APPENDIX 4A
Regional and Natural Background Evaluations

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LIST OF ATTACHMENTS

APPENDIX 4[a]
REGIONAL BACKGROUND AND MARINE NATURAL BACKGROUND EVALUATIONS

This appendix contains two attachments:

- 4A-1 Arsenic Preliminary Regional Background
- 4A-2 Marine Natural Background as a Surrogate for Freshwater Natural Background

1.1. Arsenic Preliminary Regional Background

The purpose of this attachment is to present the basis for the arsenic preliminary regional background level for the Lake Washington area, which is used in this remedial investigation (RI) report as the Sediment Management Standards (SMS) sediment cleanup screening level (CSL). The Washington State Department of Ecology (Ecology) developed a Lake Washington area regional background level for carcinogenic polycyclic aromatic hydrocarbons (cPAHs) but determined that there were insufficient data to establish a conclusive regional background level for arsenic. The limited number of sediment samples that Ecology identified as potentially representing regional background for arsenic are used in this appendix to establish a preliminary regional background level.

1.2. Marine Natural Background as a Surrogate for Freshwater Natural Background

The purpose of this attachment is to evaluate whether marine natural background values are a reasonable surrogate for freshwater natural background values in the development of SMS sediment cleanup objectives (SCOs) for cPAHs, arsenic, chromium, and nickel at the Gas Works Park Site. A surrogate is needed because Ecology has not yet established freshwater natural background values.

ATTACHMENT 4A-1
Arsenic Preliminary Regional Background

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LIST OF SUB-ATTACHMENTS

1.0 INTRODUCTION

The purpose of this attachment is to present the basis for the arsenic preliminary regional background level for the Lake Washington area, which is used in this remedial investigation (RI) as the sediment cleanup screening level (CSL). Ecology developed a Lake Washington area regional background level for carcinogenic polycyclic aromatic hydrocarbons (cPAHs) but determined that there were insufficient data to establish a conclusive regional background level for arsenic. The Lake Washington area background evaluation is documented in Ecology's "Lake Washington Area Regional Background: Data Evaluation and Summary Report" dated February 2017.

The limited number of sediment samples that Ecology identified as potentially representing regional background for arsenic are used in this attachment to establish a preliminary regional background level. The approach to develop a provisional regional background value is similar to that used by the Port of Bellingham for the I & J Waterway cleanup prior to Ecology establishing regional background values for Bellingham Bay (Anchor QEA 2015).

2.0 PRELIMINARY REGIONAL BACKGROUND APPROACH

2.1. Arsenic Regional Background Data Set

Ecology evaluated existing sediment data available in Ecology's Environmental Information Management System (EIM) for the Lake Washington area (Lake Washington, Union Bay, the Montlake Cut, Portage Bay and Lake Sammamish) and determined that sufficient data existed to evaluate if regional background values could be established for cPAHs, arsenic and mercury (Ecology 2017).

Ecology screened the EIM sediment data following the same steps used to establish regional background values for other areas with some modifications to address use of existing data rather than data specifically collected for derivation of regional background values. These screening steps include an assessment of quality control/assurance, determination of geographic scope, exclusion of unrepresentative areas, exclusion of areas under the direct influence of contaminated sites and sources, outlier analysis and precision analysis. Following these screening steps, the arsenic data set had nine values greater than the Puget Sound natural background 90/90 upper tolerance limit (UTL) of 11 milligrams per kilogram (mg/kg), with concentrations ranging from 13 to 70 mg/kg. Three of these nine samples, obtained from Lake Washington, were identified potential outliers. Ecology excluded these three samples (46, 46 and 70 mg/kg) from the "regional background data set until more information becomes available." The resulting arsenic regional background data set, which is presented in the table below, has six samples. Ecology prefers around 25 or more samples to establish regional background.

PRELIMINARY REGIONAL BACKGROUND DATA SET FOR ARSENIC

Sample Location Description	Arsenic Concentration (mg/kg)
West of I-5	13
North end of Lake Sammamish, offshore at Marymoor Park	15
Lake Sammamish State Park, nearshore west of boat launch	19
Middle of Lake Sammamish, northern portion	22
Offshore of the northeastern shoreline of Lake Sammamish (average)	23
Middle of Lake Sammamish, southern portion	24

Note:

Location descriptions and arsenic concentrations excerpted from Table 2 of Ecology's *Lake Washington Areas Regional Background, Data Evaluation and Summary R*eport (Ecology 2017). Ecology determined that these six values are in the range of Lake Washington area regional background for arsenic.

2.2. Preliminary Regional Background Level Derivation

U.S. Environmental Protection Agency's (EPA's) ProUCL (2015) statistical software (Version 5.1) was used to calculate the 90/90 UTL for use as the preliminary arsenic regional background level. This is consistent with the approach Ecology used to establish the Lake Washington area regional background value for cPAHs. The ProUCL output is included in Sub-attachment A.

According to the ProUCL output, the data appear to follow normal, gamma and lognormal distributions. The table below includes the 90/90 UTLs for normal, gamma, and lognormal distributions.

POTENTIAL 90/90 UTL VALUES

Basis of 90/90 UTL	Arsenic 90/90 UTL (mg/kg)
Normal Distribution	31
Gamma (Wilson-Hilferty) Distribution	33
Lognormal Distribution	35
Nonparametric Distribution	24

The nonparametric 90/90 UTL of 24 mg/kg was selected as the preliminary arsenic regional background level because of the limited number of samples in the preliminary regional background data set and because it is equal to the maximum detected concentration in the background data set.

The preliminary arsenic regional background falls within the range of concentrations from the original data set Ecology compiled for use in this exercise (1.4 to 70 mg/kg). Of note, the three Lake Washington sediment samples that Ecology excluded from the background dataset (46, 46, and 70 mg/kg) are similar in characteristics with Lake Union sediment in terms of grainsize and total organic carbon and may be more representative of Lake Union regional background concentrations. Consideration of these data indicate that regional background may be higher than indicated by the preliminary arsenic regional background data set.

3.0 REFERENCES

Anchor QEA 2015. Remedial Investigation and Feasibility Study Report, I&J Waterway Site. February 2015.

EPA 2015. ProUCL Version 5.1 User Guide. Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations. EPA/600/R-07/041).

Ecology 2017. Lake Washington Area Regional Background, Data Evaluation and Summary Report. Publication No. 16-09-0645. February 2017.

SUB-ATTACHMENT 4A-1.1
Arsenic Preliminary Regional Background – ProUCL Output

Arsenic Preliminary Regional Background - ProUCL Output

Background Statistics for Uncensored Full Data Sets

User Selected Options

Date/Time of Computation	ProUCL 5.17/15/2019 1:12:08 PM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	90%
Coverage	90%
New or Future K Observations	1
Number of Bootstrap Operations	2000

Arsenic Regional Background

General Statistics

Total Number of Observations	6	Number of Distinct Observations	6
Minimum	13	First Quartile	16
Second Largest	23	Median	20.5
Maximum	24	Third Quartile	22.75
Mean	19.33	SD	4.502
Coefficient of Variation	0.233	Skewness	-0.544
Mean of logged Data	2.937	SD of logged Data	0.25

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.494	d2max (for USL)	1.729

Normal GOF Test

Shapiro Wilk Test Statistic	0.906	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.788	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.223	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.325	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

90% UTL with 90% Coverage	30.56	90% Percentile (z)	25.1
90% UPL (t)	26.51	95% Percentile (z)	26.74
90% USL	27.12	99% Percentile (z)	29.81

Gamma GOF Test

A-D Test Statistic	0.397	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.697	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.248	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.332	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	20.31	k star (bias corrected MLE)	10.26
Theta hat (MLE)	0.952	Theta star (bias corrected MLE)	1.884
nu hat (MLE)	243.7	nu star (bias corrected)	123.2
MLE Mean (bias corrected)	19.33	MLE Sd (bias corrected)	6.035

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL	27.44	90% Percentile	27.36
90% Hawkins Wixley (HW) Approx. Gamma UPL	27.59	95% Percentile	30.21
90% WH Approx. Gamma UTL with 90% Coverage	33.14	99% Percentile	36.06
90% HW Approx. Gamma UTL with 90% Coverage	33.58		
90% WH USL	28.25	90% HW USL	28.43

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.89	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.788	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.231	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.325	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with 90% Coverage	35.17	90% Percentile (z)	25.98
90% UPL (t)	28.09	95% Percentile (z)	28.45
90% USL	29.05	99% Percentile (z)	33.73

Nonparametric Distribution Free Background Statistics

Data appear Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	6	90% UTL with 90% Coverage	24
Approx, f used to compute achieved CC	0.667	Approximate Actual Confidence Coefficient achieved by UTL	0.469
		Approximate Sample Size needed to achieve specified CC	22
90% Percentile Bootstrap UTL with 90% Coverage	24	90% BCA Bootstrap UTL with 90% Coverage	24
90% UPL	24	90% Percentile	23.5
90% Chebyshev UPL	33.92	95% Percentile	23.75
95% Chebyshev UPL	40.53	99% Percentile	23.95
90% USL	24		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20. Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.

The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

ATTACHMENT 4A-2
Marine Natural Background as a Surrogate for Freshwater Natural Background

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LIST OF SUB-ATTACHMENTS

1.0 INTRODUCTION

The purpose of this attachment is to evaluate whether marine natural background values are a reasonable surrogate for freshwater natural background values in the development of Sediment Management Standards (SMS) Sediment Cleanup Objectives (SCOs) for carcinogenic polycyclic aromatic hydrocarbons (cPAH), arsenic, chromium, and nickel at the Gas Works Park Site (GWPS). A surrogate is needed because the Washington State Department of Ecology (Ecology) has not yet established freshwater natural background values.

Natural background is intended to represent conditions representing minimal human inputs, while accounting for sources such as the native geology of a region (e.g., natural coal seams) or aerial deposition of natural (e.g., forest fires) and more wide-spread human-derived contaminants (e.g., polycyclic aromatic hydrocarbons [PAHs] and polychlorinated biphenyls [PCBs], etc.). Natural background values for marine sediment were derived from a series of samples collected in portions of Puget Sound and other marine areas less influenced by human activities and published as part of the Sediment Cleanup User's Manual (SCUM; Ecology 2019). The background values were calculated as the 90th confidence limit around the 90th percentile of the background values (i.e., the 90/90 upper tolerance limit or UTL). The 90/90 UTL is meant to represent an upper bound value that might occur in background areas.

To determine if marine background values might be representative of freshwater background conditions, GeoEngineers, Inc. (GeoEngineers) identified two readily available freshwater sediment data sets that are potentially representative of areas with fewer human impacts. The first data set is from Lake Sammamish in King County. King County monitored sediment quality in Lake Sammamish, one of the state's largest recreational lakes, from 1999 to 2010. The second data set is drawn from a broader geographic region. Ecology conducted a survey in 2008 of nine lakes and rivers in Washington State to evaluate their use as potential reference areas for freshwater investigations. Sediment data from the Lake Sammamish surveys and the reference area study were evaluated to characterize the concentrations that might be present in areas with more limited human influence. Data were downloaded from Ecology's Environmental Information Management (EIM) database or hand-entered from Ecology's report (Ecology 2009).

It is important to note that it is not the intent of this evaluation to independently establish natural background values for the GWPS, but rather to determine if the marine natural background values published in Ecology's SCUM guidance are a reasonable surrogate for freshwater natural background values.

2.0 BACKGROUND DATA SETS

2.1. Lake Sammamish

The Lake Sammamish data set was composed of data collected by King County between 1999 and 2010. The initial 1999 survey collected most of the samples; however, the two main basin monitoring locations were sampled over time. Where more than one sample was collected from a given location within a single survey, the replicate sample values were averaged prior to calculating background values. Where more than one sample was collected from a given location over time, the most recent value was used. The resulting data set consisted of 16 to 22 samples; several outliers were identified for the cPAH and arsenic data set and were removed prior to calculating various metrics. Characteristics of the data set are summarized in the following inset table:

Lake Sammamish Data Set Characteristics	cPAH TEQ (µg/kg)	Arsenic (mg/kg)	Chromium (mg/kg)	Nickel (mg/kg)
Number of samples	16	21	22	22
Number of detected values	16	21	21	21
Minimum concentration	22	1.9	11.7	8.8
Maximum concentration	132	30	52	53
Average concentration	68	11.5	32	32

Notes:
TEQ = toxicity equivalent µg/kg = micrograms per kilogram mg/kg = milligrams per kilogram

2.2. State-wide Reference Areas

The reference area study conducted by Ecology included three monitoring locations from each of these nine waterbodies:

- Columbia River at Beacon Rock State Park
- Chester-Morse Reservoir (King County)
- Lake Wenatchee
- Little Spokane River
- Mountain Lake (Orcas Island)
- McDowell Lake (near Cheney/Turnbull National Wildlife Refuge)
- Lake Ozette (Olympic Peninsula)
- Palouse River at the confluence with the Snake River
- South Skookum Lake (Pend Oreille County)

Sampling locations were selected to represent minimally impacted sites (away from known contaminant sources and human development) with a preference given to accessible areas within state or national parks or other protected areas. Data were assumed to represent background conditions and no outliers were removed.

Characteristics of the potential reference areas are summarized below:

State-wide Reference Area Data Set Characteristics	cPAH TEQ (µg/kg)	Arsenic (mg/kg)	Chromium (mg/kg)	Nickel (mg/kg)
Number of samples	27	27	27	27
Number of detected values	27	27	27	27
Minimum concentration	2.2	0.98	5.3	6.8
Maximum concentration	112	16.9	65	81
Average concentration	34	5.3	26	22

Notes:
TEQ = toxicity equivalent µg/kg = micrograms per kilogram mg/kg = milligrams per kilogram

3.0 BACKGROUND CALCULATIONS

U.S. Environmental Protection Agency's (EPA's) ProUCL (2015) statistical software (Version 5.1) was used to evaluate the characteristics of the data sets and calculate 90/90 UTLs for cPAHs, arsenic, chromium and nickel. The 90/90 UTLs were compared to the published marine natural background values to determine if the marine values are a reasonable surrogate for natural background conditions in freshwater systems. 90/90 UTLs were calculated separately for each data set. ProUCL outputs are included in Sub-attachment 4A-2.1.

According to the ProUCL output, the data sets have different distributions and fit the assumptions of more than one distribution in several cases. The results for all distributions that might be appropriate for a given data set are summarized below (outputs are provided in Sub-attachment 4A-2.1):

COMPARISON OF BACKGROUND VALUES (90/90 UTL)

Data Set and Basis	cPAH TEQ (µg/kg)	Arsenic (mg/kg)	Chromium (mg/kg)	Nickel (mg/kg)
Lake Sammamish				
Approximate Normal	136		54	54
Gamma Distribution	150		60	61
Log-normal Distribution	165		65	
Nonparametric Distribution		28		
State-wide Potential Freshwater Reference Areas				
Gamma Distribution	100	12.8	61	--
Log-normal Distribution	133	14.0	67	60
Marine Natural Background from Ecology's SCUM Guidance	**21**	**11**	**62**	**50**

Notes:
TEQ = toxicity equivalent µg/kg = micrograms per kilogram mg/kg = milligrams per kilogram

The 90/90 UTLs for cPAHs in the Lake Sammamish and state-wide reference area data sets exceed the marine natural background by an order of magnitude. The arsenic 90/90 UTL in Lake Sammamish is also greater than the marine natural background, while the state-wide reference area 90/90 UTL is more similar. Chromium and nickel in the Lake Sammamish and state-wide reference area data sets were very similar to the natural background values published for marine sediment in Ecology's SCUM guidance (Ecology 2019). Use of marine natural background values are therefore conservative (cPAHs and arsenic) or reasonable (chromium and nickel) estimates of freshwater natural background values. These results support the use of marine natural background as a surrogate for freshwater natural background in development of SMS SCOs for cPAHs, arsenic, chromium, and nickel in sediment at the GWPS.

REFERENCES

EPA 2015. ProUCL Version 5.1 User Guide. Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations. EPA/600/R-07/041).

Washington State Department of Ecology. 2009.Baseline Characterization of Nine Proposed Freshwater Sediment Reference Sites, 2008.Publication No. 09-03-032. July 2009.

Washington State Department of Ecology. 2019. Sediment Cleanup User's Manual (SCUM); Guidance for Implementing the Provisions of the Sediment Management Standards, Chapter 173-204 WAC. Publication No. 12-09-057. Second Revision December 2019.

SUB-ATTACHMENT 4A-2.1
Natural Background – ProUCL Output

Lake Sammamish Background Data Sets

Background Statistics for Uncensored Full Data Sets

User Selected Options

Date/Time of Computation	ProUCL 5.13/26/2020 1:10:39 PM
From File	C:\Users\nmusgrove\OneDrive - GeoEngineers, Inc\ProUCL 5.1\Data\Lake Sammamish\Lake Sam_As_v2.xlsx
Full Precision	OFF
Confidence Coefficient	90%
Coverage	90%
New or Future K Observations	1
Number of Bootstrap Operations	2000

As_recent

General Statistics

Total Number of Observations	21	Number of Distinct Observations	21
		Number of Missing Observations	22
Minimum	1.86	First Quartile	3.76
Second Largest	28.1	Median	5.09
Maximum	29.6	Third Quartile	20
Mean	11.49	SD	10.04
Coefficient of Variation	0.874	Skewness	0.766
Mean of logged Data	2.05	SD of logged Data	0.914

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.75	d2max (for USL)	2.408

Normal GOF Test

Shapiro Wilk Test Statistic	0.789	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.908	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.3	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.188	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

90% UTL with	90% Coverage	29.06	90% Percentile (z)	24.36
	90% UPL (t)	25.11	95% Percentile (z)	28
	90% USL	35.66	99% Percentile (z)	34.85

Gamma GOF Test

A-D Test Statistic	1.522	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.76	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.235	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.193	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.421	k star (bias corrected MLE)	1.249
Theta hat (MLE)	8.087	Theta star (bias corrected MLE)	9.195
nu hat (MLE)	59.66	nu star (bias corrected)	52.47
MLE Mean (bias corrected)	11.49	MLE Sd (bias corrected)	10.28

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL	25.66	90% Percentile	25.04
90% Hawkins Wixley (HW) Approx. Gamma UPL	25.86	95% Percentile	31.84
90% WH Approx. Gamma UTL with 90% Coverage	32.9	99% Percentile	47.39
90% HW Approx. Gamma UTL with 90% Coverage	33.88		
90% WH USL	47.84	90% HW USL	51.26

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.871	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.908	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.202	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.188	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with 90% Coverage	38.43	90% Percentile (z)	25.05
90% UPL (t)	26.82	95% Percentile (z)	34.91
90% USL	70.09	99% Percentile (z)	65.07

Nonparametric Distribution Free Background Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	20	90% UTL with 90% Coverage	28.1
Approx, f used to compute achieved CC	1.111	Approximate Actual Confidence Coefficient achieved by UTL	0.635
		Approximate Sample Size needed to achieve specified CC	37
90% Percentile Bootstrap UTL with 90% Coverage	28.1	90% BCA Bootstrap UTL with 90% Coverage	28.1
90% UPL	27.97	90% Percentile	27.45
90% Chebyshev UPL	42.32	95% Percentile	28.1
95% Chebyshev UPL	56.29	99% Percentile	29.3
90% USL	29.6		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Background Statistics for Data Sets with Non-Detects

User Selected Options

Date/Time of Computation	ProUCL 5.13/27/2020 11:32:44 AM
From File	Lake Sam_Cr.xls
Full Precision	OFF
Confidence Coefficient	90%
Coverage	90%
Different or Future K Observations	1
Number of Bootstrap Operations	2000

Lake Sammamish Cr_Recent

General Statistics

Total Number of Observations	22	Number of Distinct Observations	22
		Number of Missing Observations	21
Minimum	11.7	First Quartile	20.65
Second Largest	49.6	Median	35.05
Maximum	52	Third Quartile	43.25
Mean	32.33	SD	12.68
Coefficient of Variation	0.392	Skewness	-0.182
Mean of logged Data	3.387	SD of logged Data	0.457

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.737	d2max (for USL)	2.429

Normal GOF Test

Shapiro Wilk Test Statistic	0.932	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.163	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

90% UTL with	90% Coverage	54.35	90% Percentile (z)	48.58
	90% UPL (t)	49.49	95% Percentile (z)	53.19
	90% USL	63.13	99% Percentile (z)	61.82

Gamma GOF Test

A-D Test Statistic	0.766	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.746	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.159	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.186	Detected data appear Gamma Distributed at 5% Significance Level

Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics

k hat (MLE)	5.758	k star (bias corrected MLE)	5.003
Theta hat (MLE)	5.616	Theta star (bias corrected MLE)	6.463
nu hat (MLE)	253.4	nu star (bias corrected)	220.1
MLE Mean (bias corrected)	32.33	MLE Sd (bias corrected)	14.46

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL	52.27	90% Percentile	51.69
90% Hawkins Wixley (HW) Approx. Gamma UPL	52.81	95% Percentile	59.19
90% WH Approx. Gamma UTL with 90% Coverage	59.91	99% Percentile	75.03
90% HW Approx. Gamma UTL with 90% Coverage	61.02		
90% WH USL	75.51	90% HW USL	78.2

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.9	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.175	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Lognormal at 5% Significance Level

Data appear Approximate Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with 90% Coverage	65.37	90% Percentile (z)	53.09
90% UPL (t)	54.85	95% Percentile (z)	62.67
90% USL	89.66	99% Percentile (z)	85.56

Nonparametric Distribution Free Background Statistics

Data appear Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	21	90% UTL with 90% Coverage	49.6
Approx, f used to compute achieved CC	1.167	Approximate Actual Confidence Coefficient achieved by UTL	0.661
		Approximate Sample Size needed to achieve specified CC	37
90% Percentile Bootstrap UTL with 90% Coverage	49.6	90% BCA Bootstrap UTL with 90% Coverage	49.6
90% UPL	48.67	90% Percentile	46.35
90% Chebyshev UPL	71.22	95% Percentile	49.45
95% Chebyshev UPL	88.83	99% Percentile	51.5
90% USL	52		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20. Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.

The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Background Statistics for Data Sets with Non-Detects

User Selected Options

Date/Time of Computation	ProUCL 5.13/27/2020 11:23:14 AM
From File	Lake Sam_Ni.xls
Full Precision	OFF
Confidence Coefficient	90%
Coverage	90%
Different or Future K Observations	1
Number of Bootstrap Operations	2000

Lake Sammamish Ni Recent

General Statistics

Total Number of Observations	22	Number of Distinct Observations	22
		Number of Missing Observations	21
Minimum	8.8	First Quartile	20.43
Second Largest	46.8	Median	32.5
Maximum	53	Third Quartile	42.8
Mean	31.64	SD	13.08
Coefficient of Variation	0.413	Skewness	-0.206
Mean of logged Data	3.351	SD of logged Data	0.5

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.737	d2max (for USL)	2.429

Normal GOF Test

Shapiro Wilk Test Statistic	0.939	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.17	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

90% UTL with	90% Coverage	54.36	90% Percentile (z)	48.41
	90% UPL (t)	49.34	95% Percentile (z)	53.16
	90% USL	63.41	99% Percentile (z)	62.07

Gamma GOF Test

A-D Test Statistic	0.734	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.746	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.192	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.186	Data Not Gamma Distributed at 5% Significance Level

Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics

k hat (MLE)	4.974	k star (bias corrected MLE)	4.326
Theta hat (MLE)	6.362	Theta star (bias corrected MLE)	7.315
nu hat (MLE)	218.9	nu star (bias corrected)	190.3
MLE Mean (bias corrected)	31.64	MLE Sd (bias corrected)	15.21

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL	52.69		90% Percentile	52.03
90% Hawkins Wixley (HW) Approx. Gamma UPL	53.38		95% Percentile	60.09
90% WH Approx. Gamma UTL with 90% Coverage	60.92		99% Percentile	77.25
90% HW Approx. Gamma UTL with 90% Coverage	62.3			
90% WH USL	77.83		90% HW USL	81.15

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.903	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.191	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with 90% Coverage	67.97		90% Percentile (z)	54.13
90% UPL (t)	56.1		95% Percentile (z)	64.91
90% USL	96.07		99% Percentile (z)	91.26

Nonparametric Distribution Free Background Statistics

Data appear Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	21		90% UTL with 90% Coverage	46.8
Approx, f used to compute achieved CC	1.167		Approximate Actual Confidence Coefficient achieved by UTL	0.661
			Approximate Sample Size needed to achieve specified CC	37
90% Percentile Bootstrap UTL with 90% Coverage	46.8		90% BCA Bootstrap UTL with 90% Coverage	46.8
90% UPL	46.44		90% Percentile	45.55
90% Chebyshev UPL	71.77		95% Percentile	46.74
95% Chebyshev UPL	89.94		99% Percentile	51.7
90% USL	53			

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20. Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.

