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Lower Duwamish Waterway Group

Port of Seattle / City of Seattle / King County / The Boeing Company

LOWER DUWAMISH WATERWAY: COMPILATION AND ASSESSMENT OF FISH AND SHELLFISH TISSUE DATA TO REFINE BACKGROUND CONCENTRATIONS

For submittal to

The Lower Duwamish Waterway Group
Seattle, WA

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ACRONYMS AND ABBREVIATIONS

Axys	SGS AXYS Analytical Services Ltd.
COC	contaminant of concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management
EPA	U.S. Environmental Protection Agency
ESD	explanation of significant differences
FS	feasibility study
HHRA	human health risk assessment
ISIS	Integrated Site Information System
LDW	Lower Duwamish Waterway
MLE	maximum likelihood estimation
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PEF	potency equivalency factor
RBTC	risk-based threshold concentration
RI	remedial investigation
ROD	Record of Decision
ROS	regression on order statistics
SMS	Washington State Sediment Management Standards
TEQ	toxic equivalent
TTL	target tissue level
UCL	upper confidence limit
WDFW	Washington State Department of Fish and Wildlife
ww	wet weight

1 Introduction

This report presents a compilation and assessment of background tissue data for fish and shellfish from non-urban areas of Puget Sound, per the Fifth Amendment to the Administrative Order on Consent for the Lower Duwamish Waterway (LDW). Non-urban Puget Sound tissue data collected from 2009 to the present (hereinafter referred to as the "post-2008 non-urban" dataset) are presented and assessed with background data for fish and shellfish collected from 1991 to 2008, previously reported in Appendix B of the feasibility study (FS) (AECOM 2012) (herein after referred to as the "FS non-urban" dataset). This assessment provides a recommendation on whether additional fish and shellfish data from non-urban areas in Puget Sound may be necessary to establish statistically supported non-urban background levels for the four human health contaminants of concern (COCs) (EPA 2014) in relevant fish and shellfish species. The COCs are total polychlorinated biphenyls (PCBs), dioxin/furan toxic equivalents (TEQs), carcinogenic polycyclic aromatic hydrocarbon (cPAH) TEQs, and inorganic arsenic.

In the LDW Record of Decision (ROD) (EPA 2014), non-urban Puget Sound background tissue levels contributed to the derivation of target tissue levels (TTLs) for the LDW (Table 1-1[1]). Per the ROD, TTLs are not cleanup levels; rather, they will be used for informational purposes to assess ongoing risks to people who may consume resident LDW fish and shellfish. TTLs for each COC were based on either the non-urban Puget Sound background concentration or the risk-based threshold concentration (RBTC), whichever was greater, for each human health COC and relevant tissue type. The non-urban Puget Sound background tissue concentration presented in the ROD represented the 95 upper confidence level (UCL)[2] for the mean of the FS non-urban dataset (EPA 2012). The RBTCs were developed as part of the LDW human health risk assessment (HHRA) (Windward 2007) using a lifetime excess cancer risk of 1 in 1,000,000 or a hazard quotient of 1.

Table 1-1
LDW Resident Fish and Shellfish Target Tissue Concentrations (adapted from ROD Table 21)

Species Group and Tissue Type	Species[1]	Target Concentration[2]	Source of Target Concentration[3]
PCBs (µg/kg ww)			
Benthic fish, fillet	English sole	12	Non-urban background
Pelagic fish, whole body[4]	Perch	1.8	Species-specific RBTC[5]

[1] Table 1-1 in this report is based on Table 21 in the LDW ROD, except for the target concentration for clams and cPAHs, which is based on the LDW explanation of significant differences (ESD) (EPA 2021).
[2] The 95UCL is an upper bound providing 95% confidence that the true population mean is less than or equal to the calculated UCL.

Species Group and Tissue Type	Species[1]	Target Concentration[2]	Source of Target Concentration[3]
Crab, edible meat	Dungeness crab	1.1	Non-urban background
Crab, whole body	Dungeness crab	9.1	Non-urban background
Clams	Eastern softshell clam	0.42	Non-urban background
cPAH TEQ (µg/kg ww)			
Clams[6]	Eastern softshell clam	2014 ROD: 0.24 2021 ESD: 1.5[7]	Species-specific RBTC[5]
Inorganic arsenic (mg/kg ww)			
Clams[6]	Eastern softshell clam	0.09	Non-urban background
Dioxin/furan TEQ (ng/kg ww)			
Benthic fish, whole body	English sole	0.35	Non-urban background
Crab, edible meat	Dungeness crab	0.53	Non-urban background
Crab, whole body	Dungeness crab	2.0	Non-urban background
Clams	Eastern softshell clam	0.71	Non-urban background

