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APPENDIX A

**SUMMARY OF DATA COLLECTED SINCE THE
REMEDIAL INVESTIGATION/FEASIBILITY STUDY**

**Pre-Remedial Design Work Plan
Portland Harbor Superfund Site**

SUMMARY OF DATA COLLECTED SINCE THE RI/FS

This appendix summarizes the eight environmental studies that were conducted after the remedial investigation (RI) was completed in 2008. The studies were conducted between 2008 and 2016 and included collection of surface and subsurface sediments, smallmouth bass (SMB) tissue samples, and sediment profile imaging (SPI).

Field and Data Report, Downtown Portland Sediment Characterization Phase I and II, GSI and Hart Crowser, Inc. 2008 and June 2010

Phase I of the Downtown Portland Sediment Characterization (DPSC) was initiated by Oregon Department of Environmental Quality (ODEQ) in 2008 to assess the presence of environmental contaminants within the downtown Reach (River Mile [RM] 12 to RM 16). Between May and June 2008, 81 grab samples and 36 core samples were collected and analyzed for polychlorinated biphenyls (PCB) Aroclors, butyltins, dioxins/furans (D/F), metals, pesticides, polycyclic aromatic hydrocarbons (PAHs), semi-volatile organic compounds (SVOCs), and total petroleum hydrocarbons (TPHs). Surface sediment samples were collected by power-grab (with a maximum penetration capability of 22 centimeters) (GSI Water Solutions, Inc. [GSI] and Hart Crowser 2010).

ODEQ conducted a preliminary screening level evaluation of this data to identify areas where additional sampling was warranted to confirm the detection of elevated contaminants of concern (COCs), identify sources if possible, and delineate areas needing remediation. Concentrations of COCs in sediment were compared to screening values developed for the Portland Harbor Joint Source Control Strategy. Based on the relative proportion of samples exceeding screening values, ODEQ identified nine Focus Areas for additional investigation and source identification efforts (GSI and Hart Crowser 2010).

In Phase I, PCB Aroclors were detected in 69% of 100 surface and 70% of 20 subsurface sediment samples, with concentrations ranging from <1 microgram per kilogram ($\mu\text{g}/\text{kg}$) to 4,200 $\mu\text{g}/\text{kg}$ and <1 $\mu\text{g}/\text{kg}$ to 610 $\mu\text{g}/\text{kg}$, respectively. Total sum of dichlorodiphenyltrichloroethane and its derivatives (DDx) was detected in 88% of 100 surface and 75% of 20 subsurface samples, with concentrations ranging from <0.047 $\mu\text{g}/\text{kg}$ to 144 $\mu\text{g}/\text{kg}$ and <0.13 $\mu\text{g}/\text{kg}$ to 300.5 $\mu\text{g}/\text{kg}$, respectively. Total PAHs were detected in 99% of 100 surface and 100% of 20 subsurface samples, with concentrations ranging from <0.28 $\mu\text{g}/\text{kg}$ to 40,310 $\mu\text{g}/\text{kg}$ and 72 $\mu\text{g}/\text{kg}$ to 7,802 $\mu\text{g}/\text{kg}$, respectively.

Total D/F were detected in 93% of 58 surface and 14 subsurface samples, with concentrations ranging from <4.14 nanograms per kilogram (ng/kg) to 15,400 ng/kg and <2.88 ng/kg to 4,594 ng/kg, respectively (GSI and Hart Crowser 2010).

Phase II of the DPSC was conducted in 2010 to better understand the nature and extent of potential COCs within nine Focus Areas and the TriMet Supplemental Sampling Area. ODEQ identified the following Focus Areas: RM 12.1E, 12.4W, 12.5E, 12.9W, 13.1E, 13.3E, 13.5E, 14.1W, and 15.1E. Along with analysis of archived Phase I samples in these Focus Areas, an additional 27 grab samples and 9 core samples were collected between February and March 2010. Surface grabs were collected via Van Veen sampler, pneumatic power-grab sampler, diver-assisted grab samples, and, due to low water levels, dry-land sampling methods for one location. The average grab sample recovery depth was 11 centimeters below mudline (bml). Core samples were collected by vibracore with an average recovery depth of 4.8 feet bml. Surface grab samples and cores were analyzed for a focused set of target parameters (with a few exceptions). The “Partial Analyte Group” included PCB Aroclors, total organic carbon (TOC) and total solids; TriMet samples included grain size, metals, PAHs, pesticides, and TPHs (GSI and Hart Crowser 2010).

In Phase II, PCB Aroclors were detected in 79% of 38 surface and 89% of 9 subsurface sediment samples, with concentrations ranging from <1.3 µg/kg to 520 µg/kg and <1.3 µg/kg to 147 µg/kg, respectively. Total DDX was detected in 98% of 40 surface and 100% of 10 subsurface samples, with concentrations ranging from <0.05 µg/kg to 73 µg/kg and <0.14 µg/kg to 73 µg/kg, respectively. Total PAHs were detected in 100% of 29 surface and 10 subsurface samples, with concentrations ranging from 4.0 µg/kg to 32,030 µg/kg and 76 µg/kg to 5,680 µg/kg, respectively. Total D/F were detected in 100% of 16 surface and 4 subsurface samples each, with concentrations ranging from 7.7 ng/kg to 7,021 ng/kg and 112 ng/kg to 2,351 ng/kg, respectively (GSI and Hart Crowser 2010).

Upon review of the Phase II data, ODEQ identified four areas which warranted follow-up evaluations: RM 12.1E, RM 12.5E, RM 12.9W, and RM 15.1E. These areas were referred to ODEQ’s Site Assessment Program to evaluate potential sources and the need for source control. As of 2011, ODEQ did not recommend additional in-river investigation in the Downtown Reach. ODEQ expects that concentrations will decline over time as sources are identified and addressed and natural recovery occurs. The Phase II investigation found that COCs were much lower than those found in the Site and ODEQ

believes the Downtown Reach is not a significant ongoing upstream source (ODEQ 2011).

Smallmouth Bass Tissue Sampling, GSI, September 2011

In September 2011, United States Environmental Protection Agency (EPA) and the City of Portland performed SMB sampling throughout the Study Area to support the Remedial Investigation/Feasibility Study (RI/FS). The study design and methods are described in the 2011 sampling and analysis plan (SAP) (GSI 2011). The SAP identified collection of individual (non-composited) SMB fish from 136 locations between RM 1 and RM 16, with 4 samples from RM 1 to RM 1.9, four from Multnomah Channel, 123 from the Study Area (including 11 from Swan Island Lagoon), and five from RM 15E. Each sample was identified for analysis of the full suite of PCB congeners, SVOCs, PAHs, and organochlorine pesticides (GSI 2011). The analytical laboratory contracted by EPA incorrectly prepared 75% of the samples as skin-off fillets, discarding the remainder of the carcass instead of processing the whole fish. Thus, results from the 2011 sampling effort are limited. Of the 32 reconstituted whole body Site samples with total PCB data, the mean concentration was 530 µg/kg with a standard deviation of 868 µg/kg (Legacy Site Services [LSS] 2015).