The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

State-wide Reference Areas Background Data Sets

Background Statistics for Uncensored Full Data Sets

User Selected Options

Date/Time of Computation	ProUCL 5.13/26/2020 12:25:59 PM
From File	C:\Users\nmusgrove\OneDrive - GeoEngineers, Inc\ProUCL 5.1\Data\Freshwater Ref Sites\FW ref sites_As Cr
Full Precision	OFF
Confidence Coefficient	90%
Coverage	90%
New or Future K Observations	1
Number of Bootstrap Operations	2000

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General Statistics

Total Number of Observations	27	Number of Distinct Observations	26
Minimum	0.985	First Quartile	2.565
Second Largest	16.6	Median	4.21
Maximum	16.9	Third Quartile	5.99
Mean	5.325	SD	4.341
Coefficient of Variation	0.815	Skewness	1.706
Mean of logged Data	1.409	SD of logged Data	0.731

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.682	d2max (for USL)	2.52

Normal GOF Test

Shapiro Wilk Test Statistic	0.774	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.923	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.218	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.167	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

90% UTL with 90% Coverage	12.63	90% Percentile (z)	10.89
90% UPL (t)	11.14	95% Percentile (z)	12.47
90% USL	16.26	99% Percentile (z)	15.42

Gamma GOF Test

A-D Test Statistic	0.73	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.756	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.127	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.17	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.048	k star (bias corrected MLE)	1.845
Theta hat (MLE)	2.6	Theta star (bias corrected MLE)	2.886
nu hat (MLE)	110.6	nu star (bias corrected)	99.62
MLE Mean (bias corrected)	5.325	MLE Sd (bias corrected)	3.92

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL	10.64	90% Percentile	10.56
90% Hawkins Wixley (HW) Approx. Gamma UPL	10.65	95% Percentile	12.96
90% WH Approx. Gamma UTL with 90% Coverage	12.83	99% Percentile	18.32
90% HW Approx. Gamma UTL with 90% Coverage	13		
90% WH USL	19.41	90% HW USL	20.39

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.964	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.923	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0836	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.167	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with 90% Coverage	13.98	90% Percentile (z)	10.43
90% UPL (t)	10.88	95% Percentile (z)	13.6
90% USL	25.78	99% Percentile (z)	22.38

Nonparametric Distribution Free Background Statistics

Data appear Gamma Distributed at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	26	90% UTL with 90% Coverage	16.6
Approx, f used to compute achieved CC	1.444	Approximate Actual Confidence Coefficient achieved by UTL	0.767
		Approximate Sample Size needed to achieve specified CC	37
90% Percentile Bootstrap UTL with 90% Coverage	16.6	90% BCA Bootstrap UTL with 90% Coverage	16.6
90% UPL	13.48	90% Percentile	12.52
90% Chebyshev UPL	18.59	95% Percentile	15.43
95% Chebyshev UPL	24.6	99% Percentile	16.82
90% USL	16.9		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20. Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.

The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

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General Statistics

Total Number of Observations	27	Number of Distinct Observations	26
Minimum	5.32	First Quartile	13.1
Second Largest	59.5	Median	21
Maximum	65	Third Quartile	35.65
Mean	26.01	SD	18.16
Coefficient of Variation	0.698	Skewness	0.993
Mean of logged Data	3.028	SD of logged Data	0.701

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.682	d2max (for USL)	2.52

Normal GOF Test

Shapiro Wilk Test Statistic	0.85	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.923	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.239	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.167	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

90% UTL with	90% Coverage	56.56	90% Percentile (z)	49.28
	90% UPL (t)	50.33	95% Percentile (z)	55.88
	90% USL	71.77	99% Percentile (z)	68.26

Gamma GOF Test

A-D Test Statistic	0.616	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.755	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.159	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.17	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.319	k star (bias corrected MLE)	2.086
Theta hat (MLE)	11.21	Theta star (bias corrected MLE)	12.47
nu hat (MLE)	125.2	nu star (bias corrected)	112.7
MLE Mean (bias corrected)	26.01	MLE Sd (bias corrected)	18.01

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL		50.72	90% Percentile	50.09
90% Hawkins Wixley (HW) Approx. Gamma UPL		51.05	95% Percentile	60.88
90% WH Approx. Gamma UTL with	90% Coverage	60.62	99% Percentile	84.75
90% HW Approx. Gamma UTL with	90% Coverage	61.77		
	90% WH USL	90.05	90% HW USL	95.03

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.959	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.923	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.113	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.167	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with	90% Coverage	67.16	90% Percentile (z)	50.72
90% UPL (t)		52.81	95% Percentile (z)	65.43
90% USL		120.9	99% Percentile (z)	105.5

Nonparametric Distribution Free Background Statistics

Data appear Gamma Distributed at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r		26	90% UTL with 90% Coverage	59.5
Approx, f used to compute achieved CC		1.444	Approximate Actual Confidence Coefficient achieved by UTL	0.767
			Approximate Sample Size needed to achieve specified CC	37
90% Percentile Bootstrap UTL with	90% Coverage	59.5	90% BCA Bootstrap UTL with 90% Coverage	59.5
90% UPL		57.58	90% Percentile	56.98
90% Chebyshev UPL		81.49	95% Percentile	58.78
95% Chebyshev UPL		106.6	99% Percentile	63.57
90% USL		65		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20. Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.

The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

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General Statistics

Total Number of Observations	27	Number of Distinct Observations	27
Minimum	6.79	First Quartile	8.06
Second Largest	57.2	Median	13.1
Maximum	80.8	Third Quartile	33.05
Mean	22.44	SD	19.5
Coefficient of Variation	0.869	Skewness	1.522
Mean of logged Data	2.804	SD of logged Data	0.771

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.682	d2max (for USL)	2.52

Normal GOF Test

Shapiro Wilk Test Statistic	0.785	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.923	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.275	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.167	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

90% UTL with	90% Coverage	55.25	90% Percentile (z)	47.44
	90% UPL (t)	48.56	95% Percentile (z)	54.52
	90% USL	71.59	99% Percentile (z)	67.82

Gamma GOF Test

A-D Test Statistic	1.314	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.759	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.202	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.171	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.776	k star (bias corrected MLE)	1.604
Theta hat (MLE)	12.63	Theta star (bias corrected MLE)	13.99
nu hat (MLE)	95.93	nu star (bias corrected)	86.6
MLE Mean (bias corrected)	22.44	MLE Sd (bias corrected)	17.72

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL		46.43	90% Percentile	46.01
90% Hawkins Wixley (HW) Approx. Gamma UPL		46.32	95% Percentile	57.17
90% WH Approx. Gamma UTL with	90% Coverage	56.65	99% Percentile	82.27
90% HW Approx. Gamma UTL with	90% Coverage	57.28		
	90% WH USL	87.68	90% HW USL	92.2

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.897	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.923	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.148	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.167	Data appear Lognormal at 5% Significance Level

Data appear Approximate Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with 90% Coverage	60.4	90% Percentile (z)	44.35
90% UPL (t)	46.37	95% Percentile (z)	58.69
90% USL	115.3	99% Percentile (z)	99.28

Nonparametric Distribution Free Background Statistics

Data appear Approximate Lognormal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	26	90% UTL with 90% Coverage	57.2
Approx, f used to compute achieved CC	1.444	Approximate Actual Confidence Coefficient achieved by UTL	0.767
		Approximate Sample Size needed to achieve specified CC	37
90% Percentile Bootstrap UTL with 90% Coverage	57.2	90% BCA Bootstrap UTL with 90% Coverage	57.2
90% UPL	56.56	90% Percentile	52.08
90% Chebyshev UPL	82.03	95% Percentile	56.96
95% Chebyshev UPL	109	99% Percentile	74.66
90% USL	80.8		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Background Statistics for Uncensored Full Data Sets

User Selected Options

Date/Time of Computation	ProUCL 5.13/26/2020 10:51:07 AM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	90%
Coverage	90%
New or Future K Observations	1
Number of Bootstrap Operations	2000

State-wide Ref cPAH

General Statistics

Total Number of Observations	27	Number of Distinct Observations	27
Minimum	2.2	First Quartile	8.355
Second Largest	95.9	Median	20.1
Maximum	112	Third Quartile	44.7
Mean	34.11	SD	32.51
Coefficient of Variation	0.953	Skewness	1.134
Mean of logged Data	3.024	SD of logged Data	1.109

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.682	d2max (for USL)	2.52

Normal GOF Test

Shapiro Wilk Test Statistic	0.832	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.923	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.232	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.167	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

90% UTL with	90% Coverage	88.8	90% Percentile (z)	75.78
	90% UPL (t)	77.65	95% Percentile (z)	87.59
	90% USL	116	99% Percentile (z)	109.7

Gamma GOF Test

A-D Test Statistic	0.426	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.771	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.115	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.173	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.127	k star (bias corrected MLE)	1.026
Theta hat (MLE)	30.27	Theta star (bias corrected MLE)	33.23
nu hat (MLE)	60.85	nu star (bias corrected)	55.42
MLE Mean (bias corrected)	34.11	MLE Sd (bias corrected)	33.67

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL	79.33	90% Percentile	78.04
90% Hawkins Wixley (HW) Approx. Gamma UPL	80.86	95% Percentile	101.3
90% WH Approx. Gamma UTL with 90% Coverage	100.5	99% Percentile	155
90% HW Approx. Gamma UTL with 90% Coverage	105		
90% WH USL	167.4	90% HW USL	186.6

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.955	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.923	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.109	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.167	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with 90% Coverage	132.9	90% Percentile (z)	85.25
90% UPL (t)	90.86	95% Percentile (z)	127.5
90% USL	336.6	99% Percentile (z)	271.6

Nonparametric Distribution Free Background Statistics

Data appear Gamma Distributed at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	26	90% UTL with 90% Coverage	95.9
Approx, f used to compute achieved CC	1.444	Approximate Actual Confidence Coefficient achieved by UTL	0.767
		Approximate Sample Size needed to achieve specified CC	37
90% Percentile Bootstrap UTL with 90% Coverage	95.9	90% BCA Bootstrap UTL with 90% Coverage	95.9
90% UPL	91.5	90% Percentile	88.36
90% Chebyshev UPL	133.4	95% Percentile	94.25
95% Chebyshev UPL	178.4	99% Percentile	107.8
90% USL	112		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20. Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.

The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Background Statistics for Data Sets with Non-Detects

User Selected Options

Date/Time of Computation	ProUCL 5.13/26/2020 9:54:58 AM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	90%
Coverage	90%
Different or Future K Observations	1
Number of Bootstrap Operations	2000

Lake Sammamish cPAH_recent_no outs

General Statistics

Total Number of Observations	16	Number of Distinct Observations	16
		Number of Missing Observations	27
Minimum	22	First Quartile	43
Second Largest	127	Median	49.5
Maximum	132	Third Quartile	100
Mean	67.56	SD	36.96
Coefficient of Variation	0.547	Skewness	0.624
Mean of logged Data	4.068	SD of logged Data	0.564

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.842	d2max (for USL)	2.279

Normal GOF Test

Shapiro Wilk Test Statistic	0.889	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.887	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.245	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.213	Data Not Normal at 5% Significance Level

Data appear Approximate Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

90% UTL with	90% Coverage	135.6	90% Percentile (z)	114.9
	90% UPL (t)	118.6	95% Percentile (z)	128.3
	90% USL	151.8	99% Percentile (z)	153.5

Gamma GOF Test

A-D Test Statistic	0.482	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.743	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.205	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.216	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.612	k star (bias corrected MLE)	2.976
Theta hat (MLE)	18.71	Theta star (bias corrected MLE)	22.7
nu hat (MLE)	115.6	nu star (bias corrected)	95.23
MLE Mean (bias corrected)	67.56	MLE Sd (bias corrected)	39.16

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL	122.5	90% Percentile	120.1
90% Hawkins Wixley (HW) Approx. Gamma UPL	123.5	95% Percentile	142.1
90% WH Approx. Gamma UTL with 90% Coverage	149.5	99% Percentile	189.9
90% HW Approx. Gamma UTL with 90% Coverage	152.5		
90% WH USL	178.5	90% HW USL	184.5

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.944	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.887	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.172	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.213	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with 90% Coverage	165.1	90% Percentile (z)	120.4
90% UPL (t)	127.4	95% Percentile (z)	147.7
90% USL	211.3	99% Percentile (z)	216.9

Nonparametric Distribution Free Background Statistics

Data appear Approximate Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	15	90% UTL with 90% Coverage	127
Approx, f used to compute achieved CC	0.833	Approximate Actual Confidence Coefficient achieved by UTL	0.485
		Approximate Sample Size needed to achieve specified CC	37
90% Percentile Bootstrap UTL with 90% Coverage	129.5	90% BCA Bootstrap UTL with 90% Coverage	129.5
90% UPL	128.5	90% Percentile	122
90% Chebyshev UPL	181.8	95% Percentile	128.3
95% Chebyshev UPL	233.6	99% Percentile	131.3
90% USL	132		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

APPENDIX 4B
Gas Works Sediment Area
Cleanup Standard Determination

Gas Works Sediment Area Cleanup Standard Determination

Gas Works Sediment Area
Seattle, Washington

Prepared by:

The RETEC Group, Inc.
1011 SW Klickitat Way, Suite 207
Seattle, Washington 98134-1162

RETEC Project Number: PSE10-18628-610

Prepared for:

Puget Sound Energy
10885 NE Fourth Street
Bellevue, Washington 98004

Reviewed by:

City of Seattle, Seattle Public Utilities
700 Fifth Avenue, Suite 4900
Seattle, Washington 98104

September 26, 2005

Gas Works Sediment Area Cleanup Standard Determination

Gas Works Sediment Area
Seattle, Washington

Prepared by:

The RETEC Group, Inc.
1011 SW Klickitat Way, Suite 207
Seattle, Washington 98134-1162

RETEC Project Number: PSE10-18628-610

Prepared for:

Puget Sound Energy
10885 NE Fourth Street
Bellevue, Washington 98004

Prepared by:

Shannon Ashurst, Staff Scientist

Anne Fitzpatrick, Senior Scientist

Reviewed by:

Dan Baker, Project Manager

Allison Geiselbrecht, Ph.D., Floyd|Snider (Reviewer for the City of Seattle)

Marian Wineman, WR Consulting, Inc.

September 26, 2005

Executive Summary

In accordance with Agreed Order (AO) No. DE2008 for a Remedial Investigation/ Feasibility Study (RI/FS) at the Gas Works Sediment Area (GWSA), a supplemental study was conducted to determine the site-specific sediment cleanup standard. The results of this study and the recommended site-specific sediment cleanup standard are presented in this document.

The cleanup standard has two parts: cleanup level(s) addressing chemicals associated with the Gas Works Park (GWP) upland Site and a point of compliance defined by the GWSA boundary (AB) representing the area where future remedial actions will be evaluated. The data support cleanup level(s) based on TPAH, which is representative of and encompasses impacts from GWP upland sources. The recommended GWSA site-specific cleanup screening level (SCSL) for TPAH is 290 mg/kg dry weight (dw), and the site-specific sediment quality level (SSQL) for TPAH is 170 mg/kg dw.

Results indicate that the Area of Investigation (AOI) proposed in the AO encompasses GWP sources, as well as areas affected by non-GWP sources. The presence of bioassay test locations that passed the Ecology criteria within the AOI facilitated delineation of a new AB that encompasses all sediment bioassay failures associated with GWP sources. At the western perimeter of the AB, an area of overlap between total polycyclic aromatic hydrocarbons (TPAH) and metals from shipyard activities occurs. Discussions concerning next steps for solidifying the proposed boundary within this area will occur prior to submittal of the Western Study Area RI/FS document.

Background

The RI/FS is being conducted in the AOI or area of sediments containing hazardous substances, primarily PAHs associated with accidental spills or releases from historical activities on the GWP upland Site. This area, shown on Figure 1-1, was defined using chemical concentration gradients from GWP constituents and the distribution of metals and other contaminants from non-GWP sources. Lake Union has a long history as an industrial "working lake" impacted by PAHs from numerous sources and other contaminants that contribute to ambient conditions. As a result, the AOI includes impacts from off-site sources and chemicals not associated with historical GWP activities.

The cleanup standard developed in this document will be carried forward in the RI/FS process for the GWSA. Two RI/FS reports will be prepared: one for the Western Study Area and a separate, but complementary, report for the Eastern Study Area. This work was conducted in collaboration with Department of Ecology (Ecology), Puget Sound Energy (PSE), and the City of Seattle (City) under the Model Toxics Control Act (MTCA) and the Sediment Management Standards (SMS). The scope and objectives of the supplemental bioassay study are detailed in the Ecology-approved *Site-wide Supplemental Bioassay Sampling and Analysis Plan and Quality Assurance Project Plan* (RETEC and Floyd|Snider [F|S], 2005).

Executive Summary

Scope and Objectives

The cleanup standard (cleanup level(s) and point of compliance) was determined using the following assessments:

- The distribution of TPAH in surface sediments
- The impacts of non-GWP nearby sources of chemicals such as metals from marinas and shipyards
- Site-specific sediment bioassay and chemistry results
- Spatial distribution of biological responses
- Determination of TPAH effects concentrations.

Two levels are derived in this document: an SCSL and an SSQL. The SCSL, based on the bioassay results, will be applied in the RI/FS process to define the extent of sediment management areas within the AB that will require remedial action. The SSQL, also based on bioassay results, will be applied consistent with SMS in the feasibility study to evaluate if natural recovery can be achieved in portions of the AB. The remedial action will be designed to be effective, reliable, and to meet the SSQL within 10 years following remedy completion in the top 10 centimeters (cm) of the lake bottom sediments in accordance with SMS.

Results and Analysis

Surface sediment samples (0 to 10 cm) were collected from 57 stations located in the AOI and the surrounding area (Figure 2-2) to provide adequate spatial coverage. The samples were collected and analyzed to generate robust synoptic chemical and biological datasets. These data were collected from four different seasonal sampling events (2000 through 2005) using three different species and seven bioassay endpoints. The sampling stations included a range of TPAH concentrations, other GWP-related chemicals, and non-GWP-related contamination from the nearby shipyard, marina area, and other sources (e.g., metals). Biological tests were selected from freshwater sediment toxicity tests approved by Ecology using Washington State-accredited laboratories. The selected bioassay test species are adequately sensitive to organic chemicals and numerous metals analytes. Sample collection methods, quality control, and chemical and biological testing were conducted in accordance with standard methods and Ecology-approved work plans.

Extent of Bioassay Passes

Collectively, 199 of 246 benthic bioassay data endpoints passed bioassay critera according to Ecology's proposed freshwater sediment bioassay decision criteria. Nineteen percent of the data points had adverse biological effects. Most of these effects were observed close to shore. Bioassay failures were observed in areas with GWP-impacts, as well as areas where non-GWP impacts (e.g., metals) are possibly commingled with GWP impacts. These potentially commingled chemical mixtures

were particularly evident near the shipyard to the west and marina area to the northeast. The range and distribution of bioassay results show, with confidence, that the extent of the area of no adverse biological effects related to GWP chemicals has been delineated within the AOI. The area of bioassay passes, contained within the AOI, is relatively flat bathymetrically and has accumulations of soft sediment with relatively low TPAH concentrations.

Correlation between TPAH and Bioassay Results

Detailed statistical analyses were used to determine that TPAH and five metals (arsenic, chromium, copper, mercury, and zinc) were key variables associated with bioassay results within the AOI. Initial statistical analyses indicated that TPAH is significantly correlated with all detected organics (except polychlorinated biphenyls [PCBs]). Most of the metals correlated together, including tributyltin (TBT). Therefore, TPAH (as a surrogate for organics), the five metals, and other statistically significant parameters (ammonia, sulfides, and percent fines) were carried forward to secondary statistical analyses.

Secondary statistical analyses, using multiple stepwise regressions for each bioassay test result, addressed the question of which bioassay test and chemicals could be used to determine site-specific cleanup levels. These analyses showed that TPAH as a single parameter is responsible for the about 50 to 60 percent of the variability observed among bioassay test results. In addition, these analyses indicated that all of the bioassay tests and assessment endpoints could be used to determine TPAH cleanup levels, except *C. tentans* growth and Microtox®. Growth and Microtox® test results only correlated with metals and percent fines, not TPAH.

Identification of Spatial Clusters

At stations with potentially commingled chemical mixtures, both organic and metal analyte groups likely contributed to observed bioassay toxicity. A multivariate clustering tool was used to identify group(s) of stations (i.e., the Shipyard Cluster) that were primarily associated with metals effects. This step was conducted to isolate the area where TPAH is the primary parameter associated with toxicity from areas with TPAH and metals. Once confirmed, the data subset isolated via the clustering process was used to derive a TPAH cleanup level.

Determination of TPAH Effects Concentrations

Based on the range of observed effects for the 31 bioassay samples primarily associated with TPAH effects, two site-specific TPAH sediment cleanup levels were determined representative of SMS sediment quality standards (SQS) and cleanup screening levels (CSL). They were determined using a ranking approach similar to the Apparent Effects Threshold (AET) approach used in SMS. The following levels are for application within the AB:

1) The SCSL for the GWSA is 290 mg/kg dw TPAH.

2) The SSQL for the GWSA is 170 mg/kg dw TPAH.

A combination of No Observed Effects Concentrations (NOEC) and the Lowest Observed Effects Concentrations (LOEC) were used to derive these levels. Confidence intervals around concentration-response curves were used to confirm these levels.

Determination of a GWSA Boundary

The extent of bioassay passes described above confirms that the AOI boundary developed in 2004 (RETEC and F|S, 2004) encompasses and extends beyond GWP surface sediment impacts. The presence of bioassay passes within the AOI allows the area where future remedial actions will be evaluated to be refined and drawn closer to shore. The bioassay-refined area boundary, referred to as the AB, is based on the distribution of bioassay passes wrapping around the prow of GWP and refined by the extent of surface sediment TPAH concentrations exceeding the SSQL. The AB encompasses the majority of bioassay failures associated with GWP sources. Bioassay effects associated with non-GWP sources are located to the northeast, and bioassay effects associated with non-GWP or possible commingled GWP and non-GWP sources are located to the west. The western shipyard area, or Shipyard Cluster (stations NLU14, NLU15, NLU16, NLU17, and NLU86; plus LU3, LU4, LU8, NLU13, and NLU87), is based on a chemical mixture predominated by metals. The northeastern marina area, or Marina Cluster (stations NLU01, NLU02, and NLU82), is separated from the GWSA by bioassay passes. Excluding the bioassay test stations in areas to the west and northeast where non-GWP or possible commingled sources impact sediments, 23 of the 31 bioassay test stations passed all bioassay decision criteria. The band of bioassay passes occurs about 150 to 900 feet offshore from the GWP shoreline (Figure 5-3).

The AB is defined as the maximum area of responsibility associated with the cleanup of GWP-related sediments. An exception to this is the western perimeter of the AB where possible GWP and non-GWP sources commingle. With the exception of the western area boundary, any bioassay failures occurring outside of the AB will not be addressed in GWSA feasibility studies and subsequent remedial actions, as they are caused by other point or non-point sources to Lake Union. Bioassay failures occurring near the western perimeter area will be further discussed during the Western Study Area RI/FS process.

The AB does not define the footprint, or extent, of planned remedial actions. Remedial actions will occur within the AB based on factors such as remedial action levels, natural recovery processes, sediment stability, and other physical conditions; thus, the AB defines the area for which future remedial actions will be evaluated.

Executive Summary

Cleanup Standard Determination Conclusions

Detailed analysis of these synoptic sediment physical, chemical, and bioassay datasets support the following:

1) The dataset is robust compared to the number of bioassay samples and breadth of acute and chronic bioassay endpoints used to derive cleanup standards for other MTCA sediment sites.

2) The bioassay passes associated with GWP-related chemicals (e.g., TPAH) fall well within the AOI boundary showing that the AOI boundary encompasses GWP sources, as well as areas affected by non-GWP sources.

3) Statistical analysis indicates that GWP-related TPAH is an appropriate basis for determining a cleanup level(s) that is protective of other GWP-associated chemicals.

4) The bioassay passes associated with GWP sources result in a clear boundary of passes close to the shore of GWP.

5) Closer analysis identified chemically-similar groups of stations. An area of mixed metals and PAHs, called the Shipyard/Marina Cluster, was removed from the cleanup level derivation to improve the relationship between bioassay effects and TPAH concentrations.

6) The bioassay results and statistical analyses support an SCSL for TPAH of 290 mg/kg dw and an SSQL for TPAH of 170 mg/kg dw.

7) Bioassay passes combined with the SSQL define the AB shown on Figure 5-2; note that the area of mixed TPAH and metals will be further discussed in the Western Study Area RI/FS process prior to submittal of the Western Study Area RI/FS document.

In summary, the SCSL and SSQL, in combination with the new AB, represent the cleanup standard for the RI/FS process for the GWSA and subsequent remedial actions.

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List of Acronyms

2LAET	second Lowest Apparent Effects Threshold
AB	GWSA boundary
AET	Apparent Effects Threshold
afdw	ash free dry weight
AO	Agreed Order
AOI	area of investigation
City	City of Seattle
C. tentans	*Chironomus tentans*
COC	chemicals of concern
COPC	chemicals of potential concern
cm	centimeters
CSL	cleanup screening level
dw	dry weight
EC	effect concentration
Ecology	Washington State Department of Ecology
F|S	Floyd|Snider
GWP	Gas Works Park
GWSA	Gas Works Sediment Area
HAET	Highest Apparent Effects Threshold
H. azteca	*Hyalella azteca*
HPAH	High molecular weight polycyclic aromatic hydrocarbon
LAET	Lowest Apparent Effect Thresholds
LC15	lethal concentration, 15 percent
LC20	lethal concentration, 20 percent
LC25	lethal concentration, 25 percent
LOEC	Lowest Observed Adverse Effects Concentration
LOEL	Lowest Observed Apparent Effect Level
LPAH	Low molecular weight polycyclic aromatic hydrocarbon
mg/kg	milligrams per kilogram
MGP	manufactured gas plant
MTCA	Model Toxics Control Act
NOEC	No Observed Adverse Effects Concentrations
OMOE	Ontario Ministry of the Environment
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PSE	Puget Sound Energy
RDL	reported detection limit
RETEC	The RETEC Group, Inc.

List of Acronyms

RI/FS	remedial investigation/feasibility study
SAP	Sampling and Analysis Plan
SCSL	site-specific cleanup screening level
SEL	severe effect level
SMS	Sediment Management Standards
SQS	sediment quality standards
SQV	sediment quality values
SSQL	site-specific sediment quality level
SVOC	semivolatile organic chemical
TAMU	Texas A & M University
TBT	tributyltin
TOC	total organic carbon
TPAH	total polycyclic aromatic hydrocarbons (in milligrams per kilogram dry weight as appropriate, unless otherwise indicated)
TPAH-oc	carbon-normalized total polycyclic aromatic hydrocarbons
USEPA	United Stated Environmental Protection Agency
WAC	Washington Administrative Code

1 Introduction

In accordance with Agreed Order (AO) No. DE2008 for a Remedial Investigation/Feasibility Study (RI/FS) at the Gas Works Sediment Area (GWSA), a supplemental study was conducted to determine the site-specific sediment cleanup standard. The results of this study and the recommended site-specific sediment cleanup standard are presented in this document.