Notes:
1. Substitutions of similar species may be made if sufficient numbers of the species listed herein are not available (footnote a in ROD Table 21).
2. For non-urban background statistics, see also Table 4 in ROD (Table 3-1 in this memorandum). Non-urban background is based on 95UCL (footnote b in ROD Table 21).
3. The statistic used to compare site data to target tissue concentrations will be based on the 95UCL for each compound listed for fish and crabs collected throughout the waterway, and on each compound for clams collected across all clamming areas in the waterway (footnote c in ROD).
4. Based on comments from WDFW: While shiner surfperch were characterized as pelagic fish in the LDW RI and ROD, they are generally considered to be more demersal in nature, often inhabiting shallow waters around eelgrass beds, piers, and pilings, both in marine environments and in estuaries (FishBase 2023). Non-urban Puget Sound background data are not available for shiner surfperch (or for a similar demersal species) for the LDW COCs. The term perch, listed herein, refers to shiner surfperch, which were determined to be the appropriate species for the LDW represent pelagic fish in the adult one-meal-per-month scenarios, based on the recommendation of an expert panel. Shiner surfperch are opportunistic omnivores, feeding on zooplankton, small crustaceans, algae, and detritus (Gordon 1965; Bane and Robinson 1970), as well as polychaetes, mollusks, and benthic organisms (Fresh et al. 1979; Wingert et al. 1979; Miller et al. 1977).
5. Species-specific RBTCs were used to determine a target concentration when RBTCs exceeded background, or when background data were not available (footnote d in ROD Table 21).
6. Only clam tissue values are shown for inorganic arsenic and cPAH TEQ because most of the risk associated with these COCs was associated with the consumption of clams (footnote e in ROD Table 21).
7. The ESD (EPA 2021) changed the cPAH TEQ target for clams from 0.24 to 1.5 µg/kg ww.
COC: contaminant of concern
cPAH: carcinogenic polycyclic aromatic hydrocarbon
ESD: explanation of significant differences
LDW: Lower Duwamish Waterway
PCB: polychlorinated biphenyl
RBTC: risk-based threshold concentration
RI: remedial investigation
ROD: Record of Decision
TEQ: toxic equivalent
UCL: upper confidence limit
WDFW: Washington Department of Fish and Wildlife
ww: wet weight

2 Post-2008 Dataset Development

Multiple sources were queried for tissue concentration data collected since 2008 from areas of Puget Sound outside of urban areas and cleanup areas. These sources included the Washington State Department of Fish and Wildlife (WDFW) (West et al. 2011; West et al. 2017; West 2022), King County (King County and WDFW 2022; White 2022), and the Washington State Department of Ecology's (Ecology's) Environmental Information Management (EIM) database.

The following criteria were used to screen the data for inclusion in the post-2008 non-urban dataset:

- **Species:** Only those species representative of the consumption categories evaluated in the LDW HHRA (i.e., benthic fish, pelagic fish, crabs, and clams) were included in the dataset. For pelagic fish, WDFW PCB congener data are available for Pacific hake, walleye pollock, and Pacific herring (West et al. 2011; West et al. 2017). In consultation with the U.S. Environmental Protection Agency (EPA) and WDFW, it was determined that none of these species were an acceptable surrogate for shiner surfperch; therefore, the data were not included in the dataset.
- **Proximity to urban areas:** Non-urban area data were compiled. Sampling locations near urban areas were excluded from the non-urban Puget Sound tissue dataset. Examples of excluded areas include: Commencement Bay (Tacoma), Elliott Bay (Seattle), Budd Inlet (Olympia), Port Gardner (Everett), Sinclair Inlet (Bremerton), Port Angeles Harbor, and Bellingham Bay.[3]
- **Proximity to listed Sites:** *S*ampling locations near listed Sites were excluded based on the type, distance, and magnitude of known sources identified in Ecology's Integrated Site Information System (ISIS) and EIM and EPA Superfund Enterprise Management System. Examples of areas excluded based on proximity to listed Site include: Fidalgo Bay, Chevron Point Wells, Eagle Harbor, Chevron Tank Farm Port Washington Narrows, and Naval Based Kitsap Keyport.

The tissue sampling locations included in the post-2008 dataset are shown on Maps 1a and 1b, and the FS non-urban dataset locations, presented in Appendix B of the FS (AECOM 2012), are shown on Maps 2a through 2d. Many of the locations in the post-2008 dataset are in areas previously included in the FS non-urban dataset approved by EPA and Ecology. New areas sampled since 2008 that meet the above-listed criteria are shown on Map 3 using a green symbol (those included in the FS compilation also have a black rim). New areas identified from

[3] This is not a comprehensive list of urban areas with tissue data, since non-urban areas were the focus of this compilation.

the above-listed sources since 2008 that do not meet the above-listed criteria are shown on Map 3 using a red symbol.

The post-2008 non-urban dataset was developed using LDW data management rules (Windward and Anchor QEA 2022, Attachment D). PCB concentrations were determined using Aroclor analysis, homolog analysis, or congener analysis. The method used has been footnoted in the data tables, because the analysis method can affect the results. Total PCBs were calculated, in accordance with the methods of the Washington State Sediment Management Standards (SMS), using only detected values for all Aroclor mixtures. For individual samples in which none of the Aroclor mixtures were detected, total PCBs were given a value equal to the highest reporting limit of the Aroclors and assigned a U-qualifier (no detected concentrations). When PCBs were analyzed as homologs, the same summing method was applied.

The only addition to the LDW data management rules was the calculation of total PCBs in samples that were analyzed for only a subset of PCB congeners. Total PCBs were calculated from WDFW data as twice the sum of 17 PCB congeners (PCB congeners 18, 28, 44, 52, 66, 101, 105, 118, 128, 138, 153, 170, 180, 187, 195, 206, 209), as described by West et al. (2017). Samples analyzed for a subset of congeners were not included in the FS non-urban dataset, but they were included in the post-2008 non-urban dataset because the totals correlated well, as shown below.