Smallmouth Bass Tissue Study, Data Report, Kennedy/Jenks, March 2013

In late summer/early fall of 2012, the Lower Willamette Group (LWG) conducted fish tissue sampling and analysis under the oversight of EPA. The primary purpose of the sampling was to provide an additional line of evidence to support the monitored natural recovery (MNR) Site-wide evaluation presented in the draft FS (Kennedy/Jenks 2013a). A total of 83 discrete SMB samples were collected in the Study Area and 9 SMB samples were collected from RM 15 to RM 18. With one exception, 4 to 12 samples were collected per RM and in Swan Island Lagoon (n = 8); one sample was collected in RM 2. All fish were caught using conventional rods and reels, with the assistance of contract anglers from the Oregon Bass & Panfish Club and The Bass Federation of Oregon. All 92 samples were analyzed as whole-body individuals for lipids and PCB congeners.

In the Study Area, the concentrations of total PCBs in whole body SMB ranged from 0.092 milligrams per kilogram (mg/kg) to 6.47 mg/kg. The mean concentration of total PCBs in whole body SMB was 0.65 mg/kg, with a standard deviation of 1.19 mg/kg. Upriver, the concentrations of total PCBs in whole body SMB ranged from 0.051 mg/kg

to 0.63 mg/kg. The mean concentration of total PCBs in whole body SMB was 0.23 mg/kg, with a standard deviation of 0.19 mg/kg. This data was not included in the FS.

In summary, the mean 2012 PCB SMB tissue concentrations were lower than the mean concentrations of the combined 2002 and 2007 SMB data that were used in the RI/FS and risk assessments on an RM and Study Area basis, except for RM 10 (Kennedy/Jenks 2013a). Based on statistical comparisons of the two data sets on a Study Area-wide scale, total PCB congener concentrations in whole body SMB tissue show a statistically significant ($p < 0.05$) decrease from the 2002 and 2007 data (Kennedy/Jenks 2013b, LSS 2015). The 2012 SMB data support that natural recovery is occurring on a system-wide scale.

Characterization of the Lower Willamette River with Sediment Profile Imaging, Changes in Space and Time, Germano and Associates, June 2014

The purpose of the study was to provide information on the physical and biological features of the surface sediments in the Lower Willamette River through specialized photography and compare to similar work performed in many of the same locations as work performed in 2001 by the LWG during the RI. The 2014 effort used the same people and protocol as the 2001 work, but was enhanced by updated technology (Germano and Associates 2014). Results of the SPI showed significant recovery in benthic infaunal successional stage compared to the 2001 RI results. These results support the fish tissue studies indicating natural recovery is occurring throughout the Study Area.

Final Supplemental RI/FS Study Field Sampling and Data Report, River Mile 11 East, GSI, July 2014

The River Mile 11 East Early Action Area is part of the Portland Harbor Superfund Site (PHSS) and was identified as a PCB “hot spot” which required accelerated remediation as per the EPA’s settlement agreement in 2013. Surface sediment sampling was conducted in October 2013. The limited-access surface sediment samples were collected by divers using a hand-coring device during May 2014 (GSI 2014).

Nine surface (bank) soil samples were collected and analyzed for PCB Aroclors, hydrocarbons (diesel range and residual range hydrocarbons), PAHs, pesticides, metals, phthalates, SVOCs, TOC, total solids, grain size, and D/F. Surface soil samples were composited and represented the 0- to 1-foot depth (GSI 2014).

22 surface sediment samples were collected and analyzed for PCB Aroclors, TOC, total solids, and grain-size distribution. In addition, samples from six re-occupied stations were analyzed for organochlorine pesticides. Of the 22 samples, 12 were collected by a pneumatic power-grab sampler, and 10 samples were collected by divers. The target depth for surface sediment samples was 30 centimeters bml (with a minimum acceptable penetration of 20 centimeters) (GSI 2014).

Total PCB Aroclors were analyzed in 22 surface sediment samples with 100% detection frequency. Concentrations of total PCB Aroclors ranged from 2.5 µg/kg to 1,405 µg/kg, with a median concentration of 93.5 µg/kg. Total dichlorodiphenyltrichloroethane (DDT) was analyzed in six surface sediment samples with 100% detection frequency. Concentrations of total DDT ranged from 0.24 µg/kg to 9.5 µg/kg, with a median concentration of 2.05 µg/kg. Total D/F were analyzed in four samples with 100% detection frequency. Concentrations of total D/F ranged from 556 ng/kg to 2,160 ng/kg, with a median concentration of 1,357.5 ng/kg (GSI 2014).

Sediment Sampling Data Report, Portland Harbor, Kleinfelder, June 2015

The purpose of the 2014 sediment investigation was to: (i) assess the current concentrations of PCB Aroclors in surface sediments (0-30 centimeters) from RM 2 to RM 16.2; (ii) provide data to compare with prior results and with concentrations predicted by the sediment recovery food web model (FWM); and (iii) develop a dataset representative of current PCB concentrations to be used in developing future remedial actions. Samples were collected from November to December 2014 (Kleinfelder 2015).

Within the PHSS, 98 surface sediment samples were collected, and 27 surface sediment samples were collected within the Downtown Reach (RM 11.8 to RM 16). Samples were collected using a hydraulic power-grab sampler (maximum penetration of 30 centimeters bml) and analyzed for PCB Aroclors, TOC, and grain size (Kleinfelder 2015).

Total PCBs were detected in 113 of 125 (90%) surface sediment samples. In Site sediment samples, total PCBs ranged from <0.7 µg/kg to 5,180 µg/kg. One sample was reported at 7,420 µg/kg; however, due to analytical interference, this sample was flagged as non-detect. In the upstream area (RM 11.8 to 16.2), total PCBs ranged from <0.7 µg/kg to 61.1 µg/kg. TOC ranged from 820 mg/kg wet weight to 35,000 mg/kg wet weight. Grain size results for the upstream area showed a lower percentage of fines (silt and clay) compared to Site samples (Kleinfelder 2015). Results showed that PCBs in surface

sediments were generally lower when compared to RI data co-located stations suggesting that natural recovery is occurring.

Concentrations and Character of PAH in Sediments in Area of River Miles 5 to 6, 2015 Investigation, NewFields, March 2016

Two sampling events were conducted during 2014 and 2015 to investigate the nature and extent of PAHs in sediments in an area between RM 5 and the St. Johns Bridge (RM 6). The potential for Principal Threat Waste (PTW) was also assessed for the various possible dredge horizon intervals. Sediment samples were analyzed for PCBs, D/F, DDx, and carcinogenic polycyclic aromatic hydrocarbons (cPAHs) (Benzo[a]pyrene Equivalents [BaP Eq]) (NewFields 2016).