This document represents a combined effort by the project team—consisting of Puget Sound Energy (PSE), the City of Seattle (City), and the Department of Ecology (Ecology)—to develop a cleanup standard applicable to the entire GWSA. The cleanup standard developed in this document will be carried forward in the RI/FS process for the GWSA. Two RI/FS reports will be prepared: one for the Western Study Area and a separate, but complementary report, for the Eastern Study Area. This work was conducted under the Model Toxics Control Act (MTCA) and the Sediment Management Standards (SMS).

1.1 Background

The cleanup standard development process was conducted by The RETEC Group, Inc. (RETEC) and Floyd|Snider (F|S) on behalf of PSE and the City in collaboration with Ecology. The scope and objectives of the supplemental study are detailed in the Ecology-approved *Site-wide Supplemental Bioassay Sampling and Analysis Plan and Quality Assurance Project Plan* (Bioassay SAP; RETEC and F|S, 2005).

The RI/FS process is being conducted in the Area of Investigation (AOI), or area of sediments containing hazardous substances, primarily polycyclic aromatic hydrocarbons (PAHs), associated with accidental spills or releases from historical activities on the upland Gas Works Park (GWP) Site (Figure 1-1). GWP is the site of a former manufactured gas plant (MGP) and tar refinery that operated on the north shore of Lake Union in Seattle, Washington. The AOI, shown on Figure 1-1, was defined using chemical concentration gradients and the distribution of metals and other contaminants from non-GWP sources. Lake Union has a long history as an industrial "working lake" impacted by PAHs from numerous sources and other contaminants that contribute to ambient conditions. As a result, the AOI includes impacts from off-site sources and chemicals not associated with historical GWP activities.

Due to the working nature and multitude of chemical sources to Lake Union, an area background analysis was conducted using Ecology's MTCAstat software (Ecology, 2004). Based on data available in 2004, this analysis resulted in the determination of an ambient Lake Union sediment concentration of 100 mg/kg dry weight (dw) TPAH (RETEC and F|S, 2004).

Upon submittal and review of RI/FS work plans for the Eastern and Western Study Areas, the project team—including Ecology, PSE, and City representatives—held a series of meetings between March and July 2005. The focus of these meetings was to discuss the development of a site-specific sediment cleanup standard for the GWSA. The team initially worked through the scope, development, and approval of the Bioassay SAP. The team then worked out the process for determining a site-specific cleanup standard based on synoptic chemistry and bioassay data and the RI/FS investigations conducted in the Eastern and Western Study Areas.

The project team determined that, consistent with SMS, biological response of site-specific sediment toxicity tests will be the primary mechanism for determining the extent of sediment impacts. However, these results will be considered along with other assessment tools to (1) help determine the significance of biological responses, (2) further elucidate the factor(s) contributing toward observed toxicity, and (3) identify areas impacted by other nearby sources of chemicals such as metals from the shipyard to the west of the AOI and the marina area to the northeast of the AOI. A decision-making flow chart describing the process for determining a GWSA TPAH cleanup standard is presented on Figure 1-2.

1.2 Purpose and Objectives

In the absence of promulgated freshwater sediment quality standards and cleanup levels for Washington State, this document determined a site-specific cleanup standard for the GWSA. The approach used to determine the cleanup standard specifically focused on chemicals associated with former GWP upland activities (Section 1.3 below).

The objectives of this document are twofold: (1) to develop a site-specific sediment cleanup level for chemicals associated with GWP and (2) to identify the area where the level will be applied. The GWSA boundary (AB) was developed based on the spatial extent of bioassay passes and the sediment cleanup level. A bioassay pass is determined when toxicity results are compared to Ecology's draft freshwater decision criteria (Avocet/SAIC, 2003). Following SMS guidance, this bioassay approach will override chemical concentrations and account for chemical interactions, chemical exposure, and bioavailability. The AB will be used for developing sediment management areas and remedial options during the RI/FS process for both the Eastern and Western Study Areas. In accordance with the SMS, Ecology considers benthic sediment toxicity tests acceptable indicator endpoints designed to be protective of aquatic sediments.

1.3 Approach

This document describes the analytical results and statistical approach used to define the site-specific sediment cleanup standard for the GWSA. The analytical program included the SMS suite of chemicals requested by Ecology

and synoptic bioassay testing of field-homogenized surface sediment samples. Samples were also analyzed for a few additional parameters, as described in the Bioassay SAP (RETEC and F|S, 2005). The parameter list included chemicals associated with former GWP-related upland activities. Initially, the distribution of GWSA-related chemicals was evaluated to ensure that a cleanup standard could confidently be based on TPAH. Following this step, the project team agreed that TPAH would serve as an indicator chemical for GWP-related chemicals. The site-specific cleanup standard for TPAH was derived using the following parameters:

- The distribution of TPAH in surface sediments
- The impacts of non-GWP nearby sources of chemicals such as metals from marinas and shipyards
- Site-specific sediment bioassay and chemistry results
- Spatial distribution of biological responses
- TPAH effect concentrations.

The site-specific sediment cleanup standard encompasses a numerical cleanup level for TPAH and the point of compliance or location where the cleanup level will be applied to sediments. The standard will be applied in areas where unrefined MGP raw materials, products and byproducts, and other historical activities have been determined to cause chemical or biological impacts located in the submerged shorelands and sediment bed of Lake Union, generally in the vicinity of GWP.

1.3.1 Biological Dataset

The primary focus of the sediment standard development was on the physical, chemical, and associated bioassay results of surface sediment samples (0 to 10 cm) collected within the AOI or near the AOI boundary. Surface sediment samples used in this analysis were collected during five sampling events including:

Bioassay Dataset

Sampling Date	Bioassay Sampling Events			Purpose	
	Sampling Party	No. of Bioassay Samples	No. of Stations	Spatial Boundary	Derive SSQL for TPAH
April 2005	RETEC (Phase 3)	20*	18	X	X
October 2002	RETEC (Phase 2)	14	14	X	X
July 2002	Ecology/TAMU	11	11	X	
March 2002	RETEC splits of Ecology/TAMU	11	11	X	X
March 2000	King County (Station 527)	1	1	X	
TOTAL		**57**	**55**	**55**	**45****

* Original sample count was 19, but two diluted samples were added to the analytical program and one sample was not submitted for biological testing, for a total of 21 chemistry samples and 20 bioassay samples.
** GWSA TPAH Cluster Dataset includes 31 samples (the Shipyard/Marina Cluster includes 14 samples).

The July 2002 dataset was not used in the cleanup level determination because the chemistry results (March) were not synoptic with the bioassay results (July). The March 2000 data point (sample 527) was used for spatial delineation and not a cleanup level determination because the source data were not available to evaluate data quality. These dataset determinations were made in collaboration with Ecology. Table 1-1 presents a summary of samples and analyses associated with each sampling event.

The Phase 3 sampling event was conducted in 2005 to address data gaps identified by Ecology and outlined in the *Bioassay Data Gap Analysis* (RETEC, 2005) requested by Ecology. The Phase 3 biological sampling event included synoptic chemistry and bioassay results and was designed with the following objectives in mind:

- Use benthic toxicity test results to spatially determine the boundary of adverse biological effects that can be attributed to former GWP-upland activities
- Use benthic toxicity test results to identify TPAH concentrations associated with biological effects and to derive a site-specific TPAH cleanup level
- Establish an AB based on TPAH concentrations, bioassay passes, and chemical clusters.

Surface sediment samples analyzed from the Phase 3 sampling event and previous sampling events collectively fulfill the data gaps described in the *Bioassay Data Gap Analysis* (RETEC, 2005). In a project team meeting (June 14, 2005), Ecology concluded that the 55 bioassay sampling locations provide adequate spatial coverage in the AOI and the surrounding area. The bioassay sampling programs were designed to include a range of TPAH concentrations, and to identify effects from shipyard- and marina-area-associated contaminants (e.g., metals). The Phase 3 sampling event included a few re-sampled stations (NLU13, EPA5, and EPA19) to confirm observed results.

Biological tests were selected from Ecology-approved freshwater sediment toxicity tests using Washington State accredited laboratories. Sample collection methods, quality control, and chemical and biological testing were conducted in accordance with standard methods and Ecology-approved work plans. Grain size, synoptic chemistry, and bioassay results are presented in Appendices A, B, and C, respectively.

1.3.2 Statistical Methodology

The overall methodology used to interpret GWSA bioassay data and derive a TPAH cleanup standard is a series of sequential steps developed in collaboration with Ecology. These steps include tools such as (a) multivariate

evaluation of data, (b) aggregation of parameters into a few variables that explain toxicity, (c) clustering of data stations into groups, and (d) use of AET and concentration-response relationships to derive protective chemical concentrations. These steps are described below and in Appendix D, as well as in a graphic summary (Figure 1-2):

- **Step 1.** Visually explore the distribution of the dataset and log-transform the data if necessary. Check for outliers. Statistical tools include histograms and scatterplots (Graphical Data Distribution).

- **Step 2.** Determine if chemical and spatial clusters exist in the dataset. Statistical tools include hierarchical cluster analyses (Initial Screening – Spatial Analysis).

- **Steps 3 and 4.** Examine how variables are correlated to each other. Determine which variables can explain most of the toxicity observed among biological endpoints. Statistical tools include correlations and stepwise regressions (Initial and Secondary Screening).

- **Step 5.** Determine TPAH effects levels using AET and concentration-response curves. The AET values are the concentrations of specific chemicals of concern (COC) in sediment above which a significant adverse biological effect or "hit" always occurs (Ecology, 1997). For this document, "hits" and "no hits" are expressed by ranking the data and determining the Lowest Observed Adverse Effects Concentration (LOEC) and No Observed Adverse Effects Concentrations (NOEC) for each bioassay endpoint. These effect concentrations are confirmed from concentration-response curves. Statistical tools include non-parametric rank tables and regressions (TPAH Effect Levels).

- **Step 6.** Conduct a Confidence Analysis to verify that the site-specific TPAH cleanup level will also be protective of non-TPAH GWP-related chemicals. Statistical tools include sensitivity analysis, spatial overlap analysis or co-occurrence analysis and model validation (Confidence Analysis).

Chemicals other than TPAH were compared to Ecology's draft chemical criteria based on Lowest Apparent Effects Threshold (LAET) and second-lowest LAET (2LAET) for freshwater sediments (Avocet/SAIC, 2003). The LAET and 2LAET values represent the chemical sediment quality standard (SQS) and the cleanup screening level (CSL), similar to a low and high screen respectively, for freshwater sediments. The tools and findings associated with each of these steps are summarized in the following sections. Detailed methodologies and assumptions are described in the appendices.

2 Analytical Results

This section presents a summary of chemical, physical, and biological results for samples recently collected during the Phase 3 sampling event (April 2005), a summary of cumulative bioassay results for samples collected within the AOI from 2000 to 2005, and a correlation analysis of TPAH concentrations and biological responses. Grain size results and field water quality parameters are summarized in Appendix A. Appendix B presents a summary of the surface sediment chemistry results for three sampling events in March 2002 (Phase 2 split samples), October 2002 (Phase 2), and April 2005 (Phase 3); the chemical testing programs for these events are summarized in Table 1-1. Appendix C summarizes the bioassay results for Phase 3.

RETEC was the principle investigator for the October 2002 and April 2005 sampling events. Ecology was the lead investigator for the March 2002 sampling event; Ecology collected field-homogenized split samples and provided them to RETEC. RETEC worked closely with F|S in developing the scope, analyzing the data, and preparing documents for the April 2005 sampling event. Ecology re-sampled the March 2002 stations in July 2002, but chemistry results were not available; therefore, the July 2002 results are used for spatial analysis only and not for determining a site-specific TPAH cleanup level. The statistical methodology tools used to evaluate synoptic bioassay and chemistry data are outlined in Appendix D.

Previous physical, chemical, biological and radioisotope data packages sent to Ecology (RETEC, 2002; RETEC and F|S, 2003; RETEC 2004a, 2004b, 2004c) can be referenced for complete background information regarding datasets used in the RI/FS process for the GWSA.

2.1 Phase 3 Chemistry Results

A total of 19 stations were sampled for synoptic biological and chemical testing during Phase 3, in addition to one field duplicate, two reference samples, and two dilution samples, for a total count of 24 samples. Among the Phase 3 sample results, TPAH concentrations ranged from 0.55 to 176 mg/kg dw for 16 of 21 samples. The remaining three test samples (NLU51, NLU55, and NLU117) had TPAH concentrations between 1,064 and 4,826 mg/kg dw. Two samples were diluted with 50 percent reference material to generate sample concentrations in the middle range between 200 and 1,000 mg/kg dw TPAH (diluted samples NLUD55 and NLUD117). Sample results for these diluted samples were 301 and 170 mg/kg dw TPAH, respectively.

Most of the other semivolatile organic compounds (SVOCs) and organics were non-detect. The SVOCs detected above Ecology's draft freshwater screening levels (LAETs, Avocet/SAIC, 2003) were carbazole, dibenzofuran, and retene. Polychlorinated biphenyls (PCBs) were detected above the LAET

in one sample, NLU86-TX-0010. Phenols were detected at a frequency less than 5 percent and, therefore, were not carried forward in the analysis (USEPA, 1989). Reported detection limits for phthalates, benzoic acid, and 2-methylnaphthalene were occasionally above the LAETs, but resulting bioassay data will be used to override chemistry results with elevated reported detection limits (RDLs), as discussed with Ecology. Low percent total solids, ranging from 9 to 40 percent, likely contributed to elevated detection limits.

The SMS metals detected above LAETs (and detected in more than 5 percent of the samples) were arsenic, copper, lead, mercury, silver, zinc, and tributyltin (TBT). The highest detected concentrations for these metals were 360, 574, 810, 3, 1,490, and 2.3 mg/kg, respectively. All of these concentrations were measured in one sample, NLU86-TX-0010, located near the North Lake Union Shipyard on the far western side of the AOI. RDLs for arsenic were occasionally above the LAETs, but resulting bioassay data will be used to override chemistry results with elevated detection limits.

Total cyanide concentrations ranged from non-detect in about half the samples to detections ranging from 1.9 to 38 mg/kg. Total sulfide concentrations ranged from 90 to 3,600 mg/kg. Ammonia concentrations ranged from 23 to 76 mg-N/kg. Total organic carbon (TOC) ranged from 7 to 98 percent. Grain size results ranged from 10 to 75 percent fines (sum of silt and clay fractions) with a mean of 54 percent fines. Grain size fractions for the two reference samples were 35 and 70 percent fines for REF-1 (Quendall) and REF-2 (Webster Point), respectively.

Concentration ranges observed in Phase 3 surface sediment samples were consistent with concentrations detected in previous sampling events, except TOC concentration ranges were higher likely because sediment samples were collected closer to shore in Phase 3. Two stations re-sampled in 2005 (NLUEPA5 and NLUEPA19) had TPAH concentrations an order of magnitude lower than when they were originally sampled in 1995.

Grain size data were used to determine which test samples best matched one of two reference samples, for subsequent comparison to bioassay decision criteria. Field water quality parameters documented surface water conditions at the time of sampling. Salinity levels were low and not likely a contributing factor to bioassay tests (Appendix A).

2.2 Bioassay Results

Various combinations of sediment toxicity tests were conducted on the 57 surface sediment samples collected between 2000 and 2005. Each test location included a suite of one acute test (*Hyallea azteca* [*H. azteca*] 10-day mortality and *Chironomus tentans* [*C. tentans*] 10-day mortality), one chronic test (*H. azteca* 28-day growth and mortality and *C. tentans* 20-day growth and mortality), and/or Microtox® (100 percent porewater). Results are

summarized below and collectively presented in Tables 2-1 and 2-2 for percent mortality/growth endpoints and pass/fail endpoints, respectively. Bioassay results were compared to Ecology's draft freshwater decision criteria (Avocet/SAIC, 2003) to screen for biological SQSs and CSL failures (Table 2-3). A summary of 2005 laboratory bioassay results are provided in Appendix C. Pre-2005 bioassay results are presented in the GWSA Bioassay Report (RETEC, 2004b). The statistical tools used to determine the relationship between chemical concentrations and bioassay results are presented in Appendix D.

2.2.1 Phase 3 Bioassay Results

Phase 3 samples were tested for *H. azteca* 10-day mortality, *C. tentans* 20-day growth and mortality, and Microtox® toxicity endpoints. One sample, NLU41-TX-0010, located in an area with spatially similar TPAH concentrations, was not selected for biological testing based on Ecology consensus that the nearby sample NLU83-TX-0010 would be sufficient to represent the area. The two diluted samples (NLUD55 and NLUD117 [D = diluted]) were generated from site samples, mixed with 50 percent equally mixed material from the two reference stations, and analyzed for SVOCs and conventional and bioassay parameters. The total bioassay test count was 20 site samples plus two reference samples. The control and reference samples passed quality assurance criteria for all tests. A total of 16 out of 20 samples passed the *H. azteca* test, 17 out of 20 samples passed the *C. tentans* growth test, and 14 out of 20 samples passed the *C. tentans* mortality and Microtox® tests.

2.2.2 All Bioassay Results

Collectively, 199 of the 246 sediment bioassay data endpoints (or 117 of 136 endpoints excluding Microtox®) passed all of the bioassay decision criteria. Stated alternatively, 47 endpoints failed a bioassay screening decision criterion (Figures 2-1 and 2-2). A wide range of biological responses were observed among the test endpoints ranging from 0 to >98 average percent survival for the mortality tests; 0.1 to 2.7 mg ash-free dry weight (afdw) for the growth tests, and 39 to 100 percent light reading for the Microtox® test. These concentrations bracket a spectrum of biological responses ranging from biological passes (no significant biological effect), to SQS and CSL failures according to Ecology's draft freshwater decision criteria (Avocet/SAIC, 2003). The bioassay dataset is robust, providing a bioassay data point located approximately every 200 to 300 feet in the AOI to determine the spatial extent of biological effects and determine the AB. The concentration and effects gradients are adequate to develop a site-specific cleanup level for the GWSA.

2.3 Data Distributions

Chemical results were visually evaluated using histogram plots of concentrations versus frequency of occurrence with a normal curve fitted to the dataset. If the data distributions shown on the histograms had substantial outliers or showed a skewed distribution, then the data were log transformed. If the data distribution improved, then the log transformed dataset for a particular parameter was carried forward. Histograms of non-transformed and transformed data are compared in Appendix E for the parameters carried forward. Determinations of whether to proceed with log transformation were conducted by comparing histograms, scatterplots, and differences in correlations. Final determinations are summarized below; parameters not identified in the table below were carried forward using normal distributions.

Data Transformations

Dataset	Which parameters have non-normal distribution or outliers?	Which parameters should be log- transformed to improve distribution and to minimize outliers? *
Phase 3	TOC, cyanide, arsenic, lead, zinc, carbazole, dibenzofuran, PCBs	TOC, cyanide, lead, PCBs, TPAH
Phases 2 and 3 combined	TOC, arsenic, copper	TOC, TPAH

* After transformation, parameters were re-run in a correlation matrix to look for significant changes. Correlations were also viewed as scatterplots to assess the influence of outliers. TPAH was run both ways.

2.4 Relationship between Bioassays and Chemical/Physical Parameters

Several statistical tools were used to interpret relationships between biological, physical, and chemical parameters. The results are summarized as an initial exploration of the data and a secondary screening of the data. Initially, simple single-variable correlations were conducted using all parameters to determine if relationships exist between variables. After the initial exploratory step, secondary screening using regressions was conducted to address the strength of observed relationships.

The statistical analyses were designed to answer specific questions about the relationship between chemical concentrations and sediment bioassay results. Goals of these analyses:

- To reduce the number of chemical and physical variables that explain the observed bioassay results
- To remove stations or variables that confound the relationship between TPAH and bioassay results

- To determine which parameters explain most of the toxicity observed among bioassay results.

2.4.1 Initial Exploration

The statistical methodology, approach, and results of the initial exploration are presented in Appendix F. Appendix F describes the initial exploratory methodology, rationale for a smaller data subset, and results for statistical correlations. The initial explorations used pair-wise statistical correlations to explore physical, chemical, and biological relationships between samples and to identify key parameters, or variables, to use in the secondary screening with stepwise regressions. The initial screening was conducted on the combined Phases 2 and 3 dataset and then repeated for the Phase 3 only dataset as a verification tool, since the Phase 3 dataset included a larger suite of chemicals. The questions used to focus the initial explorations were:

1) Does TPAH correlate with other organic chemicals of concern in the GWSA (e.g., individual PAHs, carbazole, and dibenzofuran)? Can TPAH serve as a predictor variable for organics?

2) How are the various metals detected in the GWSA correlated? Can a subset of metals serve as predictor variables?

3) Which conventional parameters are potentially contributing to bioassay response?

The correlation analyses indicated that TPAH is significantly correlated with all detected organics (except PCBs) including individual PAHs, carbazole, and dibenzofuran. Therefore, TPAH was identified as a key parameter and surrogate for other organics to be carried forward in subsequent analyses. Although TPAH is carried forward as a surrogate for other organics, these chemicals are re-evaluated regarding spatial overlap in Section 5.4. TPAH was also significantly correlated with carbon-normalized TPAH (TPAH-oc). TPAH in mg/kg dw was carried forward instead of the TPAH-oc form because the TOC concentrations are fairly high, much higher than the Puget Sound average range (0.5 to 3 percent) used for carbon normalization (Michelsen, 1992). At high TOC levels, the equilibrium partitioning theory of sediment preferentially partitioning to the organic fraction of sediment becomes less clear, especially when the nature of carbon may be different across the area.

TPAH was significantly correlated with the Phase 3 bioassay tests (-0.632 to -0.787 correlation coefficient) providing confidence that a site-specific cleanup level can be derived using the *H. azteca* and *C. tentans* endpoints. TPAH was also correlated to Microtox® (-0.447) but the relationship was less significant, indicating that other parameters (i.e., metals) are likely

contributing to observed responses. These patterns were generally the same for the combined Phase 2 and 3 dataset.

Most of the metals correlated together, including TBT. Metals with lake-wide distributions or relatively low concentrations throughout the AOI (i.e., lead, mercury, and cadmium) were also correlated with TPAH or TPAH-oc. Chromium was also correlated with TPAH among the combined Phase 2 and 3 dataset. The metals carried forward to subsequent analyses were arsenic, chromium, copper, mercury, and zinc. Arsenic is a GWP-related chemical of interest (Parametrix, 1998); the other four metals correlated with bioassay results and are typically associated with shipyard/marina activities. The remaining metals are assumed to be represented by patterns observed among the five metals being carried forward. Lead and cadmium are excluded from further analysis because of lake-wide distributions; silver is not a chemical of concern in the GWSA. A summary of the parameters carried forward in the secondary screening is presented below.

Selected Parameters

Chemical Group	Which parameters will be carried forward for comparison with bioassay tests?*
Organics	TPAH
Metals	arsenic, chromium, copper, mercury, zinc
Conventionals	ammonia, sulfides, percent fines

* This model was tested in the regression analyses to ensure that no important variables were omitted (Appendix I). Chemical concentrations are independent variables and survival rates are dependent variables.

Build-up of ammonia or sulfides can act as confounding factors in bioassay results. Sulfides and ammonia did not clearly correlate with bioassay results. When water depth was entered into the analysis, it generally dominated the correlations; therefore, it was excluded from further analyses, as it is likely a correlative parameter and not a causative parameter (water depth reflects the steep TPAH gradient observed perpendicular to shore). Percent fines correlated with *H. azteca* and Microtox®, but it is also likely a correlative parameter with organic analytes. Exploratory regressions with a large number of independent predictor variables (the large suite of chemicals analyzed in Phase 3 [Appendix F]) were run to increase the confidence in the selected parameters carried forward to the secondary screening.

2.4.2 Secondary Screening – All Bioassay Data

At the conclusion of the initial exploration, the following parameters were carried forward into the stepwise regression: TPAH, arsenic, chromium, copper, mercury, zinc, percent fines, ammonia, and sulfides (independent variables); *H. azteca* percent mortality, Microtox®, *C. tentans* percent mortality, and *C. tentans* percent growth (dependent variables). The secondary screening, using multiple stepwise regressions, evaluates the relative contribution of each independent variable (e.g., TPAH and metals) to

the variability of response observed in the dependent variable (e.g., bioassay test result such as percent mortality). A combined Phase 2 and 3 dataset was carried forward in the analysis. Correlations from the smaller Phase 3 dataset (with a larger parameter list) generally matched the outcome of the larger dataset, providing confidence in the larger combined dataset. The approach and results of the secondary screening are presented in Appendix G.

The specific questions included in the secondary screening were:

1) Which chemical and physical parameters account for most of the variability observed among the bioassay test endpoint results?

2) Which bioassay tests can be reliably used to derive a site-specific TPAH cleanup level?

To answer these questions, stepwise regressions compare the relationship between independent and dependent variables and produce a model, a group of independent parameters that has the most predictive power for explaining variance among toxicity test endpoints. The model outputs are summarized in Table 2-4. While TPAH alone accounted for 50 to 60 percent of observed variability in the models for *H. azteca* and *C. tentans,* other parameters (copper, mercury, arsenic, chromium, and percent fines) were also included in the models. The percent of the bioassay variance accounted for by the regression models ranged from 58 to 73 percent for *H. azteca* and *C. tentans*. For Microtox®, only copper and mercury were included in the final regression model; they accounted for 30 percent of the variance.

Based on the multiple stepwise regression results for each bioassay test (Table 2-4), it appears that TPAH and metals contribute to the observed effects. To minimize the influence and contribution of metals effects, a cluster analysis was conducted on the bioassay dataset (Section 3.1) to identify chemically-similar groups of data. A smaller subset of chemically-similar data was re-run through the stepwise regression (Section 3.2) to increase the reliability of the model for TPAH and to determine which bioassay endpoints can be used to determine a TPAH cleanup level.