The correlation between the total PCB sum calculated as twice the sum of 17 congeners and the sum of 209 congeners was investigated using the LDW baseline tissue dataset (Windward 2020). Tissue samples included benthic invertebrates (8 samples), clams (14 samples), fish (79 samples), and crabs (53 samples). All of the LDW tissue samples were analyzed for 209 congeners by SGS AXYS Analytical Services Ltd. (Axys) following the modified EPA 1668 high-resolution method. The total PCB sums calculated based on twice the sum of 17 congeners were within approximately ±20% of the sum of 209 congeners over a wide range of concentrations (Figure 2-1). The linear correlation results were good ($r2 = 0.984$, $p < 0.001$, $n=152$, slope coefficient = 0.978, intercept not significantly different from 0, $p = 0.435$).[4] This result is consistent with the correlation between the total PCB sums based on twice the sum of 17 congeners and the sum of 209 congeners for a subset of five English sole and herring samples from the Puget Sound-wide WDFW dataset ($r^2 = 0.997$, $p=0.003$, slope coefficient = 0.991, intercept not significantly different from 0, $p=0.892$) (West et al. 2017).

[4] Results calculated excluding two shiner surfperch samples with total PCBs greater than 8,000 µg/kg wet weight (ww).

Figure 2-1
Total PCBs (Sum of 209 Congeners) Compared to Total PCBs (Twice the Sum of 17 congeners) in LDW Pre-design Studies Baseline Tissue Samples

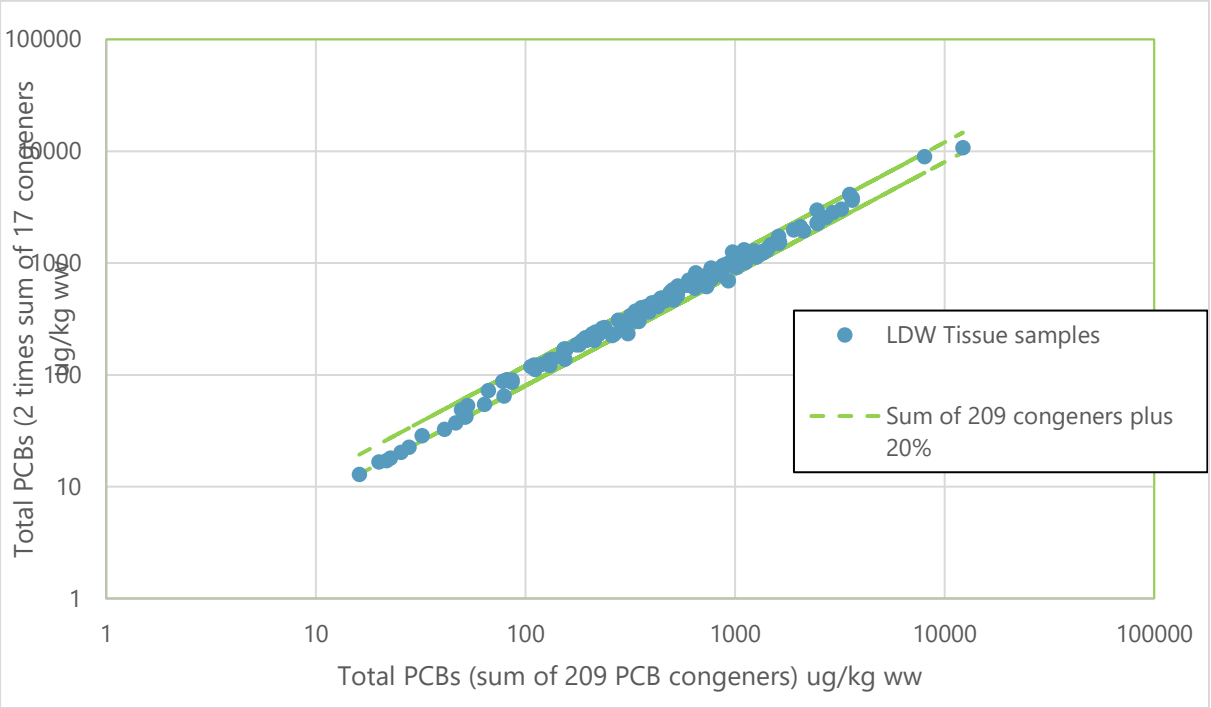

Figure source: Windward (2020)

With respect to cPAHs, TEQs were calculated using potency equivalency factor (PEF) values based on the individual polycyclic aromatic hydrocarbon (PAH) components' toxicities relative to the toxicity of benzo(a)pyrene (California EPA 2009) (Table 2-1). The cPAH TEQ was calculated as the sum of each individual PAH concentration multiplied by the corresponding PEF value. When the individual PAH component concentration was reported as non-detected, the PEF was multiplied by one-half the reporting limit.

Table 2-1
cPAH PEF Values

cPAH	PEF Value (unitless)[1]
Benzo(a)pyrene	1
Benzo(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.1

cPAH	PEF Value (unitless)[1]
Chrysene	0.01
Dibenz(a,h)anthracene	0.4[2]
Indeno(1,2,3-cd)pyrene	0.1

Notes:

1. The same PEFs were used in the LDW RI (Windward 2010), ROD (EPA 2014), and cPAH ESD (EPA 2021). PEFs for cPAHs are defined by California EPA (2009) by dividing the inhalation unit risk factor for the compound by the inhalation unit risk factor for benzo[a]pyrene.
2. The PEF value for dibenz(a,h)anthracene is based on the inhalation unit risk factors provided by California EPA (1994). This PEF was used in the LDW remedial investigation (Windward 2010).

cPAH: carcinogenic polycyclic aromatic hydrocarbon
EPA: U.S. Environmental Protection Agency
LDW: Lower Duwamish Waterway
PEF: potency equivalency factor
RI: remedial investigation

3 Non-Urban Puget Sound Tissue Data

Of the four COCs, post-2008 non-urban tissue data are available for only total PCBs and cPAH TEQ; no data have been identified for inorganic arsenic or dioxins/furans for non-urban tissues since 2008.[5] Summaries of the post-2008 non-urban tissue dataset are provided in Tables 3-1 and 3-2, and the complete post-2008 non-urban dataset is included in Attachment A. All data were used as reported without further data quality review, as was done in the FS compilation. All calculated values (means and 95UCLs) are presented with two significant figures.