The sediment bed depth intervals sampled in this study included: (i) Interval A, Surface, 0 to 1-foot bml; (ii) Interval B, Future Channel, -48 to -49 feet below Columbia River Datum (CRD); (iii) Interval C, Future Overdredge, -51 to -52 feet below CRD; and (iv) Interval D, Future Overdredge (plus cap buffer), -53 to -54 feet below CRD. 53 samples were taken at Sampling Interval A, 15 samples were taken at Interval B, 34 samples were taken at Interval C, and 40 samples were taken at Interval D (NewFields 2016).

The highest cPAH concentrations were detected in the proximity of the former Gasco property and were consistent with pyrogenic manufactured gas plant (MGP)-derived tar wastes. Very few sediment samples from this study detected petroleum-derived PAHs. The mean concentrations of other COCs (PCBs, DDx, selected chlorinated D/F isomers, BaP Eq) in this study did not exceed PTW classifications (NewFields 2016).

Total PCB Aroclors were detected in 26 of 31 (84%) sediment samples, with concentrations ranging from <0.02 µg/kg to 27.8 µg/kg. Total DDx were detected in 22 of 31 (71%) samples, with concentrations ranging from <0.036 µg/kg to 58.3 µg/kg. Total PAHs were detected in 100% of 150 samples, with concentrations ranging from 1.3 µg/kg to 1,376,830 µg/kg (reported as sum of 17 PAHs). Total D/F were detected in 100% of 31 samples, with concentrations ranging from 5.9 ng/kg to 5,291 ng/kg (NewFields 2016).

Sediment Sampling Data Report, Swan Island Lagoon, Geosyntec Consultants, August 2016

20 surface sediment (0-30 centimeters) samples were collected within Swan Island Lagoon (RM 8 to 9) during March 2016. Samples were analyzed for PCB Aroclors, TOC, and grain size. Sediment sample locations were co-located with previously sampled locations by the LWG for the RI/FS (1998-2007). The purpose of the study was to evaluate if natural recovery of sediments is occurring in Swan Island Lagoon by comparing the 2016 results to the older RI/FS results (Geosyntec 2016).

PCB Aroclors were detected in all 20 surface sediment samples, with concentrations ranging from 33.6 µg/kg to 996 µg/kg. 75% of these samples showed reduced PCB concentrations when compared with sample results collected over 10 years ago. These results also confirmed trends seen with PCB concentrations found in surface sediment samples collected by the 2015 Kleinfelder study. Recent sampling indicates that newly deposited sediments are covering and/or mixing with the older surface sediments both river-wide and in Swan Island Lagoon (Geosyntec 2016).

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APPENDIX B

**APPROACH FOR SAMPLING OF SURFACE
SEDIMENT**

**Pre-Remedial Design Work Plan
Portland Harbor Superfund Site**

INTRODUCTION

This appendix details the proposed design and evaluation of the proposed 640-sample surface sediment sampling plan. It is organized into two sections, as shown below:

- Section B1: Sample Placement and Design; and
- Section B2: Sample Plan Statistical Evaluation.

The proposed plan consists of 428 unbiased samples and 212 biased samples located in the Sediment Management Areas (SMAs), for a total of 640 samples. The density of unbiased samples is approximately 20 samples per bisected River Mile segment (distributed in 20 segments, plus a 20-sample segment in Swan Island Lagoon and 8 additional samples in inlet areas). Approximately 160 of the unbiased sample locations will fall within/immediately adjacent to the SMAs, enabling the delineation of the SMAs to take advantage of approximately 370 samples (212 SMA sample plus approximately 160 unbiased samples = approximately 370 samples).

This density of SMA sampling achieves the level of precision needed to delineate SMAs within an approximate 30% level of uncertainty, sufficient for the needs of the Pre-RD group and an initial dataset to inform on additional SMA delineation sampling events needed for higher levels of engineering design. Additionally, the sampling plan is sufficient to meet the needs of the Pre-RD group in evaluating natural recovery since 2004 and developing statistically robust Spatially Weighted Average Concentrations (SWACs) on Site-wide and other spatial scales. The proposed 428 unbiased samples also meets the unbiased sample count necessary to meet EPA's data objectives, in addition to the Pre-RD group's objectives.

Section B1: Sample Placement and Design

Placement of the 640 surface sediment samples will be achieved through the following steps, and a conceptual figure showing the distribution of the samples is shown in Figure 1:

1. A sample grid consisting of 428 cells will be devised for the Site (River Miles 1.9 to 11.8). This grid will be used to place the unbiased (randomly placed) samples. There will be three types of cells:

- a. **Shoal cells:** Shoal cells will be placed parallel along the center channel flow path (thalweg) of the center of the navigation channel in the areas of the river outside of the navigational channel (shoals). One set of shoal cells will be placed to the east of the navigational channel, and one set of shoal cells will be placed to the west side of the navigational channel. The length of each shoal cell will be approximately 0.067 miles such that approximately 30 shoal cells (15 on east shoal, 15 on west shoal) will be present per River Mile. The width of each shoal cell will be the distance between the navigational channel boundary and the river bank. 150 shoal cells will be placed on the east side of the river and 150 will be placed on the west side of the river for a total of 300 shoal cells.
- b. **Navigational cells:** Navigational cells will be placed parallel along the thalweg of the center of the navigation channel in the areas of the river within the navigational channel. One set of navigational cells will be placed to the east of the navigational channel thalweg centerline, and one set of navigational cells will be placed to the west side. The length of each navigational cell will be approximately 0.2 miles such that approximately 10 navigational cells (5 on eastern half of the channel, 5 on western half of the channel) will be present per River Mile. The width of each navigational cell will be the distance between the navigational channel boundary and the navigational channel thalweg centerline. 50 navigational cells will be placed on the eastern half of the navigational channel, and 50 navigational cells will be placed on the western half of the navigational channel.
- c. **Inlet cells:** Five areas of the Site (e.g., Swan Island Lagoon) do not conform well to the shoal grid placement, so these areas will be identified as inlets. In these areas, inlet cells will be placed such that the length of each cell is approximately 0.067 miles and the width is the bank-to-bank width of the inlet. Thus, these areas will be sampled at the same density as the shoal areas that border the navigational channel. 8 inlet cells will be placed in the smaller inlets, and 20 cells will be placed within Swan Island Lagoon.