3 Spatial Distribution of Biological Responses

The stepwise regression results concluded that TPAH has the dominant relationship with *H. azteca* and *C. tentans* bioassay response among the test samples, but other chemicals, particularly metals, also correlated to observed toxicity (Section 2.4.2). Several areas within the AOI have mixtures of both organic and metal analyte groups. Analyses indicated that both groups of chemicals contribute to observed toxicity. To determine the particular strength of chemical mixtures (combinations of chemicals), a spatial cluster analysis was conducted as an exploratory tool to identify chemical outliers or clustered groups of stations with similar chemical mixtures.

A spatial pattern of apparent biological effects emerges from the collective suite of bioassay test results. Sediment samples with criteria failures were located in three specific areas: (1) the shipyard area to the west; (2) the nearshore area to the southwest, south and east of the GWP; and (3) the marina area to the northeast. The spatial groupings of data and determination of a site boundary were based on bioassay passes and chemical mixtures, as described below. Groupings of chemically-similar data were spatially refined into smaller sets of data groups, or clusters, based on a statistical cluster analysis. The stepwise regressions were re-run with clustered data to refine the relationship between bioassay effects and chemical concentrations.

Data groupings, regression re-runs, and extent of bioassay passes are described below, all with spatial considerations. The confidence analysis (Appendix I) discusses the certainty that a TPAH cleanup level addresses other GWP-related chemicals.

3.1 Groupings of Chemically Similar Data

Because the AOI has multiple sources and multiple chemicals contributing to observed toxicity, a spatial exploration of the dataset is appropriate by means of cluster analysis. The purpose for conducting the cluster analysis was two-fold:

1) To identify the area where TPAH occurs with limited or no influence from metals.

2) To identify the area where metals predominate, but TPAH is also present.

Identifying these areas will allow a TPAH-driven data subset to be used for determining the relationship between TPAH concentration and bioassay response (i.e., calculation of a TPAH cleanup level). Cluster analysis is a multivariate tool that examines the relationships between sets

of variables and identifies groups or clusters of chemically similar stations. Cluster analysis methodology is described in Appendix D. Multivariate statistical techniques are well established for use in ecological assessments and are also used for ecotoxicological assessments (Sparks et al., 1999). These techniques are typically used to identify underlying patterns or confirm observations based on existing data.

The use of clustering methods has precedent in the MTCA and SMS (Washington Administrative Code [WAC] 173-204-510) process. Ecology uses clusters or groups of stations that are spatially and chemically similar and may be associated with similar sources to identify sediment areas of potential concern (Ecology, 1991). Ecology guidance states:

> To be useful for the ultimate purposes of site identification and cleanup, the sediments within a station cluster should have a similar type of chemical contamination and should be associated with the same source or sources of contamination. (Ecology, 1991)

The combined Phase 2 and 3 dataset was clustered into chemically similar groups using a hierarchical cluster analysis (square Euclidean distance, between-groups linkage, and z-scores). Only chemical parameters (not bioassay results) were included in the cluster analysis: TPAH, dibenzofuran, arsenic, copper, chromium, mercury, zinc, ammonia, and sulfides. The spatial similarity was determined afterward by plotting the stations on a map, which showed the spatial distribution between the stations (Figure 3-1). Results are summarized below and in detail in Appendix F.

Chemical Cluster Analysis

Cluster	Spatial Area	Which stations were included in a cluster?	Were stations included in a shipyard/marina cluster?
Chemical Outlier	West	NLU86	Yes
Chemical Outlier	East	NLU51[1]	No
Cluster 1	Shipyard	NLU14, NLU15, NLU16, NLU17	Yes
Cluster 2	East	NLU05 and NLU55[1]	No
Cluster 3	Offshore Western Study Area	LU-3, LU-4, LU-8, NLU13, and NLU87	Yes
Cluster 4	Eastern Study Area	Remaining Samples	No

[1] The sample is a chemical outlier because the TPAH concentration was three to four times higher than the likely next highest sample concentration.

The Shipyard/Marina Cluster includes NLU86, NLU13-NLU17, LU3, LU4, LU8, NLU87 (Clusters 1 and 3 and chemical outlier NLU86), plus NLU01, NLU02 and NLU82 from the northeast based on elevated metal concentrations and spatial proximity to each other. The remaining samples are considered the GWSA cluster, dominated by organic constituents. Although samples NLU01, NLU02 and NLU82, located in the northeast

marina area, did not cluster into a separate group using SPSS software, these three stations form a distinct chemical cluster with similar biological responses, patterns of chemical concentrations, and proximity to non-GWP upland and over-water sources. For example, TBT, in concentrations typically associated with shipyards and marinas, was higher in this area relative to GWP-related sediments.

The chemical differences between the GWSA and Shipyard/Marina clusters are further illustrated in Figure 3-2. This boxplot contrasts the two clusters using the principal metals and TPAH. The metals distributions are notably different between the clusters, reinforcing the spatial distribution that emerges from the hierarchical cluster analysis.

3.1.1 Metals Influence

The extent of metals (e.g., arsenic, copper, lead, and zinc) and other non-GWP contaminants can generally be distinguished from areas impacted by GWP-related PAHs. In some cases, the distribution of non-PAH contaminants indicates a specific source; in other cases, impacts are widespread or the distribution complex, rendering the identification of specific non-GWP sources more difficult (e.g., mercury).

One example of impacts associated with a specific source, or sources, is the area of elevated metals concentrations in the vicinity of the former and existing shipyard west of GWP (Figure 3-1). The shipyard area of elevated metals and other contaminants (e.g., PCBs) forms a shipyard-related cluster.

In addition, elevated TBT bulk sediment concentrations were associated with the shipyard area (maximum concentration of 10.7 mg/kg TBT) and northeastern marina area (maximum detected concentration of 0.85 mg/kg TBT) areas. TBT concentrations were detected in surface sediment porewater in three of the six samples analyzed, and may be associated with toxicity observed in samples from NLU82, NLU86, and NLU87. But toxicity was also observed in sample NLU13-TX in which TBT porewater was non-detect. The porewater bioaccumulation trigger level for TBT-porewater is 0.15 µg/L previously established by regulatory agencies (USEPA, 1999). Porewater samples from station NLU86 were above this trigger level. TBT in either porewater or sediment may be a good indicator, along with other metals, of other non-GWP sources likely contributing to observed toxicity.

3.1.2 Confidence in Cluster Groups

To assess the influence of outliers in the statistical analyses described above, the regressions were re-run with the two dominant chemical outliers (NLU86 and NLU51) removed. The components and subset of parameters that account for observed toxicity did not change; however, the extent of correlation, or R-squared level, did change (Appendix I). Instead of removing outliers, the

statistical analyses were conducted on log-transformed data, when appropriate, to minimize the influence of outliers on observed relationships. The cluster analyses were also re-run using all surface sediment chemistry data in the AOI (Appendix I). Results were consistent with the groups identified above; the shipyard cluster is clearly defined.

To remove the influence of metals, metal outliers (NLU86) and metal-related clusters (the Shipyard Cluster and the Marina Cluster), were eliminated before deriving a cleanup level for TPAH. Stations primarily influenced by metals were removed from the derivation of the TPAH cleanup levels to create a data subset with a stronger relationship between TPAH and bioassay response. Specifically, stations NLU86, NLU14, NLU15, NLU16, NLU17, NLU01, NLU02, and NLU82 (primarily influenced by metals and TBT), were removed from the dataset designed to derive a site-specific TPAH cleanup level (Section 4).

3.2 Secondary Re-Screening – GWSA Cluster Dataset

At the conclusion of the secondary screening with all Phase 2 and 3 bioassay data (Section 2.4.2), the chemical and physical parameters included in the regression models for predicting toxicity were TPAH, arsenic, copper, mercury, chromium, and percent fines. To improve the predictive power of the models, minimize the amount of variance observed among the dependent variables (bioassay results), and minimize the contributions by elevated metals concentrations, the GWSA TPAH-cluster dataset was used and re-run through the stepwise regressions. This model re-run excluded stations from the Shipyard/Marina Cluster. The independent variables carried forward into the stepwise regression included: TPAH, arsenic, chromium, copper, mercury, zinc, percent fines, ammonia, and sulfides. The specific questions addressed in the secondary screening included:

1) Which chemical and physical parameters account for most of the variability observed among the bioassay tests?

2) Which bioassay tests can be reliably used to derive a site-specific TPAH cleanup level?

Multiple stepwise regressions were used to answer the questions stated above. This method evaluates the relative contribution of each independent variable (e.g., TPAH and metals) to the variability of response observed in the dependent variable (e.g., bioassay test result such as percent mortality). The parameters accounting for most of the observed variance among toxicity test endpoints are summarized in the table below and in Table 2-4. The statistical methodology, approach, and results of the secondary screening, including stepwise regressions, are presented in Appendix G.

Parameters Explaining Toxicity (GWSA TPAH-Cluster Dataset)

Bioassay Test Endpoint	Which parameters have the most predictive power for observed toxicity? **	What percent of the variance is accounted for by the model?
H. azteca 10-day mortality	TPAH, arsenic*	71 percent
C. tentans 20-day mortality	TPAH, mercury*	86 percent
C. tentans 20-day growth	chromium, zinc	73 percent
Microtox®	chromium	24 percent

** The parameters listed are the variables included in the model, in order of decreasing importance.
* TPAH alone accounts for 60 to 80 percent of observed variability.

Conclusions from the multiple stepwise regression results for each bioassay test include:

- ***Hyalella azteca* 10-day Mortality –** *H. azteca* bioassay results are significantly correlated with TPAH. TPAH was the most predictive single variable explaining 63% of the observed variance. Results can be used to derive the TPAH cleanup level, but outliers should be examined for potential influence of metals.

- ***Chironomus tentans* 20-day Mortality –** *C. tentans* bioassay results are significantly correlated with TPAH. TPAH was the most predictive single variable explaining 82% of observed variance. Results can be used to derive the TPAH cleanup level but outliers should be examined for potential influence of metals.

- ***Chironomus tentans* 20-day Growth –** *C. tentans* growth results are not correlated with TPAH. TPAH was not retained in the predictive model that explains the variance observed among these bioassay results. Results should not be used to derive the TPAH cleanup level.

- ***Microtox® Porewater Luminescence –*** The Microtox® results are not correlated to TPAH. TPAH was not retained in the predictive model that explains variance observed among bioassay results. Because Microtox® is not significantly correlated to TPAH results it should not be used to derive a TPAH cleanup level.

Bioassay Endpoints for Deriving TPAH Cleanup Levels

Bioassay Test	Can this test be used to generate a site-specific TPAH cleanup level?	Which single parameter explains most of observed variance?
H. azteca 10-day mortality	Yes	TPAH
C. tentans 20-day mortality	Yes	TPAH
C. tentans 20-day growth	No	chromium
Microtox®	No	chromium*

*The R-squared value for this parameter is low indicating a limited correlation. No other parameters were included in the model.

3.3 Extent of Bioassay Passes

The approach to developing the AB was based on identifying a band of bioassay passes around GWP. A bioassay pass was determined by comparing toxicity results to Ecology's draft freshwater decision criteria. Following SMS guidance, this bioassay approach overrides chemical concentrations as it accounts for chemical interactions, chemical exposure, and bioavailability. In accordance with SMS, benthic sediment toxicity tests are considered by Ecology as acceptable indicator endpoints designed to be protective of aquatic sediments.

A "band" of bioassay passes emerges from the dataset, wrapping around the prow of GWP. Towards the western edge of the AOI boundary, the ability to establish a "band" of bioassay passes is affected by chemicals presumably related to Shipyard sources. Figure 3-3 graphically shows the extent of bioassay passes spatially across the area. The area of passes starts at station NLU76 (to the northeast) then wraps around GWP and ends, with confidence, near station NLU85-TX. The bioassay pass area may extend further west to station NLU14, but the area is uncertain due to the presence of metals, TPAH, and other chemicals.

Northeastern Extent. Bioassay samples collected from stations NLU76, NLU72, and NLU81 clearly represent a band of bioassay passes separating the GWSA from the marina and other potential influences farther to the northeast. Although the marina area did not form a separate cluster (in SPSS multivariate analysis), the "band" of bioassay passes clearly delineates the boundary. In addition, the three-sample cluster of bioassay failures to the northeast (NLU01, NLU02, and NLU82) show decreasing effects further away from shore (the two outermost samples of this cluster only have SQS failures) suggesting a non-GWP uplands or nearshore source near or northeast of the marina.

Western Extent. The western extent of bioassay passes is more complex due to the combined effects of shipyard metals and organics on toxicity. However, the western shipyard area is clearly a separate cluster due to the co-occurrence and dominance of metals (SPSS multivariate analysis). Several clustering methods were used in various combinations. The boundaries of the group sometimes varied, but the four-station or five-station cluster of NLU14,

NLU15, NLU16, and NLU17, plus NLU86, were significantly grouped together (Shipyard Cluster). Each sample from these stations had at least three to five metal exceedances of the draft freshwater chemical screening criteria; in addition, these stations had TPAH concentrations ranging from 66 to 383 mg/kg dw. An additional cluster of stations (LU3, LU4, NLU13, and NLU87) also reflected a mix of chemicals including lower concentrations of TPAH and metals. These two clusters collectively define the western extent of the AB (see Section 5.3).

4 Determination of TPAH Effects Concentrations

Currently, there are no freshwater sediment criteria promulgated under MTCA. Sediment cleanup standards under MTCA are regulated by the SMS, which were promulgated under WAC Chapter 173-204. The SMS sets SQSs, source control standards, and sediment cleanup standards to be applied in remedial actions. While the SMS provide numeric analytical and biological criteria for the evaluation of marine sediments, the freshwater sediment quality standards have been reserved pending development of criteria specific to the protection of freshwater biota (WAC 173-340). Thus, freshwater sediment criteria methods and procedures are developed on a site-specific basis necessary to meet the intent of the SMS.

The GWSA project team developed site-specific cleanup levels based on sediment bioassay results collected from the AOI. Site-specific cleanup levels were developed using two approaches:

1) **Ranking Approach –** Similar to the AET approach currently used by Ecology to establish sediment quality levels protective of benthic receptors

2) **Concentration-Response Curves –** Commonly used to establish effect concentrations based on biological response results.

To conform to state standards and the intent of SMS, the GWSA-specific sediment cleanup levels were developed following the ranking approach (Ecology, 1997; Avocet/SAIC, 2003) to the extent practicable, in accordance with SMS and MTCA (WAC 173-340-7493). A compilation of Phase 2 and 3 synoptic bioassay and chemistry results was used to derive the effect concentrations for NOEC and LOEC for TPAHs. Concentration-response curves plotting TPAH versus percent mortality/growth were used to confirm the findings from the ranking method. Each of these approaches is described below. Ranking results using all presented bioassay data are in Table 4-1; ranking results, excluding the Shipyard/Marina Cluster, are presented in Table 4-2. Results of the concentration-response approach are summarized in Table 4-3.

4.1 Background to Ranking Approach

The AET development process for Washington State uses three simple categories: Significant Adverse Effect or Hit, No Significant Adverse Effects or No Hit, and statistically inconclusive sample. Only the first two categories are used to calculate AETs for Washington State. In addition, Washington State establishes AETs for a selected subset of individual PAHs and then sums the individual AETs to derive low molecular weight PAH (LPAH) and high

molecular weight PAH (HPAH) AETs. To distinguish this site-specific cleanup level development process from the SMS-AET approach, the terms LOEC and NOEC will be used instead, but the intent is the same. Previous evaluations of the GWSA chemical data showed minimal differences between the number of LPAH, HPAH, and TPAH chemical exceedances. Therefore, the cleanup level determination process was simplified to TPAH. The regulatory background for the effects-based approaches and their uses in various programs are described below:

- **Model Toxics Control Act.** Although MTCA defers sediment cleanup specifics to SMS, it sets precedent under terrestrial ecological evaluation procedures (WAC 173-340-7490) for the determination of effects-based cleanup levels. In subsection 173-340-7493(2)(iv) under toxicological assessment, it specifies identification of significant adverse effects in the receptors of concern that may result from the COCs based on information from the toxicological literature. Under subsection 173-340-7493(4)(a) regarding literature surveys, it specifies that toxicity reference levels from the literature shall represent the lowest relevant LOEL found in the literature, and should preferably be based on chronic exposure.

- **Sediment Management Standards.** Regional sediment quality guidelines were developed based upon observed effects thresholds. USEPA Region 10 led the development of the AETs as part of the Commencement Bay Superfund Program. SMS explicitly uses AET methodology in setting marine sediment cleanup levels for Washington State. The direct implication of the AET methodology is that the standards are set using the NOEC. The AET methodology may explicitly incorporate observed effects, depending upon the reliability of the observed effect. The resultant LAET, 2LAET, and the High Apparent Effect Thresholds (HAET) have been the basis for several regulatory program guidelines within the region, including setting sediment cleanup levels in Washington (SMS), Oregon, and Alaska, and the standards for dredged sediment testing in Puget Sound, the Lower Columbia River, and for the Snake River reservoirs in Idaho (USACE and USEPA, 2002). AETs are defined as:

  > …the concentrations of specific-chemicals of concern (COC) in sediment above which a significant adverse biological effect always occurs. All synoptic samples that do not exhibit significant adverse effects, "No Hit" samples, are ranked from highest to lowest concentration for a COC. The "No Hit" sample with the highest concentration is identified as the AET. A rare exception is made when a sample is found to be chemically anomalous (i.e., three times higher than the next

> highest "No Hit"), then the sample with the next highest concentrations sets the AET. (Gries and Waldow, 1996)

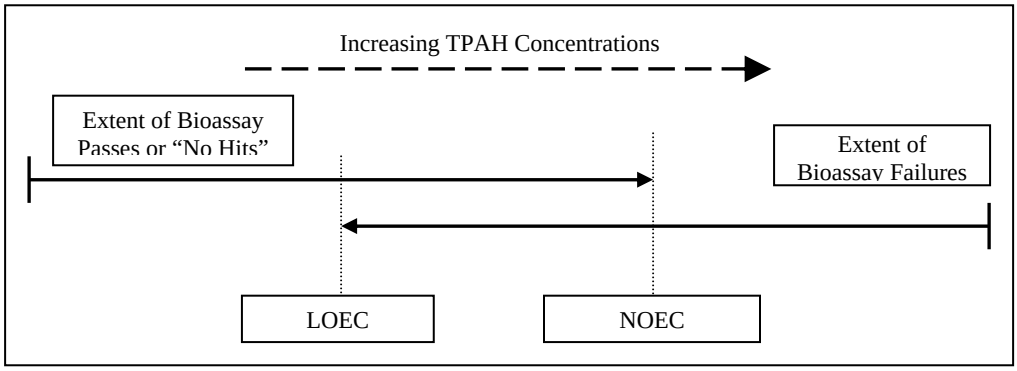
According to Ecology (Gries and Waldow, 1996), the AET is set using the highest no-hit sample, or NOEC level, which means that some samples may have significant biological failures below this NOEC concentration. Biological effects may be observed in sediments below an AET for a given chemical, and this effect may be caused by other chemicals that co-occur with the chemical of interest or other confounding factors (Ecology, 1997). Therefore, an AET value demarcates the upper boundary of a chemical concentration that may be tolerated by a given organism.

Application of an AET approach to a particular study area may require additional site-specific knowledge of physical conditions, chemical signatures, chemical mixtures, and potential sources to determine the potential influence of these factors on observed effects.

- **Ecology-Proposed Freshwater Sediment Criteria.** Avocet/SAIC (2003) recommended freshwater sediment quality values based on an AET approach. This document built upon a 1997 Ecology document (Ecology, 1997) with a more robust data analysis. Alternative methods were also evaluated including a floating percentile method; a fixed-percentile method; and a sum of individual PAHs versus molecular sum of PAHs, consistent with narcosis theory. The document recognized that AETs are highly efficient, but not the most sensitive method for predicting biological response. The lack of sensitivity in the use of this analysis may be attributed to large datasets with multiple chemical sources.

- **Other Programs.** Two effects-based sediment quality value (SQV) levels have been developed by numerous North American programs for the protection of freshwater sediments, as reviewed in the *Draft Freshwater Sediment Quality Levels Phase 1 Report* (SAIC and Avocet, 2002). An example is the Ontario Ministry of Environment (OMOE), which developed regional SQVs in 1993 based on the co-occurrence of benthic infauna (OMOE, 1993). The guidelines established two SQV levels: the Lowest Observed Effect Level (LOEL) and the Severe Effect Level (SEL).

The effects-based concentrations used in this document (following an AET-like approach) are illustrated here.



4.2 Ranking GWSA Data

When GWSA bioassay data were collectively arrayed by increasing TPAH concentration (Table 4-2), the NOEC (excluding the Shipyard/Marina Cluster) for bioassay tests ranged from 219 to greater than 1150 mg/kg dw TPAH. The LOEC (excluding the Shipyard/Marina Cluster) for bioassay tests ranged from 170 to 1150 mg/kg dw TPAH. The NOEC level represented the highest "No Hit" level observed among a bioassay suite (Table 4-2). Consistent with SMS guidance for a given test, if the highest NOEC was more than three times higher than the next highest NOEC concentration, then it was considered an outlier, then the next highest NOEC concentration was used as the NOEC (e.g., 301 versus 1096 mg/kg dw TPAH for *C. tentans* 20-day growth).

The LOEC (excluding the Shipyard/Marina Cluster) for bioassay tests ranged from 170 to 1150 mg/kg dw TPAH. The LOEC level represented the lowest concentration where a significant "hit" was observed among a bioassay test suite (Table 4-2). For Microtox®, the sample from station LU7 had significant adverse effects below the LOECs listed above, but the corresponding TPAH concentration was less than one-third the next closest TPAH concentration with an effect (LOEC); therefore, it is an outlier according to SMS. Ranking results showing all data are presented in Table 4-1 for comparison.

The effect concentrations for TPAH are relatively similar and consistent. Bioassay test organisms have different sensitivities to environmental chemicals, but the TPAH cleanup levels can be used with confidence based on the similarity of responses over a period of three years during different seasons using different species and different measurement endpoints. A summary of the LOEC and NOEC levels for the GWSA bioassay test endpoints are summarized below and detailed in Table 4-2.

TPAH Ranking Approach

GWSA bioassay endpoint (Phase 2 and 3 Datasets)	Sample Size	At what TPAH concentrations (mg/kg dw) do adverse biological effects occur?**	
		NOEC	LOEC
H. azteca 10-day mortality	49	1150	170
C. tentans 20-day mortality	38	219	170
C. tentans 20-day growth	37	301	1064
C. tentans 10-day mortality*	17	>1150*	>383
H. azteca 28-day mortality*	10	529*	1150
The Second Lowest NOEC		301	
The Lowest NOEC		219	
The Lowest LOEC			170

* Shown for reference but not used in the analysis; too few samples to array with TPAH concentrations. Concentrations shown in mg/kg dw.

** Excluding outlier stations with metals influences (NLU13-TX, NLU14, NLU86, NLU15, NLU13, NLU16, NLU17, NLU87, LU3, LU4, LU5; NLU01, NLU02 and NLU82).

Because this site-specific bioassay dataset does not contain hundreds of samples and endpoints, as was used to derive AETs for Washington State, the "no hit" or NOEC approach was expanded to include other effects-based concentrations, such as the LOEC. The combined use of a LOEC and NOEC level for GWSA brackets the uncertainties around effects resulting from chemical mixtures, spatial distributions of effects, and increases confidence in protecting long-term sediment quality.

4.3 Concentration-Response Relationship

The *H. azteca* and *C. tentans* acute and chronic mortality results, respectively, were used to derive a range of lethal concentrations (LC) and sublethal effect concentrations (EC), for a specified percentage of the population. For example, the lethal concentration for 20 percent of the population (LC20) is the TPAH concentration measured in sediment that is likely to produce an adverse biological response in 20 percent of the benthic population. Three percentile concentrations were generated for each bioassay endpoint:

- **LC15 or EC15,** similar to the SQS decision criteria
- **LC20 or EC20,** commonly used endpoint to predict biological effects
- **LC25 or EC25,** similar to the CSL decision criteria.

Toxicological benchmarks are typically established at 20 percent effects levels, as that is the lowest level for ecological effects that can reliably be detected in the field (Suter et al., 1993). The predominant percentile used in this document is the EC20/LC20 with the 15 and 25 percentiles shown to bracket the values. These percentiles were used to support the NOEC/LOEC values.

In a concentration-response relationship, the concentration represents actual benthic exposure measured in the test media. Response of the biological performance of a test organism is measured as percent mortality or percent growth at the end of a test period. The relationships between concentration and response were plotted with the logarithmic concentration on the x-axis and percent response on the y-axis. The response data were normalized to the control or the reference sample, as shown in Appendix H. Results are summarized in the table below.

TPAH Concentration-Response Effect Levels

GWSA Bioassay Endpoint (GWSA Cluster Dataset)	Sample Size	At what TPAH concentrations (mg/kg dw) do effects occur?		
		LC15/ EC15	LC20 / EC20	LC25 / EC25
H. azteca 10-day mortality *	49	220	310	440
C. tentans 20-day mortality *	38	270	395	500
Lowest LC15		220		
Lowest LC20			310	
Lowest LC25				440

* Normalized to control mortality or growth ratio of control

The draft Ecology freshwater decision criteria uses the effect thresholds of 15 percent difference and 25 percent difference from either the reference or control samples for evaluating bioassay test results. The lowest LC15 observed among the site-specific bioassay tests (excluding the Shipyard/Marina Cluster) was 220 mg/kg dw TPAH (Table 4-3). The lowest LC20 and LC25 levels observed among the site-specific bioassay tests (excluding the Shipyard/Marina Cluster) were 310 and 440 mg/kg dw TPAH, respectively.