Table 3-1
Numbers of Samples in the Post-2008 Non-urban Dataset for the Four Human Health Risk Drivers

COC	Number of Tissue Samples	Tissue Types
Total PCBs	374	163 benthic fish samples; 173 pelagic fish samples; 30 crab edible meat samples;[1] 8 crab whole-body samples[2]
cPAHs	51	31 crab edible meat samples;[1] 8 crab whole-body[2] samples; 12 horse clam samples
Inorganic arsenic	0	--
Dioxins/furans	0	--

Notes:
1. Crab edible meat consists of muscle tissue extracted from the upper body, legs, and claws.
2. Crab whole-body concentrations were calculated based on a weighted sum of the edible meat concentrations and the hepatopancreas concentrations.

COC: contaminant of concern
cPAH: carcinogenic polycyclic aromatic hydrocarbon
PCB: polychlorinated biphenyl

[5] Note that a single English sole fillet sample was collected in Carr Inlet by WDFW in 2019 and analyzed for dioxins and furans by Anchor QEA in 2020. This sample had a dioxin/furan TEQ of 0.186 ng/kg (ww). It was not included in the tissue compilation because there is no dioxin/furan TTL for benthic fish fillet.

Table 3-2
Summary of Post-2008 Total PCB Concentrations and cPAH TEQs and Percent Lipids in Fish and Shellfish Tissue Samples Collected from Non-urban Areas of Puget Sound

Species	Tissue Type	Year	Average # Individuals per Composite	Lipid (% ww)	Total PCBs (µg/kg, ww)				cPAH TEQ (µg/kg, ww)				Source
				Range	Det. Freq.[1]	Min.	Avg.	Max.	Det. Freq.[1]	Min.	Avg.	Max.	
Benthic Fish													
English sole	Fillet (skin off)	2009	20	0.19–0.72	24/24[2]	0.148	5.7	21.2	-	-	-	-	WDFW (West 2022)
		2011	20	0.23–0.60	22/22[2]	3.50	7.0	17.3	-	-	-	-	WDFW (West 2022)
		2013	20	0.31–0.63	23/24[2]	0.32	7.1	21.2	-	-	-	-	WDFW (West 2022)
		2015	20	0.19–0.66	27/28[3]	3.02	11	43.4	-	-	-	-	WDFW (West 2022), King County (White 2022)
		2017	19	0.24–0.70	29/29[4]	1.92	13	38.4	-	-	-	-	WDFW (West 2022), King County (White 2022)
		2019	19	0.23–0.88	36/36[5]	1.00	10	32.6	-	-	-	-	WDFW (West 2022), King County (White 2022)
		Total	19.7	0.19–0.88	161/163	0.148	9.2	43.4	-	-	-	-	-
Crabs													
Dungeness crab	Edible meat	2011	5	0.30–0.33	2/2[2]	1.84	3.0	4.24	0/2	0.17 U	-	0.25 U	WDFW (West 2022)
		2012	4.75	0.10–0.39	29/29[2]	1.02	3.8	9.9	0/29	0.16 U	-	0.46 U	WDFW (West 2022)
		Total	4.8	0.10–0.39	31/31	1.02	3.8	9.9	0/31	0.16 U	-	0.46 U	-
	Whole body (calc.)	2012	4.5	1.2–2.6	8/8[2]	17.0	43	71.5	0/8	0.17 U	-	0.40 U	WDFW (West 2022)

Species	Tissue Type	Year	Average # Individuals per Composite	Lipid (% ww)	Total PCBs (µg/kg, ww)				cPAH TEQ (µg/kg, ww)				Source
				Range	Det. Freq.[1]	Min.	Avg.	Max.	Det. Freq.[1]	Min.	Avg.	Max.	
Clams													
Horse clam	Soft parts (not gut)	2019	3[5]	na	-	-	-	-	1/12[6]	0.90 U	-	1.0	Ecology (2019)

Notes:

1. For calculated sums and TEQs, a sample was considered a non-detect when all congeners or compounds were identified by the laboratory as not detected.
2. Total PCBs were calculated as the sum of congeners (i.e., twice the sum of 17 detected congeners) (West et al. 2017).
3. Twenty-four of the twenty-eight samples had total PCBs calculated as the sum of congeners (West et al. 2017). Total PCBs were calculated as the sum of Aroclors for four samples (White 2022).
4. Twenty-five of the twenty-nine samples had total PCBs calculated as the sum of congeners (West et al. 2017). Total PCBs were calculated as the sum of homologs for four samples (White 2022).
5. Thirty of the thirty-six samples had total PCBs calculated as the sum of congeners (West et al. 2017). Total PCBs were calculated as the sum of homologs for six samples (White 2022).
6. Two of the twelve samples were field duplicates.

cPAH: carcinogenic polycyclic aromatic hydrocarbon
LDW: Lower Duwamish Waterway
PCB: polychlorinated biphenyl
TEQ: toxic equivalent
U: no detected concentration
WDFW: Washington State Department of Fish and Wildlife
ww: wet weight

Tables 3-3 and 3-4 compare the post-2008 data to data in the FS non-urban tissue dataset for tissue types and COCs with TTLs in the ROD. Note that direct comparisons of these datasets should be viewed in the context of factors that, like temporal changes, could affect concentrations, such as differences in non-urban sampling locations (see Section 5). For example, the increase in whole-body crab PCBs may be attributable to the addition of non-urban data from central Puget Sound, whereas pre-2008 data were from Dungeness and Padilla Bays. In addition, there is uncertainty associated with calculating whole-body concentrations.