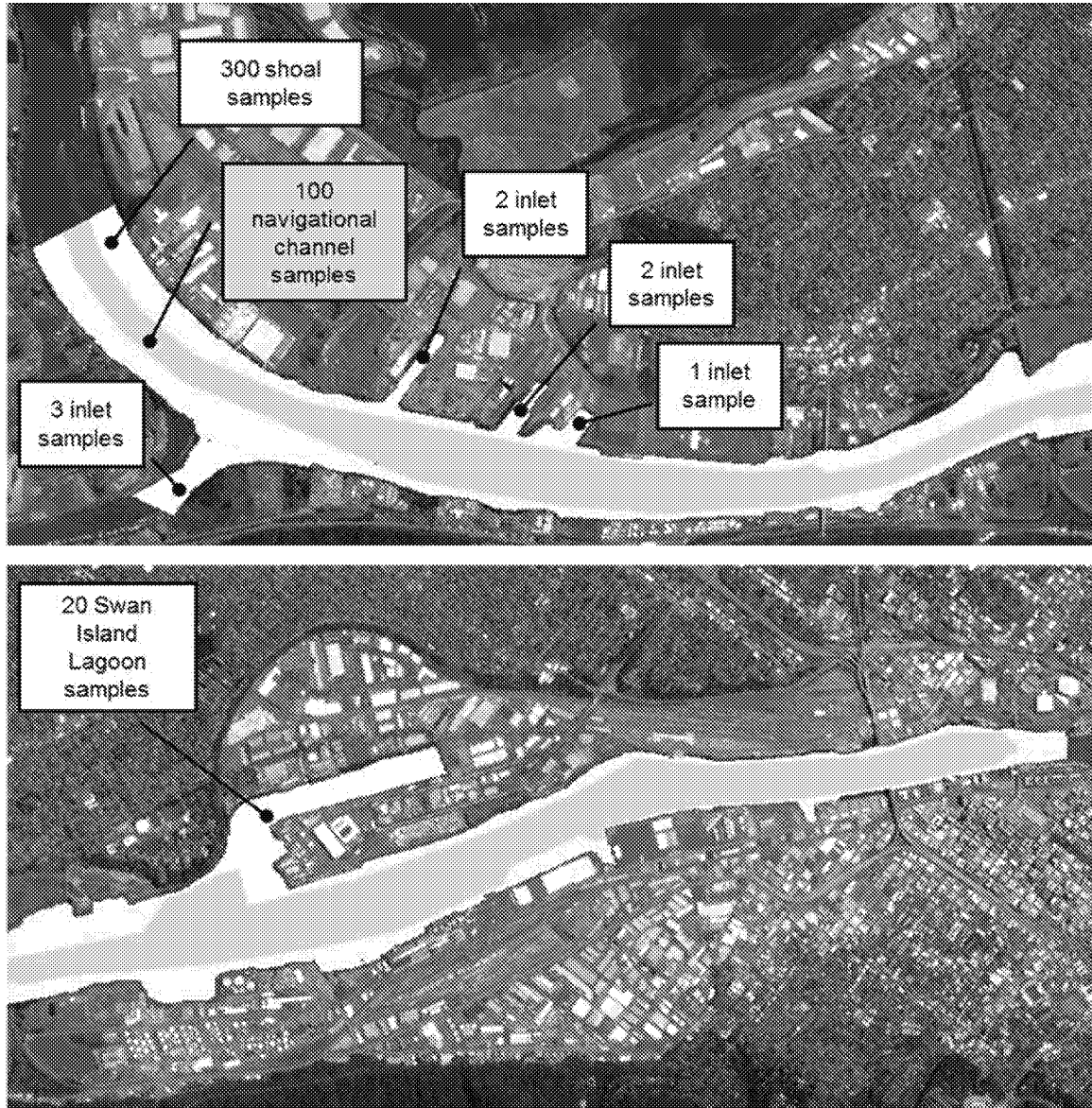


Figure 1. Conceptual distribution of the 428 unbiased samples among the shoal (light blue), navigational channel (purple), and inlet/Swan Island Lagoon (pale yellow) areas.

The 428-cells will be designed such that:

- 3 times the number of samples will be placed in the shoals relative to the navigational channel. The addition of inlet samples (which are in inlet sections of the river shoals) will slightly increase the number of shoal samples relative to navigational channels, such that 23% of the final sample count will represent navigational channel samples.
 - The sample design will be evenly balanced between east and west. Due the presence of inlets, approximately: 225 (53%) of samples will be on the eastern side and 203 (47%) of will be on the western side.
 - Approximately 40 randomized samples will be present per each River Mile (20 on east and 20 on west). This targets 15 samples on each shoal and 5 samples on each side of the navigational channel.
 - Robust sample sizes will be achieved in four segments (Segment 1 = River Mile 9 to 11.9, Segment 2 = River Mile 7.5 to 9, Segment 3 = River Mile 5 to 7.5, and Segment 4 = River Mile 1.9 to 5), as well as the four segments bisected into east and west portions, and Swan Island Lagoon (these segments are shown in Figure 3 of the Workplan).
2. In each bisected River Mile (starting with 1.9 to 2.9 on the East side), 6 cells containing at least 1 surface sediment sample station sampled in 2004 will be randomly selected for reoccupation. In 11E and 11W, no cells can be selected for reoccupation due to lack of 2004 sample locations. This will result in approximately 108 cells selected for reoccupation.
 3. In each cell, a location will be randomly determined to receive the sample location. The sample location will be selected via a random number generator to determine the x- and y-coordinates. The randomization process will exclude areas that were within 20 feet of the shoreline to avoid placing samples in the intertidal zones or in areas that could not be reached with the sample vessel. Random sample locations will be visually inspected (aerial imagery) to ensure that the sample will not be placed in an area that could not be reached with the sample vessel (e.g., underneath piers or other fixed infrastructure), with a re-randomization of the location if needed.

4. If the cell will be randomly selected for reoccupation (step 2 above), a location will be selected at random from the cell and then shifted to reoccupy the nearest 2004 sample location.
5. 212 additional samples will be added to enable 2-dimensional delineation of the Alternative F Mod active Sediment Management Area (SMA) footprint. These samples (“SMA Samples”) are not unbiased, randomly placed samples. They will be placed in two successive steps.
 - a. The first step in SMA sample placement will assume a surface sediment sample will be placed at each of the 60 proposed sediment core locations (the 30 proposed bank core locations are not included).
 - b. The second step in SMA sample placement will consist of selecting 152 sample locations within and immediately adjacent to the SMAs such that a sediment sample would be present approximately every 300 feet within the SMAs.

The 212 SMA samples specifically placed within and immediately adjacent to the SMAs plus the unbiased samples placed randomly within the SMAs (approximately 166 unbiased samples) will result in approximately 378 samples total within and immediately adjacent to the SMAs. Additionally, many unbiased sample locations near the SMAs will also be used to aid in delineation.

In summary, the 640 surface sample count will have the following distributions:

- 428 unbiased samples and 212 biased SMA samples (640 total);
- 108 re-occupied stations are expected to be evenly distributed across the range of PCB concentrations, as compared to the full 2004 dataset (Figure 2);
- Approximately 20 samples per bisected River Mile (distributed in 20 segments plus Swan Island Lagoon), achieving EPA’s goal of approximately 20 samples per rolling River Mile can be achieved in the 20 segments, plus Swan Island Lagoon;
- Among the unbiased samples, 100 will be located in the navigation channel and 328 will be located in the shoaled areas (approximate 25/75 distribution); and

- The unbiased samples will be distributed among the 9 segments as shown in Table 1 (Figure 3 of the workplan).