4.4 Sensitivity Analysis

Sensitivity is the ability of sediment cleanup levels to predict biological effects. To test this predictive ability, the Phase 3 dataset was compared to the lowest LOEC value (170 mg/kg dw) derived by a combined dataset (Phase 2 and 3 data). The LOEC value is the same whether the entire combined bioassay dataset or the GWSA TPAH-cluster dataset is used. Therefore, the larger dataset (Table 4-1) was used in the analysis.

Sensitivity is measured as the ratio of samples correctly predicted as impacted compared to the number of samples actually impacted. Sensitivity increases as Type II errors (e.g., false negatives and undetected effects) decrease. Efficiency, on the other hand, is the ratio of the number of samples where impacts were correctly predicted to the total number of samples predicted to be impacted. Efficiency increases as Type I errors (e.g., false positives) decrease.

Sensitivity Analysis

Type I or Type II Error *	Bioassay Endpoint (at 170 mg/kg dw TPAH)		
	H. azteca 10-day mortality	*C. tentans* 20-day mortality	*C. tentans* 20-day growth
Sensitivity (# of correctly predicted/ # of impacted)	$\frac{4}{4}$ = 100%	$\frac{0}{2}$ = 0% **	$\frac{2}{3}$ = 67%
Efficiency (# of correctly predicted/ # of predicted)	$\frac{18}{20}$ = 80%	$\frac{19}{20}$ = 90%	$\frac{15}{20}$ = 75%

* Analysis conducted on Phase 3 subset of data

** Bioassay impacts observed in Western Study Area with chemical mixtures.

Using this analysis, a TPAH cleanup level of 170 mg/kg dw is expected to correctly predict a bioassay response at least 75 percent of the time for the GWSA. While this analysis was conducted on a subset of the combined dataset used to derive these site-specific values (the Phase 3 data), it is an appropriate tool to double-check the predictive ability of the TPAH cleanup levels. Sensitivity for this study is better than the freshwater AET sensitivities proposed for Washington State, which ranged between 45 and 65 percent. Efficiency is about the same as the freshwater AET efficiencies, which ranged from 87 to 93 percent (Avocet/SAIC, 2003).

In addition, the bioassay responses were collectively arrayed as percent of no response relative to TPAH concentrations (Figure 4-1 and Table 4-4). A cleanup level of 170 mg/kg dw TPAH has about 66 percent probability of predicting bioassay passes. A concentration of 290 mg/kg dw TPAH has about 77 percent probability of predicting bioassay passes.

5 Findings

This section provides the findings for the GWSA cleanup standard.

5.1 Delineation of Bioassay Passes

Collectively, 47 of 246 benthic bioassay data endpoints (or 19 of 136 endpoints excluding Microtox®) result in a significant bioassay failure according to Ecology's proposed freshwater sediment bioassay decision criteria. Nineteen percent of the data points had adverse biological effects, and most of these effects were observed fairly close to shore and co-located with elevated TPAH concentrations or among stations with metals and TPAH. These chemical mixtures were particularly evident near the shipyard and marina areas.

The range and distribution of bioassay results show, with confidence, that the extent of adverse biological effects related to GWP chemicals are well within the AOI. The offshore area of bioassay passes is relatively flat bathymetrically and has accumulations of soft sediment with relatively low TPAH concentrations.

The area of bioassay passes for the GWSA is presented on Figure 3-3. It is a point-to-point boundary of bioassay passes wrapping around the prow of GWP. This boundary excludes the northeastern marina area (NLU01, NLU02, and NLU82) based on bioassay passes closer to GWP. This area of passes also excludes the Shipyard Cluster (see Section 3.1) located to the west and along the western margin of the Western Study Area. A robust set of bioassay results were used to delineate this area: from four sampling events (collected in 2000, March 2002, October 2002, and April 2005) and 55 samples, using seven bioassay endpoints and three species, including Microtox®.

5.2 TPAH Cleanup Level Determination

Based on the range of observed effects, two site-specific TPAH sediment cleanup levels, similar to the SMS SQS and CSL levels, were determined for the GSWA. The range of observed TPAH effects includes the GWSA Cluster; stations from the Shipyard/Marina Cluster, associated with elevated metals concentrations, were excluded from the analysis. The criteria used to derive these site-specific cleanup levels are described below.

The SCSL for the GWSA is 290 mg/kg dw TPAH. This level was derived based on the following measurement and assessment endpoints:

- The second lowest NOEC level among bioassay test endpoints collectively (301 mg/kg dw TPAH).

- The lowest LC20 level among the bioassay endpoints (*H. azteca* 10-day mortality of 310 mg/kg dw TPAH).

- The lower 95% confidence-like interval around the LC25 level for *C. tentans* 20-day mortality is 290 mg/kg dw TPAH.

The SSQL for the GWSA is 170 mg/kg dw TPAH. This level was derived based on the following measurement and assessment endpoints:

- The LOEC level for the *H. azteca* 10-day mortality endpoint (170 mg/kg dw TPAH)

- The LOEC level for the *C. tentans* 20-day mortality endpoint (170 mg/kg dw TPAH)

- The lowest NOEC level among bioassay test endpoints collectively (219 mg/kg dw TPAH)

- The lowest LC15 level among the bioassay endpoints (*H. azteca* 10-day mortality, 220 mg/kg dw TPAH).

Based upon the results described below, a biological response, or indication of sediment toxicity, below a range of 170 to 290 mg/kg dw TPAH is unlikely. The TPAH contours associated with the SSQL and SCSL are shown on Figure 5-1. These levels will be carried forward through the RI/FS process and used to evaluate appropriate sediment remedial actions.

5.3 Area Boundary and Point of Compliance

The extent of bioassay passes described above confirms that the AOI boundary developed in 2004 (RETEC and F|S, 2004) extends beyond the region of GWP surface sediment impacts. The presence of bioassay passes within the AOI allows the area boundary where remedial actions will be evaluated to be refined and drawn closer to shore. The bioassay-refined boundary is referred to as AB, shown on Figure 5-2.

The AB is based on the distribution of bioassay passes wrapping around the prow of GWP and refined by the extent of surface sediment TPAH concentrations exceeding the SSQL. The AB encompasses bioassay failures associated with GWP sources. Bioassay effects associated with non-GWP or possibly commingled sources are located to the west and northeast. The western AB extends to the western shipyard area, or Shipyard Cluster (stations NLU13-TX, NLU13 through NLU17, NLU86, NLU87, LU-3, LU-4, and LU-8), an area with a chemical mixture predominated by metals. At the western perimeter of the AB, an area of overlap between TPAH and metals from the Shipyard occurs. Discussions concerning this area will occur prior to submittal of the Western Study Area RI/FS document. The eastern AB

borders the northeast marina area, or Marina Cluster (stations NLU01, NLU02, and NLU82), which is separated from the GWSA by bioassay passes. Excluding the bioassay test stations in areas to the west and northeast where non-GWP or possible commingled sources impact sediments, 22 of the 30 bioassay test stations passed all bioassay decision criteria. The band of 22 bioassay passes occurs about 150 to 900 feet offshore from the GWP shoreline (Figure 5-3).

The AB is defined as the maximum area of responsibility associated with the cleanup of GWP-related sediments. Any bioassay failures occurring outside of the AB will not be addressed in GWSA feasibility studies and subsequent remedial actions, as they are caused by other point or non-point sources to Lake Union. An exception to this is the western perimeter of the AB where possible GWP and non-GWP sources commingle. The western perimeter of bioassay failures and passes will be further discussed in the Western Study Area RI/FS process prior to submittal of the Western Study Area RI/FS document.

The AB does not define the footprint, or extent, of planned remedial actions. Remedial actions will occur within the AB based on factors such as remedial action levels, natural recovery processes, sediment stability, and other physical conditions; thus, the AB defines the areas for which remedial actions will be evaluated.

5.4 Confidence Analysis

A confidence analysis was conducted to evaluate the reliability of the site-specific TPAH cleanup level(s) and the AB where the levels will be applied.

The confidence analysis is presented in Appendix I; the findings from this analysis are summarized below:

- A site-specific TPAH cleanup level(s) is a reliable indicator for other GWP-related chemicals of potential concern (COPCs). A spatial overlap analysis was conducted to ensure that the TPAH cleanup level and AB encompass other COPCs that were detected above Ecology's proposed freshwater chemical screening criteria. The exception to these findings is the western perimeter of the AB, which will be further discussed in the Western Study Area RI/FS process.

- The sediment bioassay results yielded similar responses across a suite of bioassay tests, study events, and TPAH concentrations thereby confirming the predictive ability of the concentration-response relationships for TPAH.

- The statistical evaluations were checked by re-running the correlations, regressions, and cluster analysis with either transformed variables or subsets of variables to confirm the predictive abilities of the models. This analysis showed that the strength of the TPAH–bioassay response relationship improved when the Shipyard/Marina Cluster Stations (i.e., metals effects) were removed from the analysis.

The results of this three-tiered confidence analysis confirmed the reliability of the site-specific TPAH cleanup level(s) and the GWSA boundary (AB) where the level will be applied.

6 Conclusions

Detailed analysis of these synoptic sediment physical, chemical and bioassay datasets support the following:

1) The dataset is robust compared to the number of bioassay samples and breadth of acute and chronic bioassay endpoints used to derive cleanup standards for other MTCA sediment sites.

2) The bioassay passes associated with GWP-related chemicals fall well within the AOI boundary.

3) Statistical analysis shows that GWP-related TPAH is an appropriate basis for determining a cleanup level that is protective of other GWP associated chemicals.

4) The bioassay passes associated with GWP sources result in a clear boundary of passes close to the shore to the east and south of GWP.

5) Closer analysis identified chemically-similar groups of stations. An area with a mixture of metals and TPAH, called the Shipyard/Marina Cluster, was removed from the cleanup level derivation to improve the relationship between bioassay effects and TPAH concentrations.

6) The bioassay results and statistical analyses support an SCSL for TPAH of 290 mg/kg dw and an SSQL for TPAH of 170 mg/kg dw.

7) Bioassay passes combined with the SSQL define the AB shown on Figure 5-2; note that the area with a mixture of TPAH and metals will be further discussed in the Western Study Area RI/FS process prior to submittal of the Western Study Area RI/FS document .

In summary the SCSL and SSQL, in combination with the AB, represent the cleanup standard for the Eastern and Western Study Area RI/FSs and subsequent remedial actions.

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Table 1-1 GWSA Chemistry and Conventionals Associated with Bioassay Samples

Sampling Event	Station	TOC	Ammonia	Total Sulfide	Porewater pH*	SMS Metals	PAHs/ SVOCs	PCBs / TBT	% Fines
March 2000	527	√	√	√		√	√		√
March, July 2002 (Phase 2)	LU-1	√	√	√		√	√		√
	LU-2	√	√	√		√	√		√
	LU-3	√	√	√		√	√		√
	LU-4	√	√	√		√	√		√
	LU-5	√	√	√		√	√		√
	LU-6	√	√	√		√	√		√
	LU-7	√	√	√		√	√		√
	LU-8	√	√	√		√	√		√
	LU-9	√	√	√		√	√		√
	LU-10	√	√	√		√	√		√
	LU-11	√	√	√		√	√		√
October 2002 (Phase 2)	NLU01	√	√	√		√	√	√	√
	NLU02	√	√	√		√	√		√
	NLU04	√	√	√		√	√	√	√
	NLU05	√	√	√		√	√		√
	NLU06	√	√	√		√	√	√	√
	NLU07	√	√	√		√	√		√
	NLU08	√	√	√		√	√		√
	NLU10	√	√	√		√	√	√	√
	NLU12	√	√	√		√	√	√	√
	NLU13	√	√	√		√	√		√
	NLU14	√	√	√		√	√		√
	NLU15	√	√	√		√	√		√
	NLU16	√	√	√		√	√		√
	NLU17	√	√	√		√	√	√	√
April 2005 (Phase 3)	NLU13	√	√	√	√	√	√	√	√
	NLU51	√	√	√	√	√	√	√	√
	NLU55	√	√	√	√	√	√	√	√
	NLUD55	√	√	√			√		√
	NLU64	√	√	√	√	√	√	√	√
	NLU66	√	√	√	√	√	√	√	√
	NLU69	√	√	√	√	√	√	√	√
	NLU73	√	√	√	√	√	√	√	√
	NLU76	√	√	√	√	√	√	√	√
	NLU81	√	√	√	√	√	√	√	√
	NLU82	√	√	√	√	√	√	√	√
	NLU83	√	√	√	√	√	√	√	√
	NLU84	√	√	√	√	√	√	√	√
	NLU85	√	√	√	√	√	√	√	√
	NLU86	√	√	√	√	√	√	√	√
	NLU87	√	√	√	√	√	√	√	√
	NLU117	√	√	√	√	√	√	√	√
	NLUD117	√	√	√			√		√
	NLUEPA5	√	√	√	√	√	√	√	√
	NLUEPA19	√	√	√	√	√	√	√	√

NOTES

* Assumes porewater pH is an indicator of metals bioavailability, although pH may change during the course of the biological test exposures.

Table 2-1 Summary of Gas Works Sediment Area Bioassay Results (Through 2005)

		King County (2000) [2]				RETEC Split Samples (March 2002)					Ecology/TAMU Samples (July 2002)				RETEC Phase 2 (October 2002)					RETEC Phase3 (April 2005)				
	TPAH	*H. azteca*	*C. tentans* 10-day		Microtox® [3] Light Reading	*H. azteca*	*C. tentans* 10-day		Microtox® [3] Light Reading		*H. azteca* 28-day		*C. tentans* 20-day [5]		*H. azteca*	*C. tentans* 10-day		*C. tentans* 20-day		*H. azteca*	*C. tentans* 20-day		Microtox® [3] Light Reading	
Sample ID	(mg/kg d.w.) [1]	10-day survival	survival	growth	15 min	10-day survival	survival [4]	growth	5 min	15 min	survival	growth	survival	growth	10-day survival	survival	growth	survival	growth	10-day survival	survival	growth	5 min	15 min
527	90	76	87	.24 / 10	39	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
544 *	—	80	82	.27 / 10	82	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Control	—	98	87	.25 / 10	84	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
LU-1	529	—	—	—	—	92	80	1.74	53.55	39.53	86	0.132	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-2	1150	—	—	—	—	94	70	2.09	42.12	38.21	42	0.166	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-3	453	—	—	—	—	99	84	1.86	63.24	52.63	92	0.102	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-4	51	—	—	—	—	98	78	2.25	70.72	61.36	92	0.162	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-5	15	—	—	—	—	100	90	2.36	93.10	95.84	100	0.142	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-6	22	—	—	—	—	98	68	2.49	92.82	93.35	96	0.130	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-7	34	—	—	—	—	99	82	2.92	10.89	13.93	98	0.102	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-8	16	—	—	—	—	99	84	2.45	71.38	48.17	98	0.136	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-9	10	—	—	—	—	100	72	2.92	72.68	66.17	94	0.152	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-10	23	—	—	—	—	98	78	2.75	68.42	60.39	96	0.156	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-11	54	—	—	—	—	—	—	—	—	—	92	0.144	NA	NA	—	—	—	—	—	—	—	—	—	—
Ref *	1	—	—	—	—	93	82	2.57	*multiple readings*		98	0.114	NA	NA	—	—	—	—	—	—	—	—	—	—
Control	—	—	—	—	—	99	86	2.25	*multiple readings*		80	0.088	NA	NA	—	—	—	—	—	—	—	—	—	—
NLU01	131	—	—	—	—	—	—	—	—	—	—	—	—	—	81	52	0.235	32	2.010	—	—	—	—	—
NLU02	40	—	—	—	—	—	—	—	—	—	—	—	—	—	92	58	0.985	86	2.692	—	—	—	—	—
NLU04	33	—	—	—	—	—	—	—	—	—	—	—	—	—	96	78	1.228	96	2.795	—	—	—	—	—
NLU05	195	—	—	—	—	—	—	—	—	—	—	—	—	—	87	72	0.815	84	1.740	—	—	—	—	—
NLU06	48	—	—	—	—	—	—	—	—	—	—	—	—	—	91	82	1.101	90	2.937	—	—	—	—	—
NLU07	198	—	—	—	—	—	—	—	—	—	—	—	—	—	94	78	0.839	88	2.785	—	—	—	—	—
NLU08	46	—	—	—	—	—	—	—	—	—	—	—	—	—	95	82	1.203	94	2.683	—	—	—	—	—
NLU10	30	—	—	—	—	—	—	—	—	—	—	—	—	—	96	76	0.997	92	2.844	—	—	—	—	—
NLU12	48	—	—	—	—	—	—	—	—	—	—	—	—	—	92	80	0.825	90	3.397	—	—	—	—	—
NLU13	67	—	—	—	—	—	—	—	—	—	—	—	—	—	84	74	0.515	66	2.289	*Station revisited; see below*			—	—
NLU14	79	—	—	—	—	—	—	—	—	—	—	—	—	—	95	74	0.708	96	2.724	—	—	—	—	—
NLU15	66	—	—	—	—	—	—	—	—	—	—	—	—	—	97	80	0.915	92	2.430	—	—	—	—	—
NLU16	321	—	—	—	—	—	—	—	—	—	—	—	—	—	92	66	0.450	60	1.861	—	—	—	—	—
NLU17	383	—	—	—	—	—	—	—	—	—	—	—	—	—	83	62	0.302	44	1.664	—	—	—	—	—
NLU21 *	2	—	—	—	—	—	—	—	—	—	—	—	—	—	81	78	0.930	80	2.321	—	—	—	—	—
NLU22 *	2	—	—	—	—	—	—	—	—	—	—	—	—	—	70	76	0.831	64	2.019	—	—	—	—	—
Control	—	—	—	—	—	—	—	—	—	—	—	—	—	—	90	72	1.277	82	2.496	—	—	—	—	—
NLU13	180	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	84	54	1.180	66.40	65.20
NLU51	4800	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	NA	53.60	49.60
NLU55	1060	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	51	54	0.770	49.20	44.40
NLUD55	300	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	74	48	1.816	34.60	32.40
NLU64	220	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	89	86	2.335	89.40	72.20
NLU66	28	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	92	72	2.566	82.40	71.80
NLU69	9.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	87	96	2.295	79.00	72.20
NLU73	78	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	89	92	1.942	84.40	70.80
NLU76	22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	82	94	1.711	82.20	72.80
NLU81	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	90	82	2.643	74.80	67.60
NLU82	36	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	79	76	2.247	61.40	55.80
NLU83	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	94	84	2.333	71.60	70.20
NLU84	30	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	98	88	2.184	93.20	91.20
NLU85	4.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	95	82	2.363	103.00	101.20
NLU86	110	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	87	62	1.250	80.80	79.80
NLU87	63	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	94	88	2.250	79.80	71.20
NLU117	1100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	34	1.623	61.40	53.80
NLUD117	170	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	30	40	1.902	51.20	46.40
NLUEPA5	16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	88	88	2.166	101.60	95.60
NLUEPA19	24	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	97	82	2.143	104.60	101.00
REF1*	0.55	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	84	92	1.965	*multiple readings*	
REF2*	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	86	80	2.465	*multiple readings*	
Control	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	98	82	1.541	*multiple readings*	

Notes:

[1] RETEC March TPAH results are presented for the LU-x stations.

[2] Sampling conducted by King County on April 11, 2000. Survey name is LUUCSO000.

[3] Reported as mean Percent Luminescence (5 replicates per sample).

[4] Percent mean larvae, pupae, and emerged adults (out of 20 initial organisms).

[5] Results of this test had data quality issues and have been rejected by Ecology.

* Reference station.

survival = mean %

growth = mean biomass/larvae, mg dw

= failure of Ecology Proposed Freshwater SQS or CSL Criteria

Table 2-2 Summary of Gas Works Sediment Area Bioassay Pass/Fail Results (Through 2005)

		King County (2000) [2]				RETEC Split Samples (March 2002)					Ecology/TAMU Samples (July 2002)				RETEC Phase 2 (October 2002)					RETEC Phase3 (April 2005)				
	TPAH (mg/kg d.w.)	*H. azteca* 10-day	*C. tentans* 10-day		Microtox® Light Reading	*H. azteca* 10-day	*C. tentans* 10-day		Microtox® Light Reading		*H. azteca* 28-day		*C. tentans* 20-day [4]		*H. azteca* 10-day	*C. tentans* 10-day		*C. tentans* 20-day		*H. azteca* 10-day	*C. tentans* 20-day		Microtox® Light Reading	
Sample ID	[1]	survival	survival	growth	15 min	survival	survival [3]	growth	5 min	15 min	survival	growth	survival	growth	survival	survival	growth	survival	growth	survival	survival	growth	5 min	15 min
527	90	Pass	Pass	Pass	fail/CSL	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
544 *	—	Pass	Pass	Pass	Pass	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Control	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
LU-1	529	—	—	—	—	Pass	Pass	fail/CSL	fail/SQS	fail/CSL	Pass	Pass	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-2	1150	—	—	—	—	Pass	Pass	Pass	fail/CSL	fail/CSL	fail/CSL	Pass	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-3	453	—	—	—	—	Pass	Pass	fail/SQS	Pass	Pass	Pass	Pass	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-4	51	—	—	—	—	Pass	Pass	Pass	fail/CSL	fail/CSL	Pass	Pass	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-5	15	—	—	—	—	Pass	Pass	Pass	Pass	Pass	Pass	Pass	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-6	22	—	—	—	—	Pass	Pass	Pass	Pass	Pass	Pass	Pass	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-7	34	—	—	—	—	Pass	Pass	Pass	fail/CSL	fail/CSL	Pass	Pass	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-8	16	—	—	—	—	Pass	Pass	Pass	Pass	fail/SQS	Pass	Pass	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-9	10	—	—	—	—	Pass	Pass	Pass	Pass	Pass	Pass	Pass	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-10	23	—	—	—	—	Pass	Pass	Pass	Pass	Pass	Pass	Pass	NA	NA	—	—	—	—	—	—	—	—	—	—
LU-11	54	—	—	—	—	—	—	—	—	—	Pass	Pass	NA	NA	—	—	—	—	—	—	—	—	—	—
Ref *	1	—	—	—	—	Pass	Pass	Pass	*multiple readings*		Pass	Pass	NA	NA	—	—	—	—	—	—	—	—	—	—
Control	—	—	—	—	—	—	—	—	*multiple readings*		—	—	—	—	—	—	—	—	—	—	—	—	—	—
NLU01	131	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	fail/CSL	fail/CSL	fail/CSL	Pass	—	—	—	—	—
NLU02	40	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	fail/SQS	Pass	Pass	Pass	—	—	—	—	—
NLU04	33	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass	—	—	—	—	—
NLU05	195	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass	—	—	—	—	—
NLU06	48	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass	—	—	—	—	—
NLU07	198	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass	—	—	—	—	—
NLU08	46	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass	—	—	—	—	—
NLU10	30	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass	—	—	—	—	—
NLU12	48	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass	—	—	—	—	—
NLU13	67	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	fail/CSL	Pass	Pass	*Station revisited; see below*			—	—
NLU14	79	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass	—	—	—	—	—
NLU15	66	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass	—	—	—	—	—
NLU16	321	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	fail/CSL	fail/SQS	Pass	—	—	—	—	—
NLU17	383	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	fail/CSL	fail/CSL	Pass	—	—	—	—	—
NLU21 *	2	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass	—	—	—	—	—
NLU22 *	2	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass	—	—	—	—	—
Control	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
NLU13	180	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	fail/CSL	fail/CSL	Pass	Pass
NLU51	4800	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	fail/CSL	fail/CSL	NA	fail/CSL	fail/SQS
NLU55	1060	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	fail/CSL	fail/CSL	fail/CSL	fail/CSL	fail/CSL
NLUD55	300	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	fail/CSL	Pass	fail/CSL	fail/CSL
NLU64	220	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass
NLU66	28	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass
NLU69	9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass
NLU73	78	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass
NLU76	22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass
NLU81	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass
NLU82	36	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	fail/SQS	fail/SQS
NLU83	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass
NLU84	30	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass
NLU85	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass
NLU86	110	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	fail/CSL	Pass	Pass
NLU87	63	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass
NLU117	1100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	fail/CSL	fail/CSL	Pass	fail/CSL	fail/CSL
NLUD117	170	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	fail/CSL	fail/CSL	Pass	fail/CSL	fail/CSL
NLUEPA5	16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass
NLUEPA19	24	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	Pass	Pass
REF1*	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	*multiple readings*	
REF2*	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Pass	Pass	Pass	*multiple readings*	
Control	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	*multiple readings*	

Notes:

[1] RETEC March TPAH results are presented for the LU-x stations.

[2] Sampling conducted by King County on April 11, 2000. Survey name is LUUCSO000.

[3] Based upon percent mean larvae, pupae, and emerged adults (out of 20 initial organisms).

[4] Results of this test had data quality issues and have been rejected by Ecology.

* Reference station.

survival = mean %

growth = mean biomass/larvae, mg dw

fail/CSL = failure of Ecology Proposed Freshwater SQS or CSL Criteria

Table 2-3 Draft Ecology Biological Testing Performance and SQS and CSL Decision Criteria Proposed for Freshwater Bioassay Testing *

Biological Test	QA Control	QA Reference	Draft Decision Criteria [1, 2] Test sediment has higher (statistically significant, t-test, p ≤ 0.05) mean mortality than the reference sediment AND average endpoint difference:	
			SQS	CSL
Amphipod (Hyalella azteca) 10-day Acute Test				
Survival	C <20% mortality	R < 25% mortality	T - R > 10%	T - R > 25%
Larval Midge (Chironomus tentans) 20-day Chronic Test				
Survival	C < 32% mortality	R < 35% mortality	T -R > 15%	T -R > 25%
Growth	Avg weight CF > 0.48 mg/ind afdw	RF/CF > 0.8	biomass of T/R < 0.75	biomass of T/R < 0.6
Microtox 100% Porewater Luminescence Test				
Decrease in Luminescence	CF/CI > 0.72	RF/CF > 0.8	T/R < 0.85	T/R < 0.75

Notes:

* As presented in "Development of Freshwater Sediment Quality Values for Use in Washington State, Phase 1 Task 5: Final Report"; prepared by Avocet Environmental Consulting and SAIC for Washington State Department of Ecology, Publication 02-09-050, September

C = Control Sediment, R = Reference Sediment, T = Test Sample, CI - Control Initial, CF = Control Final

[1] The draft decision criteria were based on a statistically significant difference from reference (or control if no reference), and relative increase in mortality as shown.

