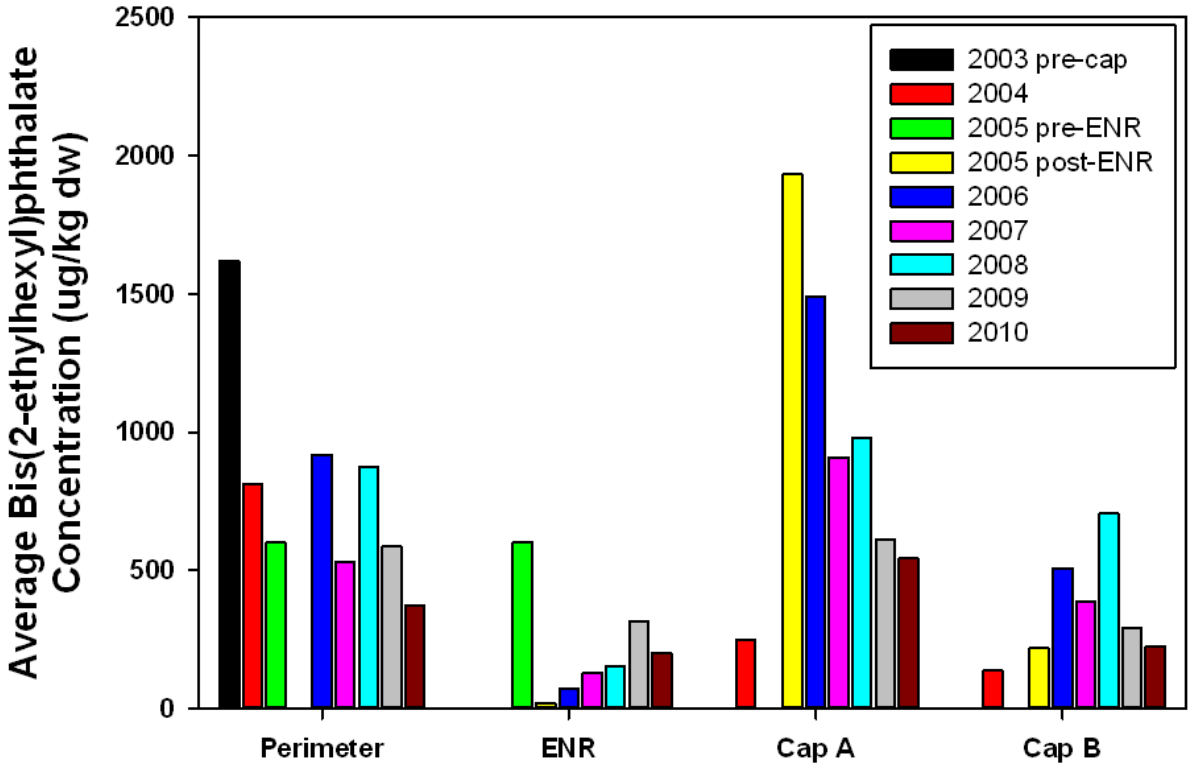

Figure 25. Annual Average Bis(2-ethylhexyl)phthalate Concentrations in each Monitoring Area (dry weight-normalized).

5.2 Monitoring Summary

The annual chemistry monitoring showed occasional and transient cap recontamination by chemicals, such as benzoic acid and dimethyl phthalate, typically at one station per year, and more persistent recontamination by certain phthalates. Based on TOC, grain size, and chemistry data, station 1A appears to be impacted by outfall discharges but effects are spatially limited and don't appear to consistently impact nearby stations. Discharges from the Diagonal CSO/SD and the Duwamish CSO appear to have resulted in elevated PCB and BEHP concentrations in 2005 and 2006 at stations 1A, 2A and 3A. Sediment deposition at these sites likely caused a decline over time of PCB and BEHP concentrations such that they became similar to other cap stations. TOC and grain size data show 5A does not accumulate sediment as quickly as other cap stations, potentially explaining its chemical concentrations remaining closer to baseline cap conditions (i.e., low concentrations). In fact, Station 5A appears to have unique characteristics resulting in lower measured PCB concentrations than any other stations sampled in the Cap, Perimeter, or ENR areas.

After the initial recontamination event on the cap, PCB concentrations overall have decreased in Cap Area A during the monitoring program to below the SQS. In 2010, the cap data show the only SMS exceedances are for two phthalates and phenol. The monitoring program data has shown that BEHP and BBP are the phthalates most commonly detected on Cap Areas A and B. Phthalates were expected to present a recontamination risk due to ongoing sources in stormwater and CSOs and this is consistent with the findings of a regional phthalate recontamination study and review (Floyd|Snider 2007). While this expectation has largely held true, it is difficult to predict how phthalate concentrations will change with time. Because phthalates are ubiquitous in urban environments with multiple ongoing sources, they are expected to continue to have variable concentrations over space and time, sometimes exceeding the SMS near the outfall.