Table 3-3
Summary of Total PCBs in Fish and Shellfish Tissue from Non-urban Areas of Puget Sound in both FS and Post-2008 Datasets

Species	Tissue Type	Sample Collection Years	Detection Frequency	Range of Composite Sizes Across Cited Studies[1]	Total PCBs Concentration (ug/kg, ww)	Source
Benthic fish						
English sole, rock sole	Fillet	1989–2005	158/242[2]	4.7–20	1.3–75	West et al. (2001); Era-Miller (2006)
English sole	Fillet	2009–2019	161/163	14.3–20	0.148–43.4	WDFW (West 2022); King County (White 2022)
Crabs						
Dungeness crab	Edible meat	1999–2006	17/17	1–5	0.43–1.9	Ecology (2000); Malcolm Pirnie (2007)
	Whole body (calc.)[3]	2006	15/15	1	3.0–16	Ecology (2000); Malcolm Pirnie (2007)
Dungeness crab	Edible meat	2011–2012	31/31	4.4–5	1.02–9.9	WDFW (West 2022)
	Whole body (calc.)[3]	2011–2012	8/8	4.4–5	17–71.5	WDFW (West 2022)

Notes:

Only tissue-COC combinations with new data are included in this table. Orange shaded rows are data from the FS non-urban tissue dataset. Note that direct comparison of the older and newer datasets should be viewed in the context of all differences, not just temporal differences (see Section 5 for details),

1. The range is for the average number of individuals per composite as reported for each study,
2. Table 4 in the ROD has 238 samples for PCBs in benthic fish. That value is not correct.
3. Total PCB concentrations in whole-body (i.e., edible meat plus hepatopancreas) crab were calculated assuming 69% (by weight) edible meat and 31% hepatopancreas. These relative tissue weights were reported for a 16.6-cm Dungeness crab in 2004 (Windward

2010); these weights also represent the average ratios from the three Dungeness crab composites (3 individuals per composite) collected from the LDW in 2017 (Windward 2020).
COC: contaminant of concern
Ecology: Washington State Department of Ecology
FS: feasibility study
LDW: Lower Duwamish Waterway
PCB: polychlorinated biphenyl
ROD: Record of Decision
WDFW: Washington State Department of Fish and Wildlife
ww: wet weight

Table 3-4
Summary of cPAH TEQs in Clam Tissue from Non-urban Areas of Puget Sound in both FS and Post-2008 Datasets

Species	Tissue Type	Sample Collection Years	Detection Frequency	Avg. # of Individuals per Composite Sample in Cited Studies	cPAH TEQ (ug/kg ww)	Source
Clams						
Various spp.	Soft parts	1999–2003	0/4	10–50	0.11U–0.89U	Ecology (2000); Parametrix (2003)
Geoduck	Soft parts	2002–2008	3/7	1–2	0.069–0.17	Malcolm Pirnie (2007); Ecology (2009)
Horse clam	Soft parts (not gut)	2019	1/12	3	0.90U–1.0	WYEH Clam Background (USACE 2019)

Notes:
Only tissue-COC combinations with new data are included in this table. Orange shaded rows are from the FS non-urban tissue dataset. Note that direct comparison of the older and newer datasets should be viewed in the context of all differences, not just temporal differences (see Section 5 for details),
cPAH: carcinogenic polycyclic aromatic hydrocarbon
COC: contaminant of concern
Ecology: Washington State Department of Ecology
EIM: Environmental Information Management
FS: feasibility Study
LDW: Lower Duwamish Waterway
TEQ: toxic equivalent
U: no detected concentration
USACE: U.S. Army Corps of Engineers
ww: wet weight
WYEH: Wyckoff/Eagle Harbor Superfund Site

4 95UCL Calculation and Comparison to TTLs

Sufficient PCB data were available in the post-2008 non-urban Puget Sound tissue dataset to calculate 95UCLs for benthic fish and crabs. These data were evaluated separately and in combination with the FS non-urban tissue dataset that was used to derive TTLs in the ROD.[6] The data were analyzed graphically and with goodness of fit tests in ProUCL to evaluate the distributional form of the data, and to calculate the appropriate 95UCL based on the distributional outcome. Stepwise ProUCL results are summarized in Table 4-1.

[6] See Table 4 in the ROD titled *Summary of PCB, Arsenic, cPAH, and Dioxin/Furan Data for Natural Background Concentrations in Fish and Shellfish Tissue*.