[2] The draft decision criteria were based on a statistically significant difference from reference (or control if no reference), and relative decrease in biomass weight as shown. For chronic tests, mortality and growth endpoints are best used in combination

afdw - ash-free dry weight.

Table 2-4 Summary of Stepwise Regression Results

Dataset	Stepwise Regression	*H. azteca* 10-day Survival	*C. tentans* 20-day Survival	*C. tentans* 20-day Growth	Microtox® Luminescence
Phases 2 and 3 Combined	Model	TPAH (61%) % Fines (4%) Mercury (4%)	TPAH (54%) Mercury (14%) Copper (7%)	TPAH (33%) Arsenic (15%) Chromium (10%)	Copper (18%) Mercury (12%)
	Total Variance Explained	69%	75%	58%	30%
	Strength of Relationship	0.831	0.867	0.764	0.550
GWSA TPAH Cluster, Phases 2 and 3 Combined	Model	TPAH (63%) arsenic (8%)	TPAH (82%) mercury (4%)	chromium (50%) zinc (23%)	chromium (24%)
	Total Variance Explained	71%	86%	73%	24%
	Strength of Relationship	0.841	0.929	0.856	0.490

Notes:
Only the final model produced by the stepwise regression analysis is summarized.
Listwise exclusion was used for all regression analyses.
Additional variance explained (R-squared) given in ( ) after each model parameter.
Strength of relationship = regression coefficient (R); the closer the value is to 1, the stronger the relationship.
No log transformations were used (see Appendix G for log transformed regressions).
The Gas Works Sediment Area (GWSA) cluster includes those stations influenced predominantly by TPAH; the Shipyard/Marina Cluster was excluded from the dataset.

Table 4-1 TPAH Ranked Concentrations and Sediment Toxicity – Phases 2 and 3

Study	sample ID	Location	Cluster	Physical	Chemical**									Biological						
				Fines (%)	**TPAH (mg/kg)**	Dibenzo-furan (mg/kg)	(ARI) TOC (mg/kg)	Ammonia (mg-N/kg)	Sulfides (mg/kg)	Arsenic (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Mercury (mg/kg)	Zinc (mg/kg)	*H. azteca* 10-day (% survival)	*H. azteca* 28-day (% survival)	*C. tentans* 10-day (% survival)	*C. tentans* 20-day (% survival)	*C. tentans* 20-day (mg afdw)	Microtox 5 min	Microtox 15 min
Phase 3	NLUREF1	Lk. Washington	0	35.4	**1**	0.01	3.8	18.7	4	< 20	25	30	0.05	55	84	—	—	92	1.97	—	—
Ph 2 - March	Ref-1	Lk. Washington	0	29.4	**1**	0.01	4.2	34.0	0	7.8	28	27	0.09	57	93	98	82	—	—	—	—
Ph 2 - October	NLU21	Lk. Washington	0	15.3	**2**	0.05	8.7	43.0	45	15	36	40	0.15	83	81	—	78	80	2.32	—	—
Ph 2 - October	NLU22	Lk. Washington	0	20.0	**2**	0.05	10.0	95.0	700	25	54	100	0.15	188	70	—	76	64	2.02	—	—
Phase 3	NLU85	West Study Area	1	63.2	**5**	0.08	11.5	25.5	2300	< 50	290	220	0.70	378	95	—	—	82	2.36	103	101
Phase 3	NLU69	East Study Area	1	61.7	**9**	0.08	15.7	150.0	2400	< 60	246	170	0.25	377	87	—	—	96	2.30	79	72
Ph 2 - March	LU-9	SW of AOI	1	90.2	**10**	0.01	8.8	89.0	290	45.5	304	468	0.87	484	99	94	72	—	—	73	66
Phase 3	NLU81	E of AOI	1	60.1	**10**	0.08	17.8	28.1	3600	< 50	223	180	0.25	338	90	—	—	82	2.64	75	68
Phase 3	NLU83	West Study Area	1	62.3	**12**	0.08	14.0	64.9	1600	< 50	313	210	0.25	389	94	—	—	84	2.33	72	70
Phase 3	NLUREF2	Lk. Washington	0	70.3	**12**	0.05	5.0	38.4	130	< 20	64	110	0.20	176	86	—	—	80	2.46	—	—
Ph 2 - March	LU-5	East Study Area	1	73.2	**15**	0.02	6.7	85.0	1400	28	310	300	0.66	412	98	100	90	—	—	93	96
Phase 3	NLUEPA5	East Study Area	1	48.7	**16**	0.07	20.6	54.4	160	< 50	204	190	0.20	348	88	—	—	88	2.17	102	96
Ph 2 - March	LU-8	W of AOI	2	87.1	**16**	0.01	8.1	100.0	430	52.6	276	438	1.56	516	99	98	84	—	—	71	48
Phase 3	NLU76	East Study Area	1	52.7	**22**	0.07	13.5	69.3	240	< 40	314	180	0.20	412	82	—	—	94	1.71	82	73
Ph 2 - March	LU-6	East Study Area	1	87.9	**22**	0.02	8.3	72.0	2200	26.6	238	253	0.63	399	100	96	68	—	—	93	93
Ph 2 - March	LU-10	S of AOI	1	85.5	**23**	0.02	8.4	100.0	700	32.9	246	341	0.78	383	100	96	78	—	—	68	60
Phase 3	NLUEPA19	East Study Area	1	61.4	**24**	0.08	20.5	67.8	1500	< 50	253	220	0.25	366	97	—	—	82	2.14	105	101
Phase 3	NLU66	East Study Area	1	61.6	**28**	0.08	12.5	59.3	2000	< 50	291	220	0.25	423	92	—	—	72	2.57	82	72
Ph 2 - October	NLU10	East Study Area	1	58.4	**30**	0.20	10.0	110.0	1700	25	298	240	0.60	388	96	—	76	92	2.84	—	—
Phase 3	NLU84	West Study Area	1	60.5	**30**	0.08	10.0	63.2	3000	< 50	574	280	1.10	528	98	—	—	88	2.18	93	91
Ph 2 - October	NLU04	East Study Area	1	63.1	**33**	0.20	9.1	100.0	3700	25	215	200	0.50	359	96	—	78	96	2.79	—	—
Ph 2 - March	LU-7	East Study Area	1	75.4	**34**	0.02	9.1	100.0	380	23.4	198	220	0.59	349	98	98	82	—	—	10.9*	14*
Phase 3	NLU82	E of AOI	2	40.9	**36**	0.12	7.8	82.8	560	40	233	200	0.40	542	79	—	—	76	2.25	61	56
Ph 2 - October	NLU02	E of AOI	2	52.7	**40**	0.19	9.2	88.0	890	20	286	250	0.70	469	92	—	58	86	2.69	—	—
Ph 2 - October	NLU08	East Study Area	1	56.7	**46**	0.20	9.5	120.0	2300	25	243	210	0.50	377	95	—	82	94	2.68	—	—
Ph 2 - October	NLU06	East Study Area	1	43.6	**48**	0.20	7.4	49.0	970	25	215	210	0.50	372	91	—	82	90	2.94	—	—
Ph 2 - October	NLU12	West Study Area	1	55.0	**48**	0.20	8.1	120.0	1500	25	456	290	0.80	460	92	—	80	90	3.40	—	—
Ph 2 - March	LU-4	West Study Area	2	86.3	**51**	0.06	6.7	100.0	320	41.3	291	368	1.26	480	99	92	78	—	—	70.7*	61*
Phase 3	NLU87	West Study Area	2	65.4	**63**	0.06	8.3	59.7	90	130	541	550	1.10	787	94	—	—	88	2.25	80	71
Ph 2 - October	NLU15	W of AOI	2	60.1	**66**	0.20	8.6	140.0	1200	80	723	450	1.30	766	97	—	80	92	2.43	—	—
Ph 2 - October	NLU13	W of AOI	2	81.7	**67**	0.19	7.4	120.0	1100	25	259	390	1.70	402	84	—	74	66	2.29	—	—
Phase 3	NLU73	East Study Area	1	45.5	**78**	0.16	17.5	60.7	220	70	273	210	0.50	399	89	—	—	92	1.94	84	71
Ph 2 - October	NLU14	West Study Area	2	62.5	**79**	0.20	7.4	150.0	1000	110	1050	560	1.30	956	95	—	74	96	2.72	—	—
Phase 3	NLU86	West Study Area	2	64.5	**109**	0.17	9.9	68.0	590	360	639	810	2.50	1490	87	—	—	62	1.25 *	81	80
Ph 2 - October	NLU01	E of AOI	2	38.0	**131**	0.28	5.1	42.0	160	30	159	252	0.80	405	81	—	52	32 *	2.01	—	—
Phase 3	NLUD117	West Study Area	1	47.6	**170**	1.00	9.4	33.1	470	—	—	—	—	—	30 *	—	—	40 *	1.90	51.2*	46.4*
Phase 3	NLU13-tx	W of AOI	2	75.3	**176**	0.27	10.4	76.1	140	100	396	380	2.20	662	84	—	—	54 *	1.18 *	66	65
Ph 2 - October	NLU05	East Study Area	1	1.2	**195**	0.45	4.5	3.8	4	3	16	18	0.14	57	87	—	72	84	1.74	—	—
Ph 2 - October	NLU07	East Study Area	1	42.9	**198**	0.20	10.0	52.0	120	25	266	280	0.60	438	94	—	78	88	2.78	—	—
Phase 3	NLU64	East Study Area	1	52.4	**219**	0.07	16.8	22.9	370	< 40	324	230	0.60	445	89	—	—	86	2.34	89	72
Phase 3	NLUD55	East Study Area	1	26.1	**301**	1.10	7.0	37.8	250	—	—	—	—	—	74	—	—	48 *	1.82	34.6*	32.4*
Ph 2 - October	NLU16	West Study Area	2	56.4	**321**	2.10	10.0	150.0	4200	140	860	1150	1.50	1200	92	—	66	60	1.86	—	—
Ph 2 - October	NLU17	West Study Area	2	83.0	**383**	1.10	8.2	160.0	1900	70	538	430	1.90	684	83	—	62	44 *	1.66	—	—
Ph 2 - March	LU-3	West Study Area	2	78.4	**453**	0.23	6.6	99.0	590	40.1	349	313	1.37	455	94	92	84	—	—	63	53
Ph 2 - March	LU-1	West Study Area	1	64.0	**529**	0.52	5.8	94.0	800	38.6	251	298	0.85	413	99	86	80	—	—	54	40*
Phase 3	NLU55	East Study Area	1	10.0	**1064**	4.70	11.6	41.7	270	70	95	97	0.50	245	51 *	—	—	54 *	0.77 *	49.2*	44.4*
Phase 3	NLU117	West Study Area	1	46.6	**1096**	5.60	54.4	49.0	1800	60	333	300	1.60	474	0 *	—	—	34 *	1.62	61.4*	53.8*
Ph 2 - March	LU-2	East Study Area	1	55.6	**1150**	2.40	9.3	79.0	130	24.1	182	219	0.58	326	92	42	70	—	—	42.1*	38*
Phase 3	NLU51	East Study Area	1	34.4	**4826**	3.90	35.3	28.2	150	30	71	97	0.40	153	0 *	—	—	0 *	—	53.6*	50
Ph 2 - March	LU-11	East Study Area	1	78.5	—	0.04	7.1	83.0	1500	36.7	233	333	0.76	399	98	92	—	—	—	—	—
	N = 50				↑ Sorted by																

NOTES:
All result sorted by TPAH (mg/kg)
**Studies = Phase 2 March (2002), Phase 2 October (2002), and Phase 3 April (2005)
— = not applicable; value not measured
< = non-detect
= failure of Ecology's SQS criteria
* = failure of Ecology's CSL criteria
underline = exceedence of Ecology's 2003 proposed freshwater 2LAET chemical criteria.

Table 4-2 Clustered TPAH Ranked Concentrations and Sediment Toxicity

Study	sample ID	Cluster	Chemical					Biological						
			TPAH (mg/kg)	Arsenic (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	*H. azteca* 10-day (% survival)	*H. azteca* 28-day (% survival)	*C. tentans* 10-day (% survival)	*C. tentans* 20-day (% survival)	*C. tentans* 20-day (mg afdw)	Microtox 5 min	Microtox 15 min
Phase 3	NLUREF1	**0**	**1**	< 20	25	30	55	84	—	—	92	1.97	—	—
Ph 2 - March	Ref-1	**0**	**1**	7.8	28	27	57	93	98	82	—	—	—	—
Ph 2 - October	NLU21	**0**	**2**	15	36	40	83	81	—	78	80	2.32	—	—
Ph 2 - October	NLU22	**0**	**2**	25	54	100	188	70	—	76	64	2.02	—	—
Phase 3	NLUREF2	**0**	**12**	< 20	64	110	176	86	—	—	80	2.46	—	—
Phase 3	NLU85	**1**	**5**	< 50	290	220	378	95	—	—	82	2.36	103	101
Phase 3	NLU69	**1**	**9**	< 60	246	170	377	87	—	—	96	2.30	79	72
Ph 2 - March	LU-9	**1**	**10**	45.5	304	468	484	99	94	72	—	—	73	66
Phase 3	NLU81	**1**	**10**	< 50	223	180	338	90	—	—	82	2.64	75	68
Phase 3	NLU83	**1**	**12**	< 50	313	210	389	94	—	—	84	2.33	72	70
Ph 2 - March	LU-5	**1**	**15**	28	310	300	412	98	100	90	—	—	93	96
Phase 3	NLUEPA5	**1**	**16**	< 50	204	190	348	88	—	—	88	2.17	102	96
Phase 3	NLU76	**1**	**22**	< 40	314	180	412	82	—	—	94	1.71	82	73
Ph 2 - March	LU-6	**1**	**22**	26.6	238	253	399	100	96	68	—	—	93	93
Ph 2 - March	LU-10	**1**	**23**	32.9	246	341	383	100	96	78	—	—	68	60
Phase 3	NLUEPA19	**1**	**24**	< 50	253	220	366	97	—	—	82	2.14	105	101
Phase 3	NLU66	**1**	**28**	< 50	291	220	423	92	—	—	72	2.57	82	72
Ph 2 - October	NLU10	**1**	**30**	25	298	240	388	96	—	76	92	2.84	—	—
Phase 3	NLU84	**1**	**30**	< 50	574	280	528	98	—	—	88	2.18	93	91
Ph 2 - October	NLU04	**1**	**33**	25	215	200	359	96	—	78	96	2.79	—	—
Ph 2 - March	LU-7	**1**	**34**	23.4	198	220	349	98	98	82	—	—	10.9*	14*
Ph 2 - October	NLU08	**1**	**46**	25	243	210	377	95	—	82	94	2.68	—	—
Ph 2 - October	NLU06	**1**	**48**	25	215	210	372	91	—	82	90	2.94	—	—
Ph 2 - October	NLU12	**1**	**48**	25	456	290	460	92	—	80	90	3.40	—	—
Phase 3	NLU73	**1**	**78**	70	273	210	399	89	—	—	92	1.94	84	71
Phase 3	NLUD117	**1**	**170**	—	—	—	—	30 *	—	—	40 *	1.90	51.2*	46.4*
Ph 2 - October	NLU05	**1**	**195**	3	16	18	57	87	—	72	84	1.74	—	—
Ph 2 - October	NLU07	**1**	**198**	25	266	280	438	94	—	78	88	2.78	—	—
Phase 3	NLU64	**1**	**219**	< 40	324	230	445	89	—	—	86	2.34	89	72
Phase 3	NLUD55	**1**	**301**	—	—	—	—	74	—	—	48 *	1.82	34.6*	32.4*
Ph 2 - March	LU-1	**1**	**529**	38.6	251	298	413	99	86	80	—	—	54	40*
Phase 3	NLU55	**1**	**1064**	70	95	97	245	51 *	—	—	54 *	0.77 *	49.2*	44.4*
Phase 3	NLU117	**1**	**1096**	60	333	300	474	0 *	—	—	34 *	1.62	61.4*	53.8*
Ph 2 - March	LU-2	**1**	**1150**	24.1	182	219	326	92	42	70	—	—	42.1*	38*
Phase 3	NLU51	**1**	**4826**	30	71	97	153	0 *	—	—	0 *	—	53.6*	50
Ph 2 - March	LU-11	**1**	**--**	36.7	233	333	399	98	92	—	—	—	—	—
	N = 31													
Ph 2 - March	LU-8	**2**	**16**	52.6	276	438	516	*Data not used to derive a TPAH cleanup level.*						
Phase 3	NLU82	**2**	**36**	40	233	200	542							
Ph 2 - October	NLU02	**2**	**40**	20	286	250	469							
Ph 2 - March	LU-4	**2**	**51**	41.3	291	368	480							
Phase 3	NLU87	**2**	**63**	130	541	550	787							
Ph 2 - October	NLU15	**2**	**66**	80	723	450	766							
Ph 2 - October	NLU13	**2**	**67**	25	259	390	402							
Ph 2 - October	NLU14	**2**	**79**	110	1050	560	956							
Phase 3	NLU86	**2**	**109**	360	639	810	1490							
Ph 2 - October	NLU01	**2**	**131**	30	159	252	405							
Phase 3	NLU13-tx	**2**	**176**	100	396	380	662							
Ph 2 - October	NLU16	**2**	**321**	140	860	1150	1200							
Ph 2 - October	NLU17	**2**	**383**	70	538	430	684							
Ph 2 - March	LU-3	**2**	**453**	40.1	349	313	455							

↑ ↑ Sorted by

NOTES

Studies = Phase 2 March (2002), Phase 2 October (2002), and Phase 3 April (2005)

— = not applicable; value not measured

< = non-detect

= failure of Ecology's SQS criteria

* = failure of Ecology's CSL criteria

underline = exceedence of Ecology's 2003 proposed freshwater 2LAET chemical criteria.

= highest No Observed Effects Concentration (NOEC)

Cluster definitions:

0 = Reference Stations

1 = GWSA Cluster

2 = Shipyard/Marina Cluster

Table 4-3 Effect Level Concentrations Based on Concentration-Response Curves
GWSA Cluster Dataset (Phases 2 and 3)

Bioassay Organism	Bioassay Endpoint	Effect Level	Effect Level Unit	GWSA Cluster Dataset (by SPSS) Approx. TPAH (mg/kg dw)	GWSA Cluster Dataset (by CETIS) TPAH (mg/kg dw)
H. azteca 10-day Mortality	Percent Mortality	LC25	25% mortality	380	365
		LC20	20% mortality	240	285
		LC15	15% mortality	160	213
	Percent Mortality Normalized to Control *	LC25	25% mortality	440	
		LC20	20% mortality	310	
		LC15	15% mortality	220	
C. tentans 20-day Mortality	Percent Mortality	LC25	25% mortality	190	338
		LC20	20% mortality	120	275
		LC15	15% mortality	75	217
	Percent Mortality Normalized to Control *	LC25	25% mortality	500	
		LC20	20% mortality	395	
		LC15	15% mortality	270	

Notes:

Concentration-Response Curves derived in SPSS version 10.0 scatterplots using cubic regression and log transformed TPAH concentrations. R-squared values ranged from 0.57 to 0.80 (a value of 1 is perfect curve fit).

LC20 values for GWSA Cluster derived by Nautilus bioassay testing lab as a QC check. Method used CETIS software version 1.1.1 scatterplots using linear regression, log transformed TPAH concentrations, probit transformation of bioassays, and 95% confidence intervals.

LC20 = lethal concentration where up to 20% of the population is expected to have biological mortality.

mg/kg dw = milligrams per kilogram dry weight

* Results normalized to control by substracting the avg percent mortality of control from the avg percent mortality of the test sample.

Table 4-4 Sensitivity Analysis for TPAH Concentrations and Percent Bioassay Response

Station ID	Location	TPAH (mg/kg dry weight)	Sensitivity Analysis - Percent Response by TPAH Level**							Biological Response				
			Total # Stations Covered by TPAH Level	Total # Stations Remaining	Bioassay Count Per Row	Hit Count	No Hit Count	Cumulative Total Count*	Cumulative No Hit Probability	*H. azteca* 10-day (% survival)	*H. azteca* 28-day (% survival)	*C. tentans* 10-day (% survival)	*C. tentans* 20-day (% survival)	*C. tentans* 20-day growth (mg afdw)
LU-11	East Study Area	—										—	—	—
NLU85	West Study Area	5	15	121	3	0	3	3	2%	95	—	—	82	2.36
NLU69	East Study Area	9	18	118	3	0	3	6	4%	87	—	—	96	2.30
LU-9	SW of AOI	10	20	116	2	0	2	8	6%	99	94	—	—	—
NLU81	E of AOI	10	23	113	3	0	3	11	8%	90	—	—	82	2.64
NLU83	West Study Area	12	26	110	3	0	3	14	10%	94	—	—	84	2.33
LU-5	East Study Area	15	31	105	2	0	2	16	12%	98	100	—	—	—
NLUEPA5	East Study Area	16	34	102	3	0	3	19	14%	88	—	—	88	2.17
LU-8	W of AOI	16	36	100	2	0	2	21	15%	99	98	—	—	—
NLU76	East Study Area	22	39	97	3	0	3	24	18%	82	—	—	94	1.71
LU-6	East Study Area	22	41	95	2	0	2	26	19%	100	96	—	—	—
LU-10	S of AOI	23	42	94	1	0	1	27	20%	100	—	—	—	—
NLUEPA19	East Study Area	24	45	91	3	0	3	30	22%	97	—	—	82	2.14
NLU66	East Study Area	28	48	88	3	0	3	33	24%	92	—	—	72	2.57
NLU10	East Study Area	30	53	83	5	0	5	38	28%	96	96	76	92	2.84
NLU84	West Study Area	30	56	80	3	0	3	41	30%	98	—	—	88	2.18
NLU04	East Study Area	33	60	76	4	0	4	45	33%	96	—	78	96	2.79
LU-7	East Study Area	34	62	74	2	0	2	47	35%	98	98	—	—	—
NLU82	E of AOI	36	65	71	3	0	3	50	37%	79	—	—	76	2.25
NLU02	E of AOI	40	69	67	4	1	3	54	39%	92	—	58	86	2.69
NLU08	East Study Area	46	73	63	4	0	4	58	42%	95	—	82	94	2.68
NLU06	East Study Area	48	77	59	4	0	4	62	45%	91	—	82	90	2.94
NLU12	West Study Area	48	81	55	4	0	4	66	48%	92	—	80	90	3.40
LU-4	West Study Area	51	83	53	2	0	2	68	49%	99	92	—	—	—
NLU87	West Study Area	63	86	50	3	0	3	71	51%	94	—	—	88	2.25
NLU15	W of AOI	66	90	46	4	0	4	75	54%	97	—	80	92	2.43
NLU13	W of AOI	67	94	42	4	0	4	79	57%	84	—	74	66	2.29
NLU73	East Study Area	78	97	39	3	0	3	82	60%	89	—	—	92	1.94
NLU14	West Study Area	79	101	35	4	0	4	86	63%	95	—	74	96	2.72
NLU86	West Study Area	109	103	33	3	1	2	89	64%	87	—	—	62	1.25
NLU01	E of AOI	131	106	30	4	2	2	93	65%	81	—	52	32	2.01
NLUD117	West Study Area	170	107	29	3	2	1	96	66%	30	—	—	40	1.90
NLU13	W of AOI	176	109	27	4	2	2	100	68%	84	—	74	54	1.18
NLU05	East Study Area	195	113	23	4	0	4	104	71%	87	—	72	84	1.74
NLU07	East Study Area	198	117	19	4	0	4	108	74%	94	—	78	88	2.78
NLU64	East Study Area	219	120	16	3	0	3	111	76%	89	—	—	86	2.34
NLUD55	East Study Area	301	122	14	3	1	2	114	77%	74	—	—	48	1.82
NLU16	West Study Area	321	126	10	4	1	3	118	79%	92	—	66	60	1.86
NLU17	West Study Area	383	129	7	4	1	3	122	82%	83	—	62	44	1.66
LU-3	West Study Area	453	131	5	2	0	2	124	83%	94	92	—	—	—
LU-1	West Study Area	529	133	3	2	0	2	126	85%	99	86	—	—	—
NLU55	East Study Area	1064	133	3	3	3	0	129	85%	51	—	—	54	0.77
NLU117	West Study Area	1096	134	2	3	2	1	132	85%	0	—	—	34	1.62
LU-2	East Study Area	1150	136	0	2	1	1	134	86%	92	42	—	—	—
NLU51	East Study Area	4826	136	0	2	2	0	136	86%	0	—	—	0	—
										44	10	15	34	33
														136

NOTES:

— = not applicable; value not measured

= failure of Ecology's proposed SQS criteria

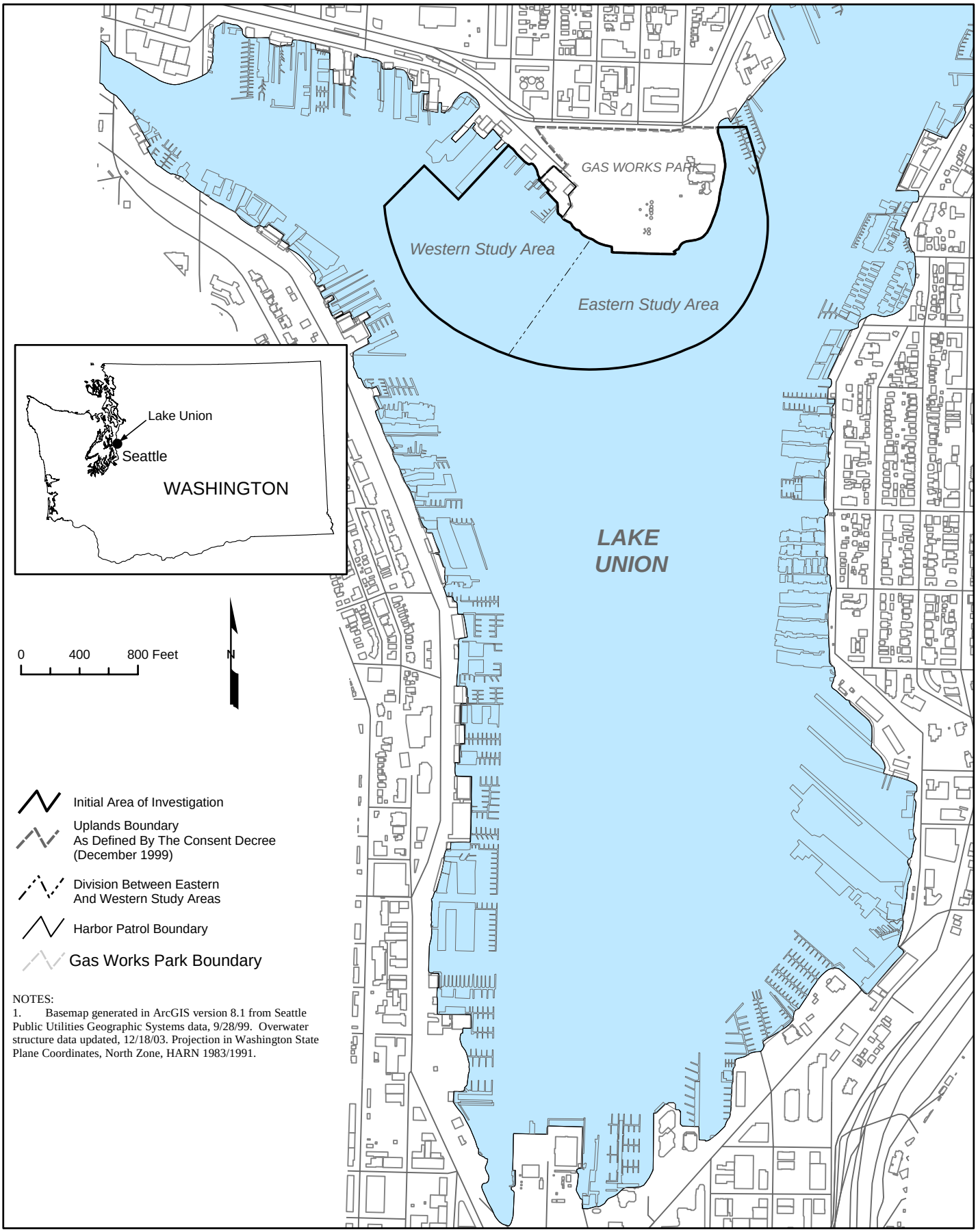
underline = exceedence of Ecology's 2003 proposed freshwater 2LAET chemical criteria

* Cumulative count does not include Microtox® data, which were only used to determine the spatial boundary and not the cleanup level.