The long-term monitoring conducted in the ENR area demonstrated the remedy of placing a thin layer of sand was successful in reducing contaminants, including PCBs, from dredge residuals in the surface sediment. There have been no monitoring samples with concentrations exceeding SMS for PCBs since thin-layer placement. The ENR area has had the fewest SMS exceedances and the lowest PCB concentrations compared to other monitoring areas. This may be due to the greater distance of the ENR Area stations from the Diagonal Way CSO/SD than the Area A and B stations. The greater distance from Diagonal Way CSO/SD may result in greater influence or deposition of sediments in the ENR Area from upstream input and less from the outfall discharges. Although its discharge volumes are much smaller, the Seattle Diagonal South SD is closer and may also influence the ENR Area. This observed relationship between proximity to discharges and surface sediment PCB concentrations is consistent with LDW sediment transport model predictions of highest lateral sediment fractions in the model cells immediately adjacent to outfalls and falling with distance, and upstream sediment fractions exhibiting the inverse (QEA 2008). Even so, the average concentration of PCBs in the ENR Area is trending to levels similar to that found in Areas A and B (Appendix F, Figure F-2). BEHP was detected at a concentration exceeding SMS in 2009 at one ENR Area station. However, the exceedance was not observed in 2010. No other chemicals exceeded the SMS in the ENR area during the monitoring program.

The Perimeter Area showed greater frequency and magnitude in SMS exceedances with high variability over space and time when compared to the other monitored areas. Concentrations of PCBs and other contaminants have been declining over time, indicating natural recovery processes are occurring in this area. The fact that the data fits an exponential curve is consistent with natural recovery modeling at the site (Appendix F). Solving the exponential equation can provide the half-life[16] of PCB concentrations in surface sediment and the recovery rate for this area of the Duwamish.

The modeling presented in Appendix F predicts the Perimeter and ENR areas to equilibrate at a long-term PCBs concentration of around 45-52 µg/kg dw. This is lower than the concentration of around 61 µg/kg dw to which all the areas appear to be equilibrating

[16] Half-life is used here to mean the point in time at which surface sediment PCB concentrations are half of the starting concentration. It does not refer to a PCB chemical degradation rate.

based on 2006-2010 data (see Appendix F; Figure F-1). While the annual variability demonstrated in the monitoring data suggests the area mean range will vary depending on factors such as weather patterns affecting local discharges and upstream deposition or localized scour (Appendix F), both of these equilibrium estimates are within the range (46-120 µg/kg dw) predicted by the LDW Feasibility Study modeling (AECOM2012). The results suggest modeling can predict recovery rate for MNR and time to equilibrium for ENR relatively accurately but that the variability in flow rates and how that impacts the deposition rate is a confounding factor. The results also support that the MNR area is undergoing recovery, consistent with the LDW Conceptual Site Model (AECOM 2012).

Monitoring surveys measured net accretion over most of the Duwamish Diagonal site. Two small erosional spots were identified where scouring prevents accretion of silt: one in front of the Diagonal Way CSO/SD outfall and another in the southeast part of Cap Area B near the pier. However, armoring of the cap should provide protection against erosion of any cap material. Evidence of surface sediment disturbances was documented from diver surveys. However, these disturbances were shallow upon inspection suggesting the disturbance did not penetrate the overlying silt layer or was quickly covered over with newly deposited material. All the physical monitoring data suggest the cap and thin layer are stable.

Because the initial ENR layer is thicker than the measured bioturbation depths at the site, comparison of empirical area mean concentrations can be compared to model-predicted concentrations as an indication of stability (Appendix F). Measurable increases in concentration above predicted levels would suggest mixing of underlying sediment containing up to 1 order of magnitude higher concentrations into the surface layer and that the ENR stability may be in question. In addition, if the ENR layer is subject to enough erosive forces, it could thin to the point that underlying sediment would begin mixing by bioturbation into the surface layer and increase concentrations. Empirical concentrations are consistent with predicted concentrations that assume no mixing of sediment underlying the thin-layer of sand, suggesting the ENR Area is stable.

Both MNR and ENR remediation strategies rely on relatively stable sediments for recovery to be successful. Absence of chemical signals from underlying sediments in either area suggests both the Perimeter and ENR Areas appear to have been stable throughout the monitoring period. A single exception has been observed in the Perimeter Area at station 8C which was subject to excessive sediment removal by repeated replicate composite sampling.