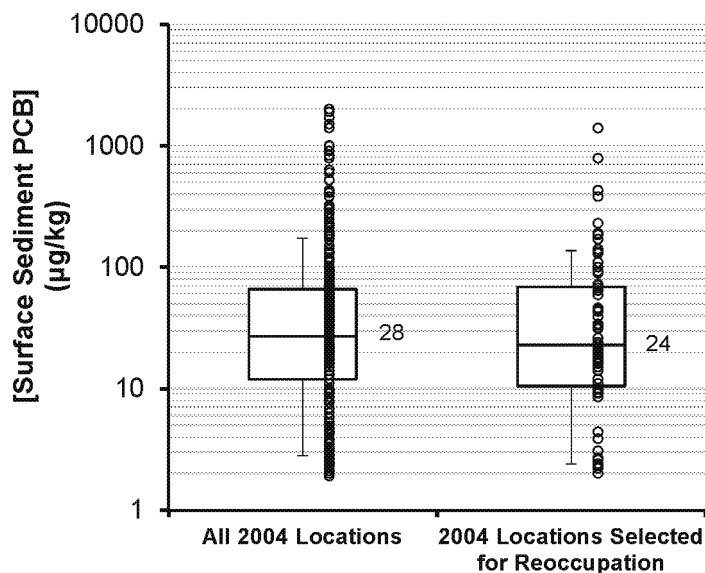


Figure 2. Concentrations of PCBs in surface sediments in all 2004 surface sediment sample locations compared to the 87 locations selected for re-occupation in an earlier draft proposed plan. This figure will be updated in the Sampling and Analysis Plan (SAP) following the placement of the approximate 108 sample reoccupations. The boxes represent the interquartile ranges of the data, whiskers represent the 10th and 90th percentiles, the empty circles represent individual data points, and the labels indicate the geometric mean of concentrations.

Table 1. Expected distribution of the 428 unbiased samples within each of the 9 segments.

Segment	Number of Unbiased Samples
1W	58
1E	59
2W	29
2E	30
Swan Island Lagoon	20
3W	50
3E	48
4W	63
4E	71
Total	428

Section B2: Sample Plan Statistical Evaluation

The ability of the sample plan to meet various data objectives in a statistically robust manner was evaluated using several statistical approaches, as detailed below. It should be noted that these approaches are conservative and tend to overestimate sample size requirements, as they are based on the 2004 PCB data. Recently-collected data have suggested concentrations of PCBs in surface sediment have decreased significantly since 2004 such that many areas are converging on lower, ambient levels of PCBs. This convergence would result in lower variability in hypothetical 2018 data (and future data), which would greatly improve the precision and power of data and lower necessary sample size requirements for the data evaluations discussed below.

Additionally, the below statistical evaluations are considered initial efforts and may be augmented by additional or alternate evaluations (as needed) if any revisions to the sampling plan are considered or other aspects of the data objectives are emphasized.

The Plan is Sufficient for SMA Delineation

The proposed sample placement density of the 378 samples within/adjacent to the SMAs is approximately 1 sample per 70,000 ft² and a spacing of approximately 290 to 300 ft between each sample. Via a Monte Carlo simulation using a hypothetical 20-sample

evaluation area and an approximated Site-wide 2004 PCB sediment data distribution, we calculated the average area that would be indicated by the number of samples that would exceed the PCB RAL of 75 µg/kg and indicate designation for inclusion within an SMA. The Monte Carlo simulation calculated the sum of the individual 70,000-ft² areas 1000 times to simulate potential results for the final total SMA area sizes. 80% of the total SMA area estimates (area that would be indicated above the PCB RAL) were within ± 25% to 38% (average of 31%) of the median estimate. This approximate level of ±30% precision was considered satisfactory for the initial SMA delineation.

The Plan is Sufficient for Spatially Weighted Average Concentration (SWAC) Determination

Spatially Weighted Average Concentrations (SWACs) for PCBs in the proposed plan were calculated using a simplified approach in which equal polygon areas were assumed for each proposed sample point and a random concentration of PCBs were assigned from approximated 2004 PCB sediment data distributions for each of the 8 segments. SWACs were calculated for each of the 8 segments shown in Table 1, assuming approximately 40 samples were present in each segment, except for segment 2W, which is expected to receive fewer samples due to its shoreline configuration and River Mile length. Actual sample sizes for the final sample plan are expected to be higher (Table 1), and this analysis will be updated in the SAP. Using Monte Carlo simulation, the PCB SWAC and 95% Confidence Intervals (95% CIs) around the SWAC were calculated 1000 times for each the 8 segments. Swan Island Lagoon, within 2E, was also assessed in an additional evaluation (segment 9) and it was noted that the proposed sample size and placement would be sufficiently robust to meet SWAC data objectives if Swan Island Lagoon is evaluated as its own segment.

The projected SWACs are shown in Figure 3, and are compared to the SWACs obtained from the 2004 data. On average, the 95% CIs of the projected SWACs¹ (that would be obtained using the sample plan) are 10% more precise than the 95% CIs calculated using the actual 2004 data and spatial placement of 2004 samples. Thus, the sampling plan will be able to generate SWACs that are as precise or more precise than the SWACs generated with the historical data used as the basis for the remedial investigation, feasibility study,

¹ The median of the 1000 SWAC 95% CIs (for each segment) was evaluated.

and record of decision at the scale of evaluation (8 segments plus Swan Island Lagoon, as shown in Figure 3 of the work plan).

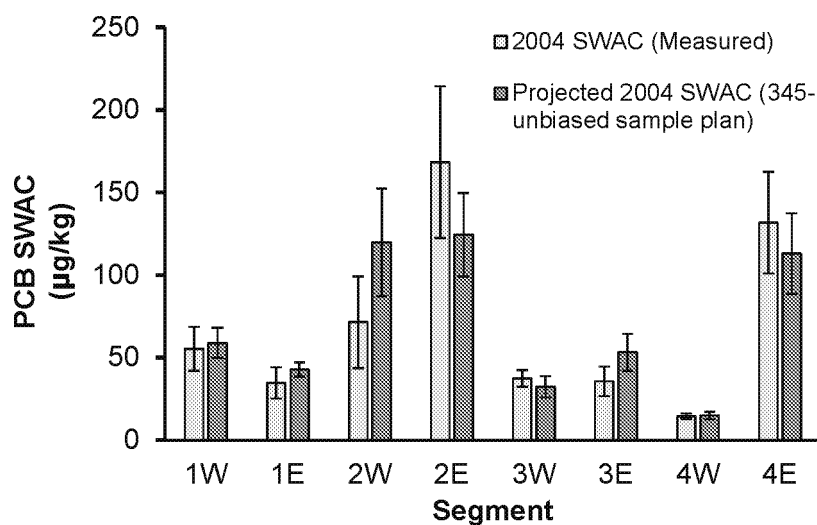


Figure 3. SWACs calculated using the 2004 sample locations and results (grey bars) and projected using a Monte Carlo simulation of the sample sizes in each segment, as placed in the sample plan (green bars). Note: this figure was generated using an earlier draft proposed plan that included fewer samples. This figure will be updated in the SAP, and overall statistical robustness of the plan will increase due to the additional samples.