** Studies = Phase 2 March (2002), Phase 2 October (2002), and Phase 3 April (2005)

Tables

Figures



NOTES:

1. Basemap generated in ArcGIS version 8.1 from Seattle Public Utilities Geographic Systems data, 9/28/99. Overwater structure data updated, 12/18/03. Projection in Washington State Plane Coordinates, North Zone, HARN 1983/1991.

RETEC

CLEANUP STANDARD DETERMINATION
GAS WORKS SEDIMENT AREA

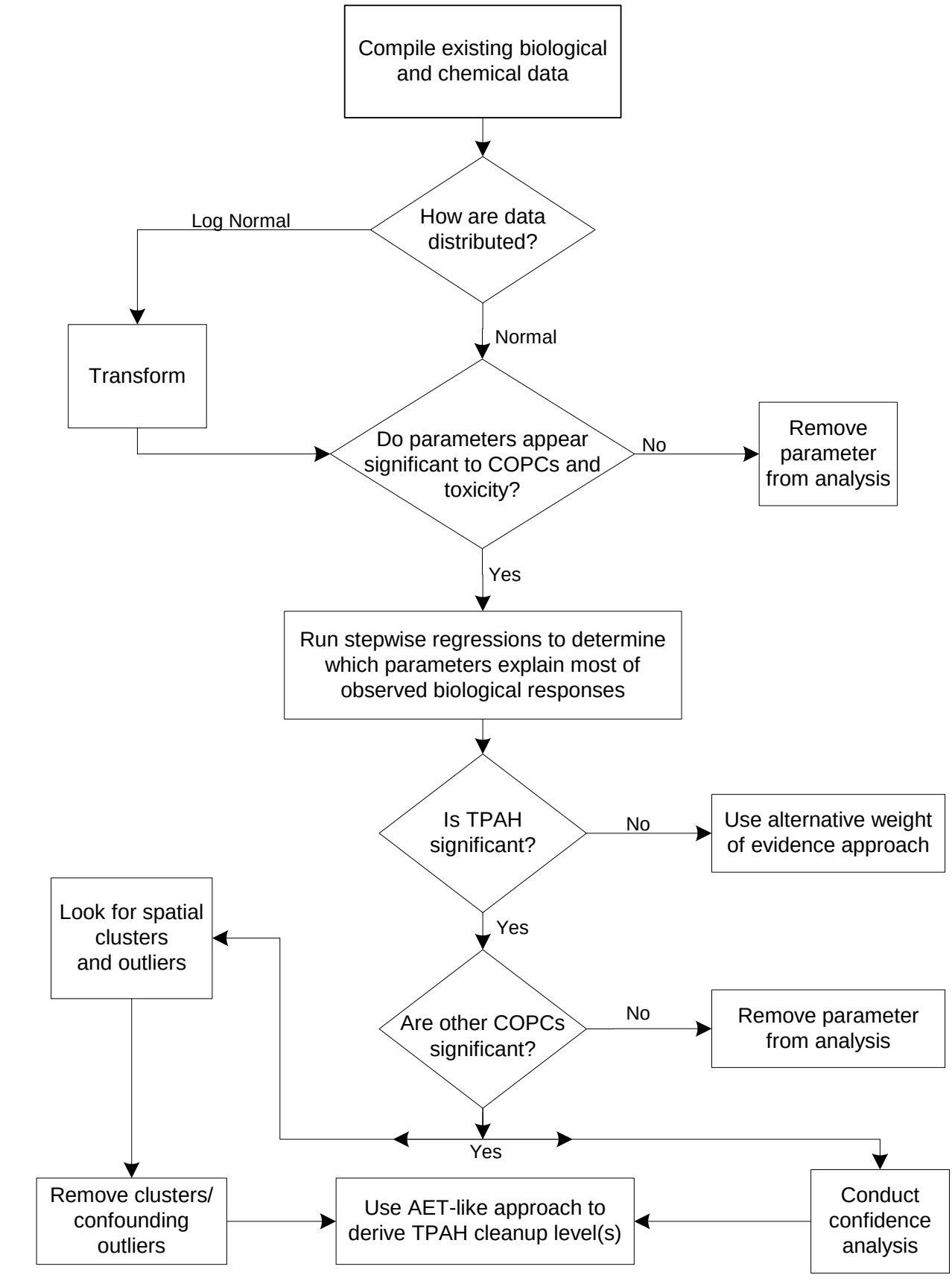
PSE10-18628-610

STUDY AREA

DATE: 7/21/05 | KBL/ftc

FIGURE 1-1

FILE: T:/LakeUnion_N83/Projects/NLU/TPAHCleanUp_SD2005/SedStudyArea_1_1.mxd



RETEC

GAS WORKS SEDIMENT AREA		GWSA CLEANUP STANDARD DETERMINATION APPROACH
Date: 08/16/05	File: PSEM\GW1\5	FIGURE 1-2

0 150 300 Feet

N

Phase 2 and Phase 3 (2002 and 2005)
Surface Sediment Bioassay Sampling Stations

- Pass
- SQS Failure
- Microtox Only SQS Failure
- CSL Failure
- Microtox Only CSL Failure

- Shipyard Consent Decree Boundary
- Uplands Boundary As Defined By The Consent Decree (December 1999)
- Division Between Eastern And Western Study Areas
- Harbor Patrol Boundary
- Gas Works Park Boundary
- Initial Area of Investigation

Interpolated TPAH Concentrations (mg/kg dry wt.) *

- < 100
- 100 - 500
- 500 - 1000
- 1000 - 2500
- >2500
- No data available, or, if data exists, interpolation not shown

* Western Study Area values are preliminary and not validated

GAS WORKS PARK

Harbor Patrol

WESTERN STUDY AREA

EASTERN STUDY AREA

Lake Union

NLU01	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	CSL	CSL
20-d Chir	CSL	NA

NLU01 131.2

NLU82	Survival	Growth
10-d Hyll	Pass	NV
20-d Chir	Pass	Pass
Microtox	SQS	SQS

NLU82-TX 35.6

NLU76	Survival	Growth
10-d Hyll	Pass	NV
20-d Chir	Pass	Pass
Microtox	Pass	Pass

NLU02 39.7

NLU02	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	SQS	Pass
20-d Chir	Pass	Pass

NLU73#	Survival	Growth
10-d Hyll	Pass	NV
20-d Chir	Pass	Pass
Microtox	Pass	Pass

NLU76 66.5

NLU81-TX 10.1

NLU81	Survival	Growth
10-d Hyll	Pass	NV
20-d Chir	Pass	Pass
Microtox	Pass	Pass

NLU73-TX 77.5

NLU55#	Survival	Growth
10-d Hyll	CSL	NV
20-d Chir	CSL	CSL
Microtox	CSL	CSL

NLU55-TX 1064.4

NLU04 32.0

NLU04	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	Pass
20-d Chir	Pass	Pass

NLU05	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	Pass
20-d Chir	Pass	Pass

NLU69-TX 9.2

NLU69	Survival	Growth
10-d Hyll	Pass	NV
20-d Chir	Pass	Pass
Microtox	Pass	Pass

NLU51#	Survival	Growth
10-d Hyll	CSL	NV
20-d Chir	CSL	(CSL)
Microtox	CSL	SQS

NLU05 195

NLUEPA5-TX 15.7

NLUEPA5	Survival	Growth
10-d Hyll	Pass	NV
20-d Chir	Pass	Pass
Microtox	Pass	Pass

NLU51-TX 4826

NLU51 4323

NLU06	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	Pass
20-d Chir	Pass	Pass

NLU06 47.3

NLU07	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	Pass
20-d Chir	Pass	Pass

NLU07 199.4

NLU08 44.8

527 88.6

LU-11	Survival	Growth
10-d Hyll	NV	NV
10-d Chir	NV	NV
28-d Hyll	Pass	Pass
Microtox	NV	NV

LU-11 16.6

NLUEPA19-TX 24.0

NLUEPA19	Survival	Growth
10-d Hyll	Pass	NV
20-d Chir	Pass	Pass
Microtox	Pass	Pass

LU-7	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	Pass
28-d Hyll	Pass	Pass
Microtox	CSL	CSL

LU-7 34.1

NLU08	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	Pass
20-d Chir	Pass	Pass

LU-10 23.2

LU-10	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	Pass
28-d Hyll	Pass	Pass
Microtox	Pass	Pass

NLU10	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	Pass
20-d Chir	Pass	Pass

NLU10 28.9

LU-6	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	Pass
28-d Hyll	Pass	Pass
Microtox	Pass	Pass

LU-6 22.3

NLU64-TX 218.8

NLU64#	Survival	Growth
10-d Hyll	Pass	NV
20-d Chir	Pass	Pass
Microtox	Pass	Pass

NLU66	Survival	Growth
10-d Hyll	Pass	NV
20-d Chir	Pass	Pass
Microtox	Pass	Pass

NLU66-TX 28.3

NLU117#	Survival	Growth
10-d Hyll	CSL	NV
20-d Chir	CSL	Pass
Microtox	CSL	CSL

NLU117-TX 1095.6

NLU83	Survival	Growth
10-d Hyll	Pass	NV
20-d Chir	Pass	Pass
Microtox	Pass	Pass

NLU83-TX 12.1

LU-1	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	CSL
28-d Hyll	Pass	Pass
Microtox	SQS	CSL

LU-1 527.7

NLU84	Survival	Growth
10-d Hyll	Pass	NV
20-d Chir	Pass	Pass
Microtox	Pass	Pass

NLU84-TX 30.3

NLU17	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	CSL
20-d Chir	CSL	NA

NLU15	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	Pass
20-d Chir	Pass	Pass

NLU15 65.5

NLU16	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	CSL
20-d Chir	SQS	Pass

NLU16 320.7

NLU86	Survival	Growth
10-d Hyll	Pass	NV
20-d Chir	Pass	CSL
Microtox	Pass	Pass

NLU86-TX 109.2

NLU17 383

NLU87	Survival	Growth
10-d Hyll	Pass	NV
20-d Chir	Pass	Pass
Microtox	Pass	Pass

NLU13-Ph2	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	CSL
20-d Chir	Pass	Pass

NLU13 66.6

NLU13-TX 176.2

NLU87-TX 62.9

NLU12	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	Pass
20-d Chir	Pass	Pass

NLU12 47.6

NLU13-Ph3	Survival	Growth
10-d Hyll	Pass	NV
20-d Chir	CSL	CSL
Microtox	Pass	Pass

NLU14 78.8

NLU14	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	Pass
20-d Chir	Pass	Pass

LU-3 452.7

LU-3	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	SQS
28-d Hyll	Pass	Pass
Microtox	Pass	Pass

LU-4 51.3

NLU85-TX 4.7

NLU85	Survival	Growth
10-d Hyll	Pass	NV
20-d Chir	Pass	Pass
Microtox	Pass	Pass

LU-4	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	Pass
28-d Hyll	Pass	Pass
Microtox	CSL	CSL

LU-8 15.9

LU-8	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	Pass
28-d Hyll	Pass	Pass
Microtox	Pass	SQS

LU-5	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	Pass
28-d Hyll	Pass	Pass
Microtox	Pass	Pass

LU-5 14.9

LU-9 9.6

LU-9	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	Pass
28-d Hyll	Pass	Pass
Microtox	Pass	Pass

LU-2	Survival	Growth
10-d Hyll	Pass	NV
10-d Chir	Pass	Pass
28-d Hyll	CSL	Pass
Microtox	CSL	CSL

LU-2 1149

NLU41 11.6

NLU83-TX 12.1

LU-1 527.7

NLUD117#	Survival	Growth
10-d Hyll	CSL	NV
20-d Chir	CSL	Pass
Microtox	CSL	CSL

NLUD55#	Survival	Growth
10-d Hyll	Pass	NV
20-d Chir	CSL	Pass
Microtox	CSL	CSL

NOTES:

1. Basemap generated in ArcGIS version 8.1 from Seattle Public Utilities Geographic Systems data, 9/28/99. Overwater structure data updated, 12/18/03. Projection in Washington State Plane Coordinates, North Zone, HARN 1983/1991.
2. Concentration contour map generated through interpolation using an Inverse Distance Weighted (IDW) scheme (power = 6) from 2004/05 grab samples and pre-2005 data. Maximum reach from each sampling location is equal to 500 feet. Contoured interval may differ from actual data shown due to influence by neighboring data values.
3. The number given below the sample name is the TPAH concentration (ppm), concentrations represent the total sum of 16 individual PAH compounds. In accordance with Ecology's Sediment Management Standards, individual PAH concentrations below the detection limit (DL) were not included when calculating the sum.
4. Data sets include King County 2000 (527), RETEC March 2002, TAMU July 2002, RETEC October 2002, and RETEC April 2005.
5. Results based on H. *azteca* 10-day mortality, H. *azteca* 28-day mortality and growth, C. *tentans* 10-day mortality, C. *Tentans* 20-day mortality and growth, and Microtox bioassay tests. The Microtox data presented for the 5 minute and 15 minute bioluminescence endpoints.
6. Bioassay pass/fail results based on Ecology's proposed freshwater bioassay decision criteria.
7. Data box footnotes: # = Diluted samples with 50% reference material (NLUD55 and NLUD117)
   NV= No value
   NA=Not analyzed

RETEC

CLEANUP STANDARD DETERMINATION
GAS WORKS SEDIMENT AREA
PSE10-18628-610

GWSA BIOASSAY PASS/FAIL RESULTS (THROUGH 2005)

DATE: 7/21/05 | DWN. BY: KBL/ftc | **FIGURE: 2-1**

FILE: T:/LakeUnion_N83/Projects/NLU/TPAHCleanUp_SD2005/BioassayPassFail_2_1.mxd

0 150 300 Feet

N

Phase 2 and Phase 3 (2002 and 2005)
Surface Sediment Bioassay Sampling Stations

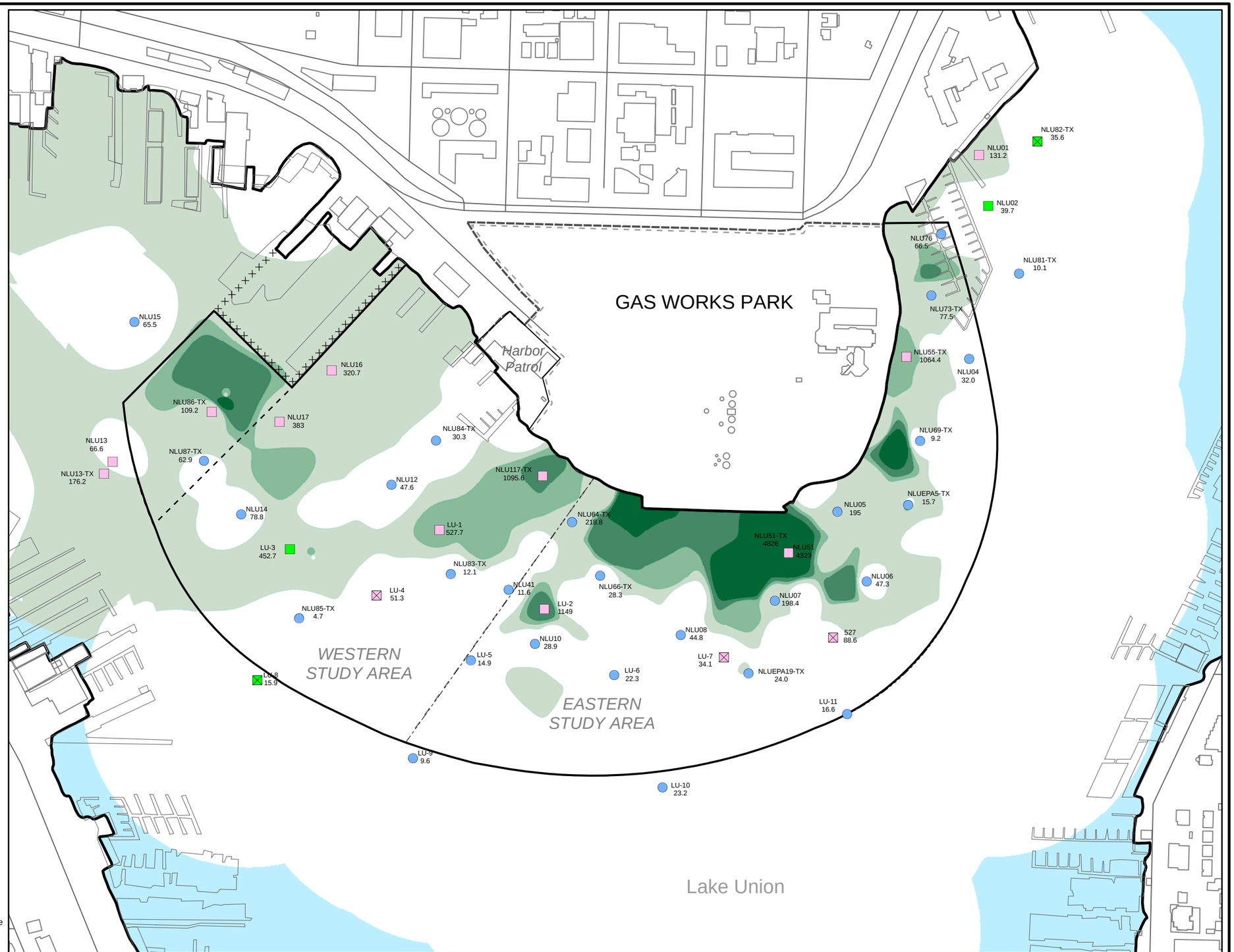
- Pass
- SQS Failure
- Microtox Only SQS Failure
- CSL Failure
- Microtox Only CSL Failure

- Shipyard Consent Decree Boundary
- Uplands Boundary As Defined By The Consent Decree (December 1999)
- Division Between Eastern And Western Study Areas
- Harbor Patrol Boundary
- Gas Works Park Boundary
- Initial Area of Investigation

Interpolated TPAH Concentrations (mg/kg dry wt.) *

- < 100
- 100 - 500
- 500 - 1000
- 1000 - 2500
- >2500
- No data available, or, if data exists, interpolation not shown

* Western Study Area values are preliminary and not validated



NOTES:
1. Basemap generated in ArcGIS version 8.1 from Seattle Public Utilities Geographic Systems data, 9/28/99. Overwater structure data updated, 12/18/03. Projection in Washington State Plane Coordinates, North Zone, HARN 1983/1991.
2. Concentration contour map generated through interpolation using an Inverse Distance Weighted (IDW) scheme (power = 6) from 2004/05 grab samples and pre-2005 data. Maximum reach from each sampling location is equal to 500 feet. Contoured interval may differ from actual data shown due to influence by neighboring data values.
3. The number given below the sample name is the TPAH concentration (ppm), concentrations represent the total sum of 16 individual PAH compounds. In accordance with Ecology's Sediment Management Standards, individual PAH concentrations below the detection limit (DL) were not included when calculating the sum.
4. Data sets include King County 2000 (527), RETEC March 2002, TAMU July 2002, RETEC October 2002, and RETEC April 2005.
5. Results based on *H. azteca* 10-day mortality, *H. azteca* 28-day mortality and growth, *C. tentans* 10-day mortality, *C. Tentans* 20-day mortality and growth, and Microtox bioassay tests. The Microtox data presented for the 5 minute and 15 minute bioluminescence endpoints
6. Bioassay pass/fail results based on Ecology's proposed freshwater bioassay decision criteria.

RETEC

CLEANUP STANDARD DETERMINATION
GAS WORKS SEDIMENT AREA
PSE10-18628-610

DISTRIBUTION OF BIOASSAY RESULTS (THROUGH 2005)

DATE: 7/21/05 | DWN. BY: KBL/ftc | **FIGURE: 2-2**

FILE: T:/LakeUnion_N83/Projects/NLU/TPAHCleanUp_SD2005/PassFailSum.mxd

0 150 300 Feet

N

Marina Area Based on Metal Concentrations and Surrounding Bioassay Passes

GAS WORKS PARK

EASTERN STUDY AREA

WESTERN STUDY AREA

Harbor Patrol

Lake Union

Bioassay Stations

- Phase 3 Grab Stations (2005)
- Phase 2 Stations (2002)
- Historical Stations (2000)

- Shipyard Cluster
- Extended Shipyard Area Cluster
- Outlier 1
- Outlier 2

Remaining Stations Comprise the GWSA Cluster

- Initial Area of Investigation
- Shipyard Consent Decree Boundary
- Uplands Boundary As Defined By The Consent Decree (December 1999)
- Division Between Eastern And Western Study Areas
- Harbor Patrol Boundary
- Gas Works Park Boundary

Interpolated TPAH Concentrations (mg/kg dry wt.) *

- < 100
- 100 - 500
- 500 - 1000
- 1000 - 2500
- >2500
- No data available, or, if data exists, interpolation not shown

* Western Study Area values are preliminary and not validated

NLU15 65.5
NLU16 320.7
NLU86-TX 109.2
NLU17 383
NLU13 66.6
NLU13-TX 176.2
NLU87-TX 62.9
NLU14 78.8
LU-3 452.7
LU-4 51.3
LU-8 15.9
NLU84-TX 30.3
NLU12 47.6
NLU117-TX 1095.6
LU-1 527.7
NLU83-TX 12.1
NLU41 11.6
NLU85-TX 4.7
LU-2 1149
NLU64-TX 218.8
NLU66-TX 28.3
NLU10 28.9
LU-5 14.9
LU-6 22.3
LU-9 9.6
LU-10 23.2
NLU01 131.2
NLU82-TX 35.6
NLU02 39.7
NLU76 66.5
NLU81-TX 10.1
NLU73-TX 77.5
NLU55-TX 1064.4
NLU04 32.0
NLU69-TX 9.2
NLUEPA5-TX 15.7
NLU05 195
NLU51-TX 4826
NLU51 4323
NLU06 47.3
NLU07 198.4
NLU08 44.8
527 88.6
LU-7 34.1
NLUEPA19-TX 24.0
LU-11 16.6

NOTES:

1. Basemap generated in ArcGIS version 8.1 from Seattle Public Utilities Geographic Systems data, 9/28/99. Overwater structure data updated, 12/18/03. Projection in Washington State Plane Coordinates, North Zone, HARN 1983/1991.
2. Concentration contour map generated through interpolation using an Inverse Distance Weighted (IDW) scheme (power = 6) from 2004/05 grab samples and pre-2005 data. Maximum reach from each sampling location is equal to 500 feet. Contoured interval may differ from actual data shown due to influence by neighboring data values.
3. Total polycyclic aromatic hydrocarbon (TPAH) concentrations represent the total sum of 16 individual PAH compounds. In accordance with Ecology's Sediment Management Standards, individual PAH concentrations below the detection limit (DL) were not included when calculating the sum.
4. Data sets include King County 2000 (527), RETEC March 2002, TAMU July 2002, RETEC October 2002, and RETEC April 2005.
5. Spatial cluster analysis conducted using SPSS version 10.0 square euclidean distance, between groups linkage and z-scores to reduce variance. Variables included PAHs, dibenzofuran, carbazole, and metals.