5.3 Future Monitoring Recommendations

The long-term monitoring program met its objectives and demonstrated success of the remedial actions in reducing surface sediment contaminant concentrations and isolating remaining contamination under the cap. The long-term monitoring results indicate that PCBs and certain phthalates are the key chemicals to monitor for change at the site. More recent monitoring events indicate average PCB concentrations in all monitoring areas except the Perimeter appear to be stabilizing. Analysis conducted for the LDW Feasibility

Study examined background concentrations of PCBs in urban water bodies of western Washington and, based on this, concluded the expected range of anthropogenic/area[17] background for the Lower Duwamish is between 40 and 90 µg/kg dw (AECOM 2012). Natural background for Puget Sound, a measure of PCB concentrations that have not been influenced by localized human activity, is 2 ug/kg dw; this is the site-wide PCB cleanup level in the Lower Duwamish Waterway established by EPA (EPA 2014). In 2010, the mean PCB concentration across the remediated areas (i.e., the cap and ENR areas) is 60.8 µg/kg dw (Appendix F), which falls within this expected range of anthropogenic/area background but is above natural background. In addition, the average PCB concentration for each remediated area appears to be equilibrating around this value (Figure 23, Figure F-3 in Appendix F). Even the PCB concentrations in the Perimeter Area, which has only been subject to natural recovery processes (no active remediation), are decreasing toward the expected range of anthropogenic background and the mean remediated area concentration (Appendix F). If this information is an indicator, changes in PCB concentrations at Duwamish Diagonal after 2010 would be relatively small for the ENR and Cap Areas and greatest in the Perimeter Area stations as it continues to descend toward the remediated area average.

SEDCAM modeling suggests that the MNR area is recovering faster and the ENR area is approaching equilibrium faster than predicted (Appendix F). This may be due to (1) a higher sediment deposition rate during the monitoring period than the 30-year average deposition rate predicted by the LDW STM, and (2) the larger storms associated with the higher sedimentation also increasing the lateral input from the Diagonal Duwamish CSO/SD. Significantly higher than average sediment deposition is predicted in the LDW STM in years with larger flow events and there were several 20-year-return-frequency[18] or higher flow events during the monitoring period.

Ongoing sources of phthalates are expected to continue to recontaminate the cap and possibly the ENR area in the future. Phthalates will be an ongoing source from the air-water-sediment pathway for decades with current source control and treatment options not expected to adequately control sources (Floyd|Snider 2007). There can be expected recurring site contamination by this type of contaminant. Based on the monitoring results, localized exceedances will likely remain near the outfall with sporadic transient exceedances farther from the outfall. Phthalates will remain a recontamination risk near outfalls. Further monitoring of the cap and ENR for phthalates would allow documentation of large recontamination events (i.e., with increases lasting greater than one year).

However, the Duwamish Diagonal remediation was conducted with the awareness that phthalate recontamination was possible and likely, but that remediation of PCBs and mercury was the main objective. PCB concentrations in Cap Areas A and B and the ENR Area appear to be stable and within the range of anthropogenic background. The

[17] Ecology then used term "area background" in the SMS until it was updated in 2013. The term used now is regional background and the definition is similar to but slightly different from anthropogenic background.
[18] The 20-year return frequency is the calculated flow rate predicted to occur on average with a frequency of once every 20 years for the Lower Duwamish River based on the historical measured flows.

monitoring results showed that mercury, the remaining chemical of concern did not exceed SMS post-remediation. Therefore, the objectives of chemical monitoring (Objective 7) were met and further chemical monitoring is not expected to contribute new information. In addition, long-term monitoring demonstrated the cap and thin layer to be stable and resistant to existing disturbances. SPI surveys of the ENR Area also demonstrated benthic recolonization. Thus, the physical monitoring objectives (Objective 8) were met and further monitoring under the original objectives is not recommended.

Monitoring of the ENR Area was planned to cease after five years (King County 2005). The project SAP discussed consideration of reducing the monitoring frequency on Cap Areas A and B after 5 years (King County 2003a). King County voluntarily conducted annual monitoring of all areas in 2011 and 2012 in order to extend the valuable time series on recovery and recontamination in this portion of the LDW[19]. However, due to the consistency of the cap and ENR area monitoring data over time and the continued, steady decline in the Perimeter area monitoring data, King County believes the existing data is sufficient to evaluate the long-term status of recontamination potential from the four chemicals of concern and stability of the remedies. No further monitoring of Cap Areas A and B or the ENR Area is planned or recommended.

[19] 2011 and 2012 monitoring data will be reported under a separate cover when available.

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