Table 4-1
Summary Statistics for Total PCBs in the Non-urban Puget Sound Tissue Datasets, Reported Separately and Combined

Dataset	Species Group	Tissue Type	Detection Frequency	Recommended Distribution	Mean	95UCL for Total PCBs (µg/kg ww)	Basis for Recommended UCL	Notes
Post-2008	Benthic fish	Fillet	161/163	Lognormal	9.1	11	95% H-UCL	Log-normal ROS
Combined	Benthic fish	Fillet	319/405	Lognormal	9.7	11	95% H-UCL	Log-normal ROS
Post-2008	Crab	Whole body	8/8	Normal	37	50	95% Students-t UCL	Arithmetic mean
Combined	Crab	Whole body	23/23	Gamma	18	26	95% Adjusted Gamma UCL	Max. likelihood estimated mean
Post-2008	Crab	Edible meat	31/31	Gamma	3.8	4.6	95% Adjusted Gamma UCL	Max. likelihood estimated mean
Combined	Crab	Edible meat	48/48	Gamma	2.8	3.4	95% Adjusted Gamma UCL	Max. likelihood estimated mean
FS[1]	Clam	Whole body	24/70	Indeterminate	0.3	0.42	95% KM (% Bootstrap) UCL	Kaplan Meier mean

Notes:
1. Statistical results are as reported in the *Technical Memorandum: Calculating natural background in selected Puget Sound marine fish and shellfish tissue for development of tissue PRGs* (EPA 2012).
FS: feasibility study
PCB: polychlorinated biphenyl
ROS: regression on order statistics
UCL: upper confidence limit
ww: wet weight

Insufficient post-2008 tissue data were identified to calculate 95UCLs for cPAHs; individual cPAHs were detected in only 1 of 12 clam tissue composite samples (Table 3-2). cPAH compounds are typically not detected in non-urban tissue samples using standard analytical methods with typical detection limits of 0.3 to 3.0 µg/kg ww. High-resolution analytical methods, which are not commonly used for cPAHs in tissue, can achieve detection limits of less than 0.1 µg/kg ww.

When cPAH TEQs were calculated for samples with no detected cPAH compounds (i.e., detection limits were used in the TEQ calculation), the TEQs ranged from 0.89 µg/kg ww to 0.96 µg/kg ww. The single clam tissue sample with one detected cPAH compound had a cPAH TEQ of 1.0 µg/kg ww.[7] All results were below the cPAH ESD TTL of 1.5 µg/kg ww; thus, the TTL will be based on the RBTC, regardless of the sensitivity of the analytical method used.

No post-2008 non-urban inorganic arsenic data were identified for clams. The TTL in the ROD for inorganic arsenic and clams was 0.09 mg/kg ww, based on a 95UCL for eastern softshell (*Mya arenaria*) tissue data from Dungeness Bay in the Strait of Juan de Fuca (Table 1-1). Additional inorganic arsenic clam data are available in the LDW FS dataset (AECOM 2012; Windward 2010); these data are a compilation of mixed species composites (which included butter clam, cockle, bent-nose clam, white-sand macoma, horse clam, and littleneck clam species). These mixed data were not combined with the *Mya arenaria* data because *Mya arenaria* accumulate arsenic in the siphon sheath to a degree not seen with other clams. Instead, a 95UCL was calculated separately using the mixed species data (Table 4-2). The ROD TTLs are compared with the calculated 95UCLs in Table 4-3.

Other than the single Carr Inlet fillet sample noted in Section 3, no dioxin/furan data were identified for tissue samples in non-urban Puget Sound post-2008. Therefore, no updates to non-urban Puget Sound background data are presented.

[7] The cPAH TEQ was calculated using the detected concentration for indeno(1,2,3-cd) pyrene and one-half the reporting limits for the non-detected cPAHs.

Table 4-2
Summary Statistics for Inorganic Arsenic in the FS Non-urban Tissue Dataset

Dataset	Species Group	Tissue Type	Detection Frequency	Recommended Distribution	Mean	95UCL for Inorganic As (mg/kg ww)	Basis for Recommended UCL	Notes
FS	*Mya arenaria* clams (Dungeness)[1]	Whole body	6/6	Normal	0.064	0.087[2]	95% Approximate Gamma UCL	MLE gamma mean
FS	Mixed clams (Bainbridge Island)[3]	Whole body	6/6	Gamma	0.18	0.65[4]	95% Adjusted Gamma UCL	MLE gamma mean

Notes:

1. This category is a subset of the full "mixed clams and *Mya*" dataset, using only *Mya arenaria* results from Dungeness Bay, with results as reported by EPA (2012).
2. This number was rounded to 0.09 mg/kg ww in LDW ROD Table 21.
3. This dataset includes mixed clam results from Bainbridge Island, which were collected as part of the RI (Windward 2010) to represent areas outside of the ASARCO influence. The Bainbridge Island data include butter clam, cockle, bent-nose clam, white-sand macoma, horse clam, and littleneck clam species.
4. The 95UCL is greater than the maximum value (0.446 mg/kg ww), reflecting the variability in this small dataset.

EPA: U.S. Environmental Protection Agency
FS: feasibility study
LDW: Lower Duwamish Waterway
MLE: maximum likelihood estimation
ROD: Record of Decision
UCL: upper confidence level
ww: wet weight

Table 4-3
TTLs from ROD Table 21 Compared to 95UCLs based on the Post-2008 Dataset and Combined Datasets

Species/Group and Tissue Type	Species	Detection Frequency[1]	ROD TTL	Source of ROD TTL	Post-2008 and Combined Non-Urban Data 95UCL
Total PCBs (µg/kg ww)					
Benthic fish, fillet	English sole, rock sole	158/242[2]	12	95UCL – FS non-urban dataset	Post-2008: 95UCL = 11 Combined: 95UCL = 11
Pelagic fish, whole body	Shiner surfperch (whole body)	NA	1.8	RBTC	No post-2008 data
Crab, edible meat	Dungeness crab	17/17	1.1	95UCL – FS non-urban dataset	Post-2008: 95UCL = 4.6 Combined: 95UCL = 3.4
Crab, whole body	Dungeness crab	15/15	9.1	95UCL – FS non-urban dataset	Post-2008: 95UCL = 50 Combined: 95UCL = 26
Clams	Butter clam, geoduck, horse clam, littleneck clam	24/70	0.42	95UCL – FS non-urban dataset	No post-2008 data
cPAH TEQ (µg/kg ww)					
Clams	Butter clam, geoduck, littleneck clam	NA (1999–2008)	1.5	RBTC[3]	Insufficient detects in FS and post-2008 datasets to calculate 95UCLs; detected concentrations and detection limits below RBTC
Inorganic arsenic (mg/kg ww)					
Clams	Eastern softshell clam (*Mya arenaria*)	6/6	0.09	95UCL – FS non-urban dataset with only *Mya arenaria* data from Dungeness Bay	No post-2008 data
Dioxin/furan TEQ (ng/kg ww)					
Benthic fish, whole body	English sole, rock sole	7/7	0.35	95UCL – FS non-urban dataset	No post-2008 data