It should also be noted that this projected SWAC analysis was performed assuming that the samples would not be composited. The 3-point composting approach is likely to reduce variability by approximately 50% on a Site-wide basis (see below), so the precision of the projected SWACs (shown in Figure 3) is likely to be reduced significantly such that precision of the SWACs in all segments (including 4W and 3W) should be more precise from those calculated in 2004.

The Plan is Sufficient for Comparing Differences in Concentrations Since 2004

A variety of data evaluation approaches will likely be used to evaluate differences in concentrations of PCBs in surface sediment between 2004 and 2018 (or going forward by EPA), including regression and multi-variate analyses and consideration of various other data, including water depth, grain size, organic carbon, and other sample location-specific factors that influence natural recovery processes. Data will also be modeled and evaluated spatially, including statistical comparisons of SWACs estimated in 2004 and 2018.

A simple analysis would include a comparison of 2004 and 2018 data at the stations proposed for reoccupation. A Site-wide power analysis indicated that approximately 90 reoccupations of the 2004 samples, if paired and compared on a log-transformed basis ($n = 90$), will be sufficient to detect an approximate 40% or more reduction in PCB concentrations (power of 0.8, α of 0.05). This is likely conservative (i.e., lower levels of reduction will likely to be detectable) given the analysis was based on single samples (not composited samples, as identified in the sampling) plan, and the fact that 2018 are likely to be of lower variability than 2004 data. The approximate 40% reduction from 2004 to 2018 (14 years) is less than that hypothesized by EPA in the natural recovery trend analysis (i.e., assumption of 5% to 10% per year, which would equate to a 50% or greater reduction in concentrations over the 2004 to 2018 time period). Additionally, as proposed, approximately 108 samples will be used for the reoccupation, further increasing power (analysis will be updated in the SAP).

Assuming a reduction in variability as a result of the 3-point compositing approach proposed in the workplan² the 87 reoccupations should be able to detect a 25% (or greater) difference at a Site-wide scale. At the segment level, this approach should enable approximate 30 to 40% differences (or more) to be detected. The statistical power at this level should be further augmented by additional variables and approaches (as described above) or sensitivity analyses that include portions (or the entirety) of data from samples collected in the SMAs. In particular, spatial weighing of the data (using SWAC or equivalent geostatistical analyses) is likely to greatly improve the power of the statistical

² Variability of the data should decrease from an approximate 40% coefficient of variation (CV) to a 20% CV, based on Monte Carlo simulation.

comparisons, enabling in lower levels of differences between 2004 and 2018 SWACs to be detected at the 8-segment scale.

The Plan is Sufficient for PCB Natural Recovery Power Analysis

As noted above, the proposed plan will achieve approximately 20 samples per bisected River Mile, and each of these samples is represented by a 3-point composite. EPA's statistical power analysis (Figure 9 of Appendix A of the June 6 draft plan³, shown in Figure 4 below) indicates that 20 samples bisected River Mile segment would likely be sufficient to achieve statistical power to evaluate their stated goal of evaluating natural recovery trends for PCBs (the basis of the 20 unbiased samples per bisected River Mile segment sample size determination). The proposed-sampling approach is projected at a level of statistical power of 0.9 power for PCBs according to EPA calculations⁴.

3 EPA. 2017. Portland Harbor Superfund Site Sampling Plan for Pre-Remedial Design, Baseline, and Long-Term Monitoring. Revised Working Draft. June 6.

4 This power analysis was based on PCBs; the same analysis based on DDx and PAHs indicates higher sample sizes are needed, but these chemicals are located in hotspots at the Site such that the power analysis likely overestimates the sample sizes needed.

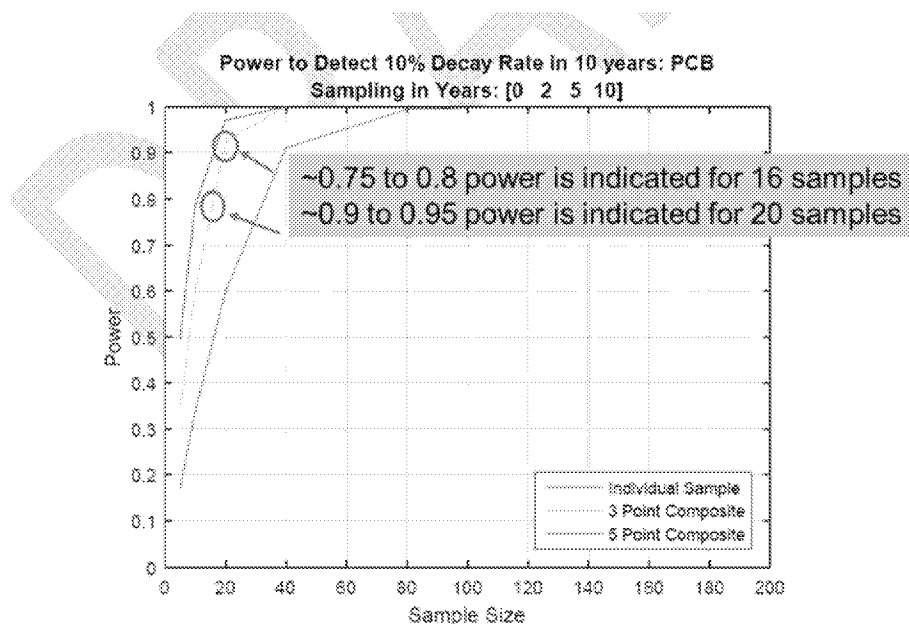


Figure 9. Power to detect a 10% annualized recovery rate in sediment by monitoring in year 0, 2, 5 and 10 for total PCBs.

Figure 4. Reproduction of Figure 9 in Appendix A of EPA’s draft June 6, 2017 sampling plan. The green ovals, arrows, and text box have been added (see discussion).

Summary of Plan Evaluation

In summary, the above evaluations indicate the proposed plan is sufficiently robust for addressing the Pre-RD group data needs:

- SMA areas will be delineated at an approximate $\pm 30\%$ level of uncertainty;
- SWACs for each of the segments will be as precise or more precise than previously-calculated SWACs; and
- Differences in sediment concentrations (including SWAC and other data expressions) between 2004 and 2018 will be statistically detectable ($\alpha = 0.05$) an approximate 0.8 level of statistical power, assuming concentrations have decreased approximately 25-40% or more since 2004.

In addition, the proposed sampling density achieves a statistical power of 0.9 based on one of the key power analyses used by EPA to support their approximate sample size requirements.