Species/Group and Tissue Type	Species	Detection Frequency[1]	ROD TTL	Source of ROD TTL	Post-2008 and Combined Non-Urban Data 95UCL
Crab, edible meat	Dungeness crab	27/27	0.53	95UCL – FS non-urban dataset	No post-2008 data
Crab, whole body	Dungeness crab	25/25	2.0	95UCL – FS non-urban dataset	No post-2008 data
Clams	Butter clam, geoduck, horse clam, littleneck clam	32/32	0.71	95UCL – FS non-urban dataset	No post-2008 data

Notes:

1. Detection frequency values as reported in Table 2 of EPA (2012).
2. Table 4 in the ROD has 238 samples for PCBs in benthic fish. That value is not correct.
3. This TTL is based on the ESD for cPAHs (EPA 2021).4. Table 1 of EPA (2012) reports 43 clam samples with dioxin/furan TEQs.

cPAH: carcinogenic polycyclic aromatic hydrocarbon
ESD: explanation of significant differences
FS: feasibility study
LDW: Lower Duwamish Waterway
NA: not applicable
PCB: polychlorinated biphenyl
RBTC: risk-based threshold concentration
ROD: Record of Decision
TEQ: toxic equivalent
TTL: target tissue concentration
UCL: upper confidence limit
ww: wet weight

5 Data Sufficiency

This section evaluates the sufficiency of non-urban data to calculate 95UCLs for PCBs, cPAHs, inorganic arsenic, and dioxins/furans.

5.1 PCBs

For PCBs and benthic fish, the post-2008 data were collected by WDFW and King County, which used identical sampling methodology but different analytical methods (congeners for WDFW and Aroclors or homologs for King County). In the combined FS and post-2008 dataset (Puget Sound Ambient Monitoring Program between 1989 and 1999 and King County or WDFW between 2009 and 2019), the majority of samples used consistent composite sizes, and the entire Puget Sound basin was represented. Because of the consistency of methods and broad geographic representation, the post-2008 data further bolster the already robust non-urban tissue dataset that was used to calculate the TTL in the ROD.

For PCBs and pelagic fish, no FS non-urban data were available, and the TTL was based on an RBTC calculated for shiner surfperch. After 2008 (i.e., between 2010 and 2020), WDFW collected herring from south, central, and north Puget Sound using consistent sampling and analysis methodology as part of its long-term monitoring study. In 2009, WDFW collected pollock and hake throughout Puget Sound to assess contaminant concentrations in mid-trophic level pelagic fish. However, the species analyzed were not deemed suitably similar in diet and trophic level to shiner surfperch, so it was concluded that no post-2008 non-urban data were available for comparison to the RBTC.

For PCBs and crab, the post-2008 and FS non-urban datasets differed in terms of sample methodology and geographic representation. Five individuals were targeted for each composite sample in the post-2008 non-urban dataset, while the FS non-urban dataset was dominated by results for individual crabs (all 15 whole-body samples are individual crabs and 15 of the 17 edible meat samples are individual crabs). The post-2008 dataset included random samples from throughout the Puget Sound basin, while most of the edible meat and all of the whole-body samples in the FS non-urban dataset were from either Freshwater Bay or Dungeness Bay (representative of the Strait of Juan de Fuca). The post-2008 crab datasets represent statistical samples from Puget Sound non-urban areas; the edible meat dataset has sufficient sample size (n=31) to calculate a 95UCL with good spatial coverage and consistent methodology, while the crab whole-body dataset is more limited in size (n=8) but has better spatial coverage.

No post-2008 non-urban clam tissue samples were analyzed for PCBs. The FS non-urban dataset was composed of a mixture of species, individual specimens or variable composite sample sizes (from 10 to 50 individuals, or unspecified), and geographic locations (Map 2a). Outside of the Strait of Juan de Fuca, PCBs were analyzed for Aroclors in clam tissues and were not detected with detection limits ranging from 2.5 µg/kg to 13 µg/kg. The Aroclor detection limits are higher than the clam RBTC of 0.15 µg/kg. Within the strait, clam tissues collected from Freshwater Bay and Dungeness Bay were analyzed for PCB congeners, and PCBs were detected in horse clams and geoducks.

5.2 cPAHs

Detected cPAH TEQs in clam tissues and cPAH detection limits have consistently been below the RBTC of 1.5 µg/kg ww (EPA 2021) in both the FS and post-2008 non-urban tissue datasets. In the FS non-urban dataset, cPAHs were detected in three geoduck samples that were analyzed using a high-resolution method that was more sensitive than the standard methods. The range of detected cPAH TEQs was 0.069 to 0.171 µg/kg ww. cPAHs were not detected in clam samples analyzed by standard methods with cPAH TEQs based on detection limits that ranged from 0.85 µg/kg ww to 0.89 µg/kg ww.

The post-2008 non-urban dataset included one clam composite sample with detected cPAHs, with a cPAH TEQ of 1.0 µg/kg ww. cPAH TEQs were not detected in the clam composite samples analyzed by standard methods with cPAH TEQs based on detection limits that ranged from 0.89 µg/kg ww to 0.96 µg/kg ww. Consequently, the TTL is based on the RBTC value.

5.3 Inorganic Arsenic

No post-2008 inorganic arsenic data were identified for clam tissues. In the FS non-urban dataset, 24 clam samples were collected for LDW remedial investigation in 2005 and analyzed for inorganic arsenic (Windward 2010). Of the 24 samples collected, only the 6 from Dungeness Bay were considered usable by EPA (2012), both to avoid influence from the Tacoma ASARCO smelter plume (see Map 2c) and to restrict results to *Mya arenaria* species. *Mya arenaria* species have had elevated inorganic arsenic concentrations relative to those for other clam species exposed to the same levels of arsenic, as discussed in the LDW RI (Windward 2010) and the East Waterway HHRA (Windward 2012) and cited in EPA (2012). Thus, the six Bainbridge Island mixed clam species samples collected for the LDW RI outside of the ASARCO plume were not included.

5.4 Dioxins/Furans

Other than the single Carr Inlet fillet sample noted in Section 3, no dioxin/furan data were identified for non-urban Puget Sound tissue samples collected since 2008. The FS non-urban whole-body benthic fish tissue dataset was relatively limited, with dioxin/furan TEQ data for four samples from Dungeness Bay or Freshwater Bay (single individuals of rock sole) and three composites of five English sole from the Anderson-Ketron Island disposal site. The uncertainty in the non-urban dataset caused by the limited number of samples and geographic representation of this dataset has not changed.

The FS non-urban crab tissue dataset was a mixture of individual crabs from the Strait of Juan de Fuca and composite samples from Padilla Bay and the Anderson Ketron disposal site (three and five individuals per composite, respectively). Sample sizes were sufficient (n=27 for edible meat and n=25 for calculated whole body) to calculate the 95UCL for non-urban Puget Sound crab tissues.

The FS non-urban dioxin/furan TEQ dataset for clams was composed of a mixture of species, individual specimens or composites of 4 to 50 individuals per sample, tissue types (specified as "whole body" or "edible meat"), and geographic locations. With 37 of the 43 samples being single specimens of horse clams and geoducks from the Strait of Juan de Fuca (i.e., Freshwater Bay and Dungeness Bay), this dataset is fairly limited in geographic scope. Sample size (n=43) is sufficient to calculate a 95UCL.

Table 5-1 provides a summary of data sufficiency to calculate non-urban 95UCLs. Using the combined FS and post-2008 non-urban tissue datasets, sufficient data exist for PCBs, cPAHs, and inorganic arsenic. No post-2008 data were identified for dioxins/furans. Because only limited data are available for dioxins/furans and benthic fish, this dataset would benefit from the analysis of dioxins/furans in Puget Sound fish collected from non-urban areas.

Table 5-1
Data Sufficiency Summary

Species/Group and Tissue Type	Species	FS Dataset	Post-2008 Dataset	Data Sufficiency
Total PCBs (µg/kg ww)				
Benthic fish, fillet	English sole, rock sole	12 (n=242)	11 (n=405)	Sufficient data available
Pelagic fish, whole body	Shiner surfperch	1.8 (RBTC)	No update	Data insufficient to calculate a non-urban concentration
Crab, edible meat	Dungeness crab	1.1 (n=17)	4.6 (n=31)	Sufficient data available
Crab, whole body	Dungeness crab	9.1 (n=15)	50 (n=8)	Sufficient data available
Clams	Butter clam, geoduck, horse clam, littleneck clam	0.42 (n=70)	No update	Sufficient data available
cPAH TEQ (µg/kg ww)				
Clams	Butter clam, geoduck, littleneck clam	1.5 (RBTC)	No update	Additional cPAH clam tissue data are unnecessary. Both existing detection limits and improved detection limits with the high-resolution methods are below the RBTC. Based on results to date, analysis of additional samples is unlikely to result in TEQs higher than the RBTC.
Inorganic arsenic (mg/kg ww)				
Clams	Eastern softshell clam (*Mya arenaria*)[1]	0.09 (n=6)	No update	Data are insufficient due to limited geographical representation of samples with only *Mya arenaria* species.
Dioxin/furan TEQ (ng/kg ww)				
Benthic fish, whole body	Starry flounder, rock sole	0.35 (n=7)	No update	Data are insufficient; ROD TTL based on non-urban background could be improved with additional data.
Crab, edible meat	Dungeness crab	0.53 (n=27)	No update	Sufficient data available
Crab, whole body	Dungeness crab	2.0 (n=25)	No update	Sufficient data available

Species/Group and Tissue Type	Species	FS Dataset	Post-2008 Dataset	Data Sufficiency
Clams	Butter clam, geoduck, horse clam, littleneck clam	0.71 (n=32)	No update	Sufficient data available

Notes:
cPAH: carcinogenic polycyclic aromatic hydrocarbon
FS: feasibility study
PCB; polychlorinated biphenyl
RBTC: risk-based threshold concentration
ROD: Record of Decision
TEQ: toxic equivalent
TTL: target tissue level
WDFW: Washington State Department of Fish and Wildlife
ww: wet weight

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FINAL

Attachment A
Post-2008 Non-Urban Dataset