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APPENDIX C

POWER ANALYSIS FOR FISH TISSUE SAMPLE SIZE
PREPARED BY AECOM

Pre-Remedial Design Work Plan
Portland Harbor Superfund Site

POWER ANALYSIS FOR FISH TISSUE SAMPLE SIZE, PREPARED BY AECOM

A statistical analysis was performed using the 2012 smallmouth bass (SMB) tissue data set for the Portland Harbor Superfund Site (Kennedy/Jenks Consultants, 2013) to estimate sample sizes for re-baselining fish tissue chemistry. Prior analyses of 2002, 2007, and 2012 data for polychlorinated biphenyls (PCBs) in SMB indicate fish tissue concentrations have declined over time. The primary focus of this analysis was to estimate the number of SMB samples needed to determine with statistical significance whether PCB concentrations have continued to decline since 2012. Comparison of historical and new means and 95% confidence intervals, as well as trend analysis, provide robust and statistically-valid approaches for evaluating the data to evaluate natural recovery, and are likely to be used following data collection in 2018.

An important aspect of monitoring design is power analysis, which was performed to estimate the difference that can be detected between the 2012 and re-baselining fish tissue data sets. This was illustrated by calculating the effect size (d) or the standardized difference between two means that could be detected (Cohen, 1988); and the minimum detectable difference (MDD) as a function of sample size and variance. The MDD is the difference between two means that must exist to detect a statistically significant effect/difference. The MDD is a commonly employed technique to indicate the potential significant difference at a given sample size in fish tissue monitoring (e.g., United States Environmental Protection Agency [EPA], 2000).

METHODS AND RESULTS

Two scenarios were evaluated: (i) assuming sample size equivalent to the 2012 smallmouth bass data set (n=83 Study Area, n= 9 upriver background); and (ii) assuming sample size equivalent to the targets set forth in the 2012 work plan (n=95 Study Area, n=10 upriver background) (Windward Environmental, 2012). The sample size calculations were performed considering two spatial scales: (i) site-wide; and (ii) four 2 to 3-mile segments.¹ Both spatial scales are relevant to evaluation of SMB in the risk assessment and bioaccumulation modeling.² Sample size estimation

¹ The segmentation is based on prior analysis of the available data (Wolf, 2015).

² A spatial scale of 2 to 3 mile segments may better reflect the home range of SMB which ranges from 0.5 to 5.5 miles (Scott and Crossman, 1998). Based on a radio-tracking study of predator species in the Lower Willamette River, the median total distance traveled (upstream and downstream) by SMB was 4.3 kilometers (km) (2.7 miles), with 25th and 75th percentiles of 0.8 km and 8.0 km (Friesen, 2005).

to support statistical analysis of trend/natural recovery on an individual river mile (RM) basis is not a data use objective; large sample sizes would be needed to detect trends with adequate power. The power analysis was performed using the following assumptions:

- Confidence = 95% (alpha [α] = 0.05);
- Power = 80% (1- β = 0.80); and
- PCB data lognormally distributed.

The assumption that PCB concentrations in the 2012 whole body SMB data set are lognormally distributed is based on distribution testing performed using @Risk v.6 (Palisades, 2012). Table 1 presents summary statistics for the 2012 SMB data set. PCB fish tissue concentrations were log (base 10) transformed for the power analyses. The assumptions of 95% confidence ($\alpha = 0.05$) and power of 80% are used by convention to support statistically significant results (e.g., EPA, 2000). However, statistically robust changes may still be concluded using less stringent hypothesis test statistics (e.g., lower confidence or power).

The calculation of effect size (Cohen's d) was performed using the pwr package (Champely, 2017) in the R statistical computing (R Core Team, 2015). The calculation of the minimum detectable difference (MDD) as a function of the sample size and variance in the 2012 data was performed using the following formula and expressed as a percentage of the 2012 mean³ (Harcum and Dressing, 2015):

$$\text{MDD} = \sqrt{[(4\sigma^2 (Z(1-(\alpha/2)) + Z(1-\beta)))^2 \div N]}$$

where:

N = total sample size (number of samples in 2012 and new baseline)

σ = standard deviation (assumed equal to 2012 sample populations)

$Z(1-(\alpha/2)) = 1.96$

$Z(1-\beta) = 0.84$

MDD = minimum detectable difference between 2012 and new baseline means

³ While log transforming the data results in the power analysis being on the population geometric mean, results using the techniques described here are considered to be adequate practical approximations for the purpose of this analysis.

The effect size analysis indicates that replicating the 2012 sample sizes (actual or target sample sizes) will allow for moderate differences between the means to be detected on a site-wide basis (Cohen's *d* of ~0.4). For the four segments, the 2012 sample sizes will allow for large differences between the means to be detected (Cohen's *d* of ~0.8).⁴

Results of the MDD analysis are summarized in Table 2 for the full Site (RM 2-12), each of the four segments, and the upriver background area. The MDD analysis was also performed excluding Segment 1 (RM 9-12), which has the highest mean and variance; eight of the ten highest 2012 PCB SMB samples were from Segment 1, which includes the RM11 area. Table 2 includes MDD results for combined Segments 2, 3, and 4 (RM 2-9).

As shown in Table 2, sample sizes consistent with the 2012 program (actual or target) result in a MDD of about 30% on a site-wide basis. The MDD improves slightly (about 1%) when the 2012 target sample size is used (increase of 12 samples site-wide). When the area with high variance is removed (Segment 1), the MDD is about 23% for the remainder of the Site.

On a river segment basis, sample sizes of 20 to 23 result in MDDs of about 28% to 40% in Segments 2, 3, and 4. In Segment 1 (RM 9-12) where variance is highest, sample sizes of 22 to 28 result in a MDD of about 60%. For upriver background, a sample size of 9 to 10 results in an MDD of about 60%. For upriver background, the means for the 2002 (n=6 composite samples) and 2012 (n=9 discrete samples) SMB data sets are similar (170 micrograms per kilogram [$\mu\text{g}/\text{kg}$] and 230 $\mu\text{g}/\text{kg}$, respectively).

Based on prior trend analysis indicating a decline of about 4% per year (Nielsen, 2015), the maximum change that could be expected in the new baseline data would be approximately 24% in 2018 from the 2012 site-wide mean assuming a linear response (declines may become asymptotic over time as conditions reach equilibrium). Based on the MDD values calculated in this analysis, sample sizes consistent with the 2012 program should be sufficient to detect a change of this magnitude on a site-wide basis (excluding Segment 1/RM11 area) with a high degree of statistical significance.

⁴ The Cohen's *d* statistic is a standardized measure of the size of the effect that can be observed between two means, with smaller values indicating smaller differences can be observed. Per Cohen (1977): 0.2 = small effect; 0.5 = moderate effect; and 0.8 = large effect.

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Table 1
Summary Statistics for 2012 Smallmouth Bass Data Set
Portland Harbor Superfund Site
Pre-Remedial Design Baseline Study

Domain	River Miles	2012 SMB Data (a)					
		n	Minimum (ug/kg)	Maximum (ug/kg)	Mean (ug/kg)	SD (ug/kg)	CV
Site-wide	2-12	83	92.4	6470	648.7	1185.9	1.8
Segment 1	9-12	22	134	6470	1531.6	2057.7	1.3
Segment 2	7.5-9 & SIL	23	118	1060	331.3	203.7	0.6
Segment 3	5-7.5	19	92.4	440	225.1	85.4	0.4
Segment 4	2-5	19	148	1280	434.2	299.8	0.7
Upriver Background	15-18	9	50.7	634	234.0	187.5	0.8

Notes

(a) PCB wet weight data from 2012 Smallmouth Bass Tissue Study (whole body). Kennedy/Jenks 2013.

n = sample size

CV = coefficient of variation

SD = standard deviation

SMB = smallmouth bass

**Table 2
Summary of Power Analysis for Smallmouth Bass Sample Size
Portland Harbor Superfund Site
Pre-Remedial Design Baseline Study**

Domain	River Miles	2012 SMB Data (a)				Sample Size Equals 2012 Actual Catch		Sample Size Equals 2012 Targets		Increase in MDD due to attaining targets	
		n	Mean log ₁₀ PCB (ug/kg)	SD log ₁₀ PCB (ug/kg)	Geometric Mean (ug/kg)	MDD log PCB (ug/kg)	MDD (%)	n	MDD log PCB (ug/kg)		MDD (%)
Site-wide	2-12	83	2.56	0.38	364	0.17	31.6%	95	0.16	30.7%	0.9%
Segments 2, 3 & 4 (b)	2-9	61	2.45	0.23	282	0.12	23.9%	67	0.12	23.4%	0.5%
Segment 1	9-12	22	2.87	0.52	745	0.44	63.5%	28	0.41	61.2%	2.4%
Segment 2	7.5-9 & SIL	23	2.46	0.22	290	0.18	33.8%	23	0.18	33.8%	0.0%
Segment 3	5-7.5	19	2.32	0.16	211	0.14	28.3%	21	0.14	27.6%	0.6%
Segment 4	2-5	19	2.56	0.27	359	0.24	42.8%	23	0.23	41.2%	1.6%
Upriver Background	15-18	9	2.26	0.33	180	0.44	63.8%	10	0.43	62.8%	1.0%

Notes

(a) PCB data from 2012 Smallmouth Bass Tissue Study. Kennedy/Jenks 2013.

(b) Site-wide domain after exclusion of Segment 1 (highest 2012 SMB PCB levels were observed in RM11 area).

Analyses performed using alpha of 0.05 and power of 0.80.

n = sample size

MDD = Minimum Detectable Difference

SD = standard deviation of the log base 10 transformed mean

SMB = smallmouth bass

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APPENDIX D

**CALCULATION OF WHOLE BODY – FILLET RATIOS
FOR FOCUSED CHEMICALS OF CONCERN IN
SMALLMOUTH BASS TISSUE
PREPARED BY AECOM**

**Pre-Remedial Design Work Plan
Portland Harbor Superfund Site**

Appendix D
 Calculation of Whole Body - Fillet Ratios for Focused Chemicals of Concern in Smallmouth Bass Tissue

Location	Fraction (a)		DDx (b)				Dioxins_Furans (b)				PCB_Congeners (b)						
	Body w/o fillet	Fillet	Body w/o fillet µg/kg	Fillet µg/kg	Whole Body (c) µg/kg	Ratio WB:F	Body w/o fillet pg/g	Fillet pg/g	Whole Body (c) µg/kg	Ratio WB:F	Body w/o fillet pg/g	Fillet pg/g	Whole Body (c) µg/kg	Ratio WB:F			
SB010E	0.71	0.28	92.02	7.87	67.95	8.63	4.78	0.55	3.57	6.45	857040	83375	635686	7.62			
SB010W	0.71	0.29	254.22	15.55	184.21	11.85	13.50	1.17	9.88	8.48	1117067	122842	825177	6.72			
SB011E	0.76	0.23	43.11	6.41	34.29	5.35	9.66	1.12	7.61	6.81	8162565	1481605	6554652	4.42			
SB011W	0.75	0.24	86.47	7.36	66.60	9.05	10.37	1.25	8.07	6.46	675258	83874	526546	6.28			
SB02E	0.68	0.31	127.54	14.91	91.78	6.16	8.19	0.87	5.86	6.76	1997918	199566	1427353	7.15			
SB03E	0.72	0.28	129.37	13.75	96.38	7.01	5.60	0.66	4.19	6.39	371940	40694	277425	6.82			
SB03W	0.73	0.26	135.96	14.37	103.62	7.21	7.33	0.91	5.62	6.21	264052	26961	201006	7.46			
SB04E	0.72	0.27	123.33	14.85	93.24	6.28	10.30	1.37	7.82	5.70	1855376	241418	1407655	5.83			
SB04W	0.73	0.27	172.39	18.07	129.92	7.19	6.93	1.15	5.34	4.62	379264	38773	285558	7.36			
SB05W	0.76	0.24	184.29	17.03	143.62	8.43	7.75	0.89	6.08	6.85	345978	34276	270171	7.88			
SB06E	0.74	0.26	116.97	11.38	89.25	7.84	7.03	0.78	5.39	6.90	872325	82290	664932	8.08			
SB06W	0.75	0.24	279.18	20.47	215.42	10.52	16.54	1.67	12.87	7.70	352513	28952	272752	9.42			
SB07E	0.72	0.27	153.26	12.34	114.06	9.24	34.49	3.71	25.92	6.98	2687788	210859	1998729	9.48			
SB07W	0.77	0.23	1843.30	180.58	1461.08	8.09	430.22	57.27	344.43	6.01	678402	65752	537571	8.18			
SB08E	0.75	0.25	81.59	9.46	63.19	6.68	12.12	1.56	9.43	6.05	369306	43015	286074	6.65			
SB08W	0.66	0.33	593.47	48.25	408.18	8.46	43.44	4.21	30.10	7.16	651255	51441	447423	8.70			
SB09E	0.65	0.34	100.62	10.99	69.18	6.29	8.13	0.97	5.62	5.78	496991	53205	341323	6.42			
SB09W	0.71	0.28	238.42	20.06	175.81	8.76	10.83	0.93	7.99	8.63	1318052	104333	970079	9.30			
Average	0.72	0.27	Average Ratio				7.95	Average Ratio				6.66	Average Ratio				7.43
			Standard Deviation				1.64	Standard Deviation				0.96	Standard Deviation				1.33
			Table B3-3 of Final FS (EPA 2016)				7.17	Table B3-3 of Final FS (EPA 2016)				6.13	Table B3-3 of Final FS (EPA 2016)				8.02

Notes:

(a) Fractions calculated using fillet and body without fillet weights in Table 3-3 of Round 3B Fish and Invertebrate Tissue and Collocated Sediment Field Sampling Report (Integral and Windward 2008). Average of individuals in composite sample.

(b) Smallmouth bass tissue chemistry data from SCRA database (sum of detected congeners for dioxins_furans and PCBs).

(c) Whole body concentration calculated as sum of (fillet concentration X fillet mass fraction) + (body w/o fillet concentration X body w/o fillet mass fraction).

Abbreviations:

w/o - without; DDx - sum of dichlorodiphenyltrichloroethane and its derivatives; µg/kg - microgram per kilogram; pg/g - picogram per gram; WB - whole body; F - fillet; FS - Feasibility Study

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