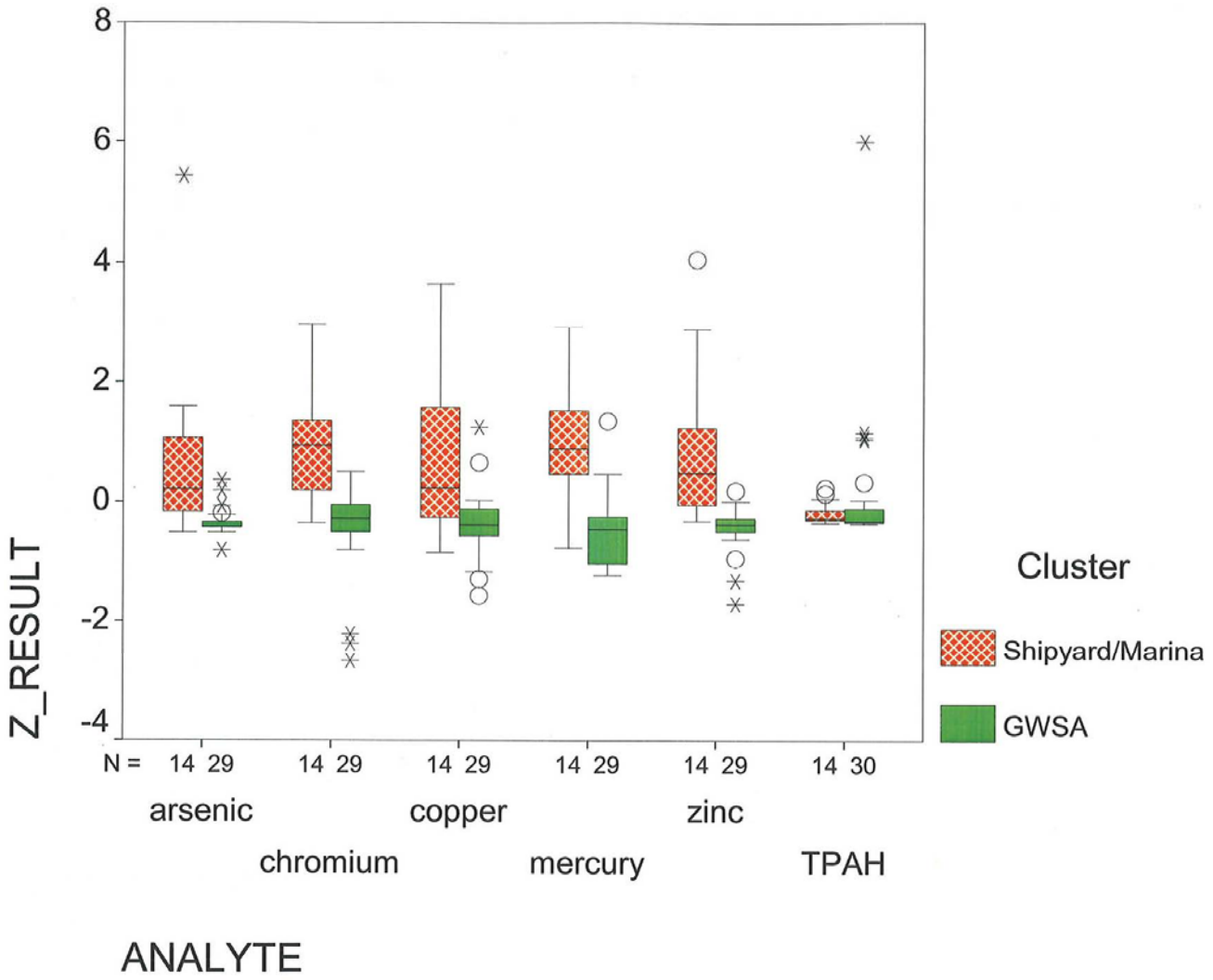
RETEC

FILE: T:/LakeUnion_N83/Projects/NLU/TPAHCleanUp_SD2005/ClusterMap_3_1.mxd

CLEANUP STANDARD DETERMINATION
GAS WORKS SEDIMENT AREA
PSE10-18628-610

SPATIAL CLUSTER MAPPING OF DATA GROUPS AMONG BIOASSAY STATIONS

DATE: 7/21/05 | DWN. BY: KBL/ftc | **FIGURE: 3-1**



NOTES

z-score = transformation of the data values to standard deviation units (range is from -3 to +3 with zero z-score as the mean value of the dataset); indicates the relative position of each value within its distribution.

Boxplot = The horizontal line in the box represents the median value. The lower edge of the box marks the 25th percentile; the upper edge of the box marks the 75th percentile. The upper and lower horizontal lines on the "whiskers" represent the highest and lowest observed non-outlier values, respectively. A circle denotes values more than 1.5 box lengths from the 75th (or 25th) percentile; an asterisk denotes values more than 3 box lengths from the 75th (or 25th) percentile.

N = Sample size. Data results shown in pairs (corresponding to Shipyard/Marina and GWSA clusters) for each chemical.

RETEC

GWSA CLEANUP STANDARD DETERMINATION GAS WORKS SEDIMENT AREA PSE10-18628-610		GWSA CLUSTER COMPARISON, PHASES 2 & 3 PRINCIPAL CHEMISTRY (z-scores)
Date: 08/31/05	File: PSE/PSEN GW1/5	FIGURE 3-2

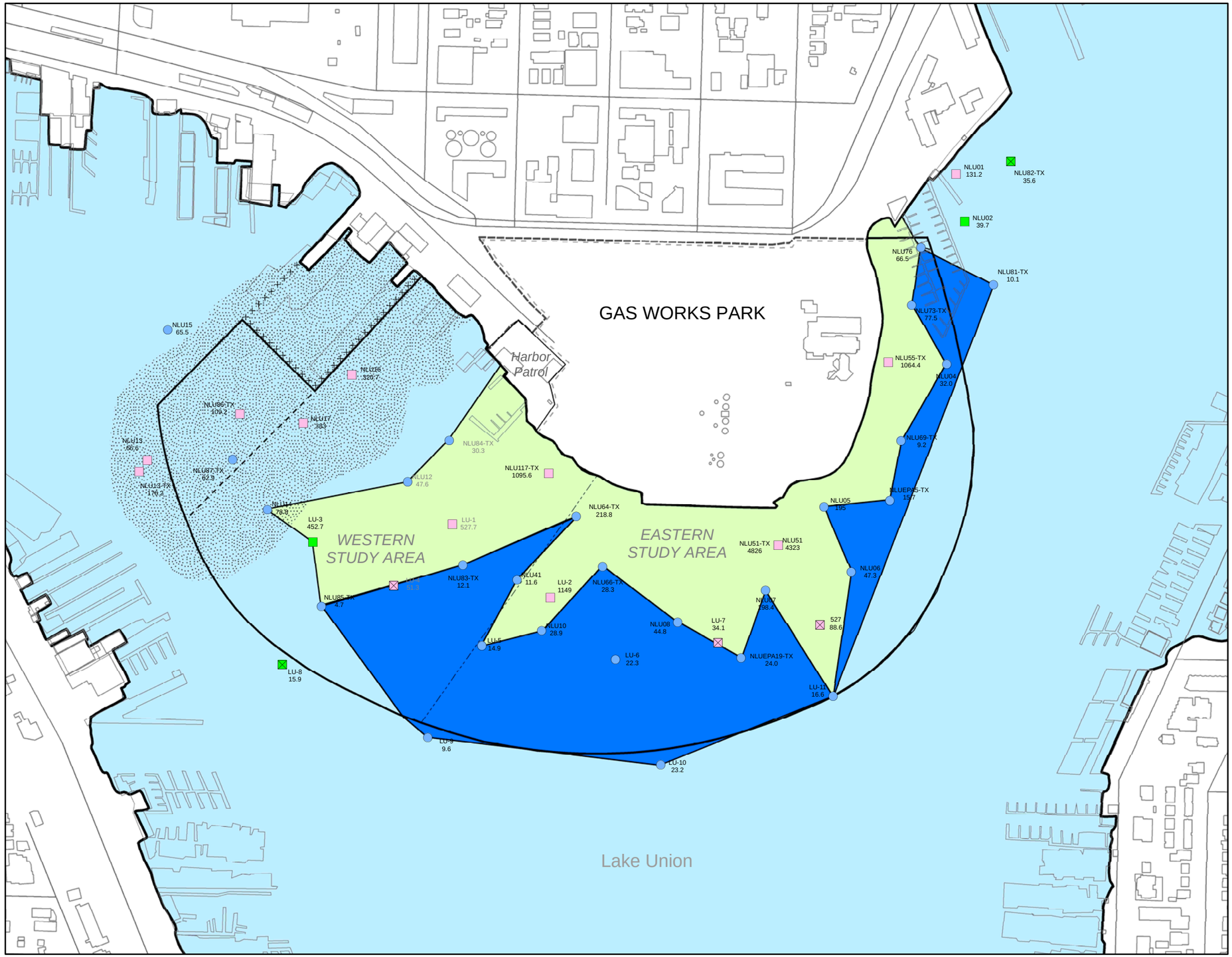
0 150 300 Feet

N

Phase 2 and Phase 3 (2002 and 2005)
Surface Sediment Bioassay Sampling Stations

- Pass
- SQS Failure
- Microtox Only SQS Failure
- CSL Failure
- Microtox Only CSL Failure

- Initial Area of Investigation
- Shipyard Consent Decree Boundary
- Uplands Boundary As Defined By The Consent Decree (December 1999)
- Division Between Eastern And Western Study Areas
- Harbor Patrol Boundary
- Gas Works Park Boundary
- Bioassay Fail Area
- Bioassay Pass Area
- Primary Shipyard Metals Impact



NOTES:

1. Basemap generated in ArcGIS version 8.1 from Seattle Public Utilities Geographic Systems data, 9/28/99. Overwater structure data updated, 12/18/03. Projection in Washington State Plane Coordinates, North Zone, HARN 1983/1991.
2. Concentration contour map generated through interpolation using an Inverse Distance Weighted (IDW) scheme (power = 6) from 2004/05 grab samples and pre-2005 data. Maximum reach from each sampling location is equal to 500 feet. Contoured interval may differ from actual data shown due to influence by neighboring data values.
3. The number given below the sample name is the TPAH concentration (ppm), concentrations represent the total sum of 16 individual PAH compounds. In accordance with Ecology's Sediment Management Standards, individual PAH concentrations below the detection limit (DL) were not included when calculating the sum.
4. Data sets include King County 2000 (527), RETEC March 2002, TAMU July 2002, RETEC October 2002, and RETEC April 2005.
5. Results based on H. *azteca* 10-day mortality H. *azteca* 28-day mortality and growth, C. *tentans* 10-day mortality, C. *tentans* 20-day mortality and growth, and Microtox bioassay tests. The Microtox data presented for the 5 minute and 15 minute bioluminescence endpoints
6. Bioassay pass/fail results based on Ecology's proposed freshwater bioassay decision criteria.
7. SQS failure = avg T-R >10 or 15% for mortality endpoint; avg biomass of T/R < 0.75 for growth endpoint; avg decrease T/R <0.85 for luminescence. T = test and R = reference.
8. CSL failure = avg T-R >25% for mortality endpoint; avg biomass of T/R < 0.6 for growth endpoint; avg decrease T/R < 0.75 for luminescence; two SQS failures.

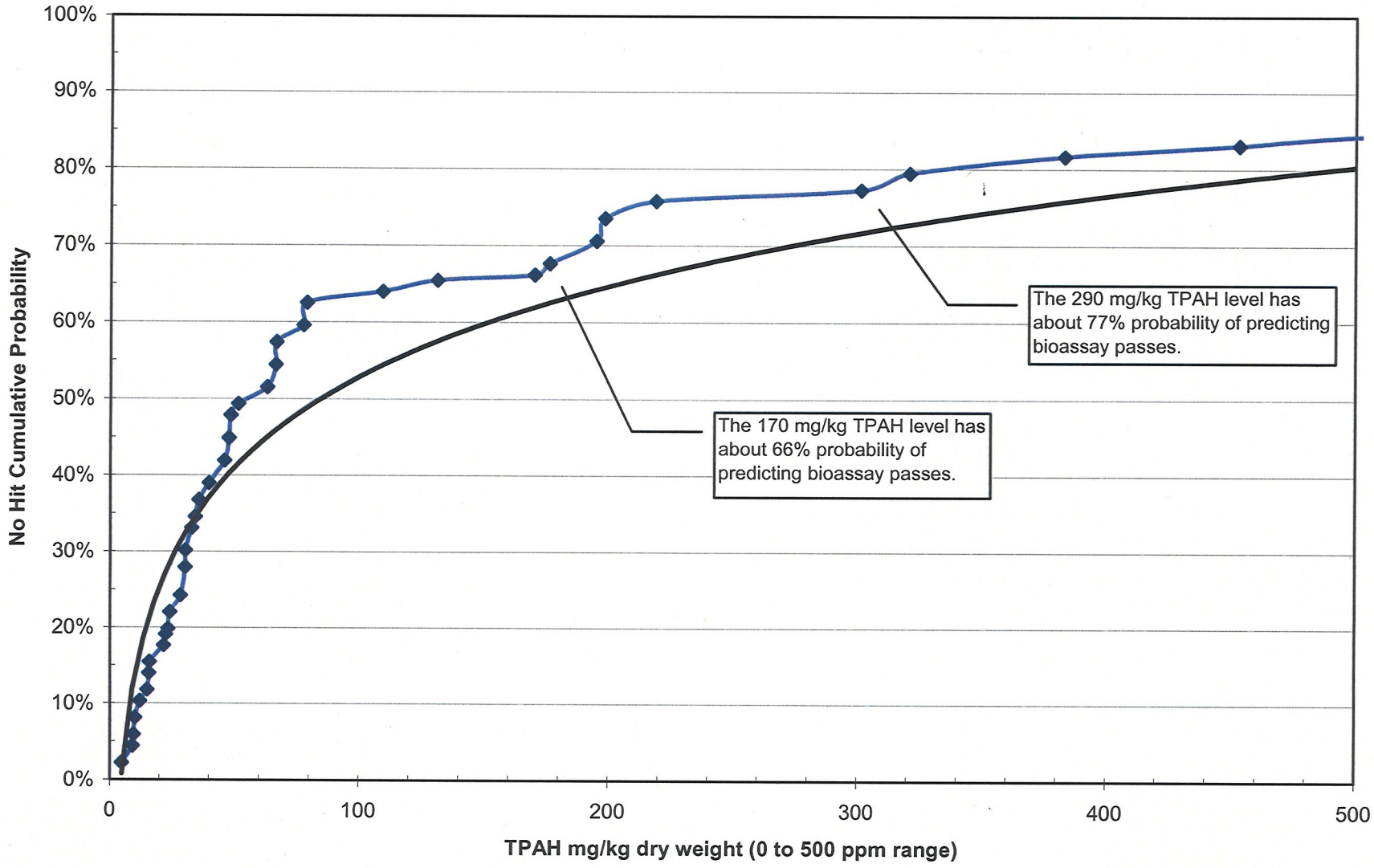
RETEC

FILE: T:/LakeUnion_N83/Projects/NLU/TPAH/CleanUp_SD2005/Bioassay_PassArea_3_2.mxd

GWSA CLEANUP STANDARD DETERMINATION
GAS WORKS SEDIMENT AREA
PSE10-18628-610

BIOASSAY PASS AREA

DATE: 7/21/05 | DWN. BY: KBL/ftc | **FIGURE: 3-3**



RETEC

GWSA CLEANUP STANDARD DETERMINATION GAS WORKS SEDIMENT AREA PSE10-18628-610		CUMULATIVE PROBABILITY OF BIOASSAY PASSES AND TPAH CONCENTRATION
Date: 08/16/05	File: PSE/PSEN GW1/5	FIGURE 4-1

0 150 300 Feet

N

Phase 2 and Phase 3 (2002 and 2005)
Surface Sediment Bioassay Sampling Stations

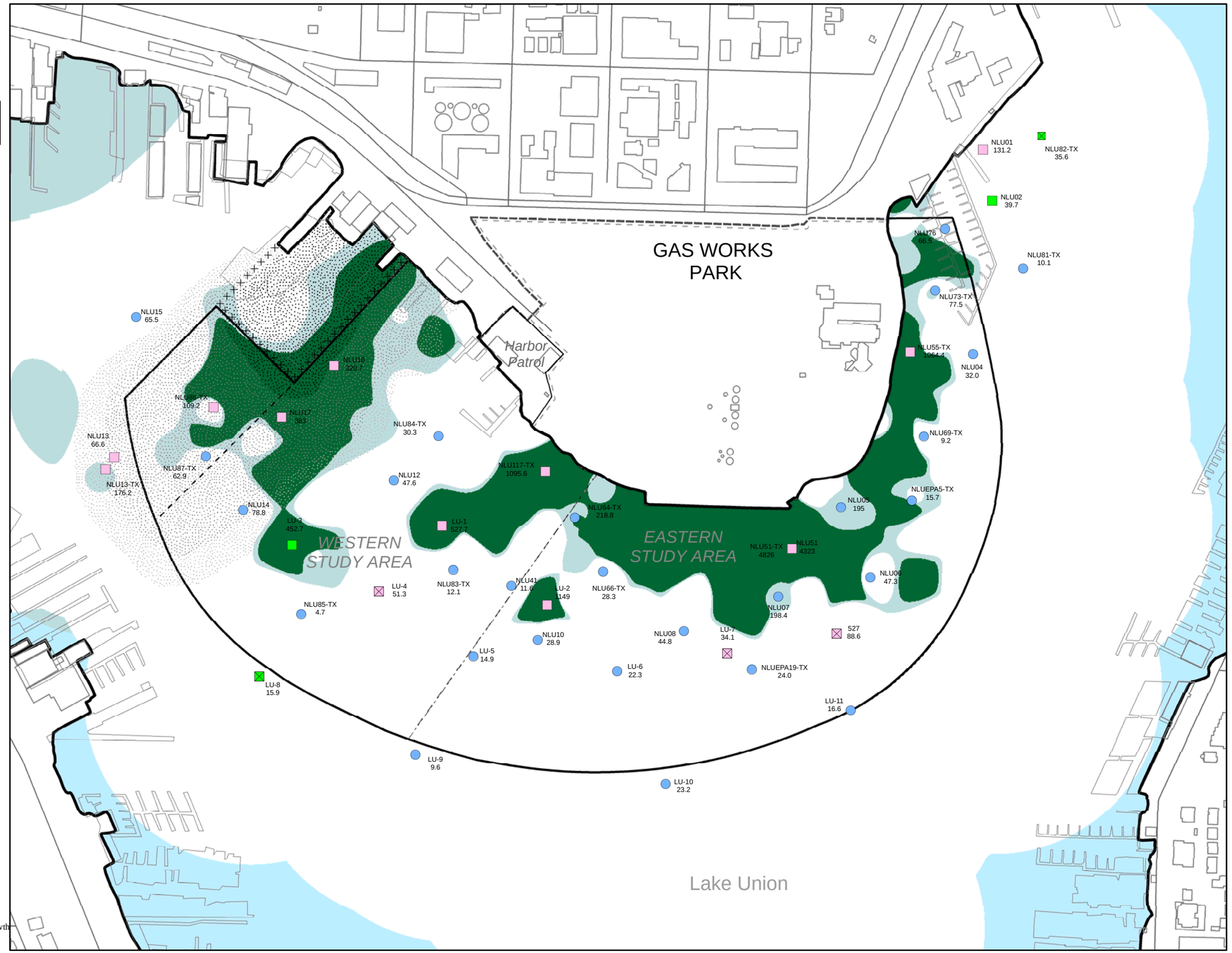
- Pass
- SQS Failure
- Microtox Only SQS Failure
- CSL Failure
- Microtox Only CSL Failure

- Initial Area of Investigation
- Shipyard Consent Decree Boundary
- Uplands Boundary As Defined By The Consent Decree (December 1999)
- Division Between Eastern And Western Study Areas
- Harbor Patrol Boundary
- Gas Works Park Boundary
- Primary Shipyard Metals Impact

Interpolated TPAH Concentrations (mg/kg dry wt.) *

- < 170
- 170 - 290 (SSQL Area)
- > 290 (SSCL Area)
- No data available, or, if data exists, interpolation not shown

* Western Study Area values are preliminary and not validated



NOTES:
1. Basemap generated in ArcGIS version 8.1 from Seattle Public Utilities Geographic Systems data, 9/28/99. Overwater structure data updated, 12/18/03. Projection in Washington State Plane Coordinates, North Zone, HARN 1983/1991.
2. Concentration contour map generated through interpolation using an Inverse Distance Weighted (IDW) scheme (power = 6) from 2004/05 grab samples and pre-2005 data. Maximum reach from each sampling location is equal to 500 feet. Contoured interval may differ from actual data shown due to influence by neighboring data values.
3. The number given below the sample name is the TPAH concentration (ppm), concentrations represent the total sum of 16 individual PAH compounds. In accordance with Ecology's Sediment Management Standards, individual PAH concentrations below the detection limit (DL) were not included when calculating the sum.
4. Data sets include King County 2000 (527), RETEC March 2002, TAMU July 2002, RETEC October 2002, and RETEC April 2005.
5. Results based on H. *azteca* 10-day mortality H. *azteca* 28-day mortality and growth, C. *tentans* 10-day mortality, C. *Tentans* 20-day mortality and growth, and Microtox bioassay tests. The Microtox data presented for the 5 minute and 15 minute bioluminescence endpoints.
6. Bioassay pass/fail results based on Ecology's proposed freshwater bioassay decision criteria.
7. The number given below the sample name is the TPAH concentration (ppm).
8. SQS failure = avg T-R >10 or 15% for mortality endpoint; avg biomass of T/R < 0.75 for growth endpoint; avg decrease T/R <0.85 for luminescence. T = test and R = reference.
9. CSL failure = avg T-R >25% for mortality endpoint; avg biomass of T/R < 0.6 for growth endpoint; avg decrease T/R < 0.75 for luminescence; two SQS failures.

RETEC

FILE: T:/LakeUnion_N83/Projects/NLU/TPAHCleanUp_SD2005/Bioassay_AreaBound_5_1.mxd

CLEANUP STANDARD DETERMINATION
GAS WORKS SEDIMENT AREA
PSE10-18628-610

SSQL AND SCSL AREAS

DATE: 7/21/05 | DWN. BY: KBL/ftc | **FIGURE: 5-1**

0 150 300 Feet

N

Phase 2 and Phase 3 (2002 and 2005)
Surface Sediment Bioassay Sampling Stations

- Pass
- SQS Failure
- Microtox Only SQS Failure
- CSL Failure
- Microtox Only CSL Failure

- GWSA Boundary
- Initial Area of Investigation
- Shipyard Consent Decree Boundary
- Uplands Boundary As Defined By The Consent Decree (December 1999)
- Division Between Eastern And Western Study Areas
- Harbor Patrol Boundary
- Gas Works Park Boundary
- Primary Shipyard Metals Impact

Interpolated TPAH Concentrations (mg/kg dry wt.) *

- < 170
- 170 - 290 (SSQL Area)
- > 290 (SSCL Area)
- No data available, or, if data exists, interpolation not shown

* Western Study Area values are preliminary and not validated

NOTES:

1. Basemap generated in ArcGIS version 8.1 from Seattle Public Utilities Geographic Systems data, 9/28/99. Overwater structure data updated, 12/18/03. Projection in Washington State Plane Coordinates, North Zone, HARN 1983/1991.
2. Concentration contour map generated through interpolation using an Inverse Distance Weighted (IDW) scheme (power = 6) from 2004/05 grab samples and pre-2005 data. Maximum reach from each sampling location is equal to 500 feet. Contoured interval may differ from actual data shown due to influence by neighboring data values.
3. The number given below the sample name is the TPAH concentration (ppm), concentrations represent the total sum of 16 individual PAH compounds. In accordance with Ecology's Sediment Management Standards, individual PAH concentrations below the detection limit (DL) were not included when calculating the sum.
4. Data sets include King County 2000 (527), RETEC March 2002, TAMU July 2002, RETEC October 2002, and RETEC April 2005.
5. Results based on H. *azteca* 10-day mortality H. *azteca* 28-day mortality and growth, C. *tentans* 10-day mortality, C. *Tentans* 20-day mortality and growth, and Microtox bioassay tests. The Microtox data presented for the 5 minute and 15 minute bioluminescence endpoints.
6. Bioassay pass/fail results based on Ecology's proposed freshwater bioassay decision criteria.
7. SQS failure = avg T-R >10 or 15% for mortality endpoint; avg biomass of T/R < 0.75 for growth endpoint; avg decrease T/R <0.85 for luminescence. T = test and R = reference.
8. CSL failure = avg T-R >25% for mortality endpoint; avg biomass of T/R < 0.6 for growth endpoint; avg decrease T/R < 0.75 for luminescence; two SQS failures.
9. The dashed portion of the AB will be further refined as part of the Western Study Area RI/FS process.

RETEC

GAS WORKS PARK

Harbor Patrol

WESTERN STUDY AREA

EASTERN STUDY AREA

NLU15 65.5
NLU16 320.7
NLU86-TX 109.2
NLU17 383
NLU13 66.6
NLU13-TX 176.2
NLU87-TX 62.9
NLU14 78.8
LU-3 452.7
NLU84-TX 30.3
NLU12 47.6
LU-1 527.7
LU-4 51.3
NLU83-TX 12.1
NLU85-TX 4.7
LU-8 15.9
LU-5 14.9
NLU10 28.9
LU-6 22.3
LU-9 9.6
LU-10 23.2
LU-11 16.6
NLU117-TX 1095.6
NLU64-TX 218.8
NLU01 11.9
LU-2 1149
NLU66-TX 28.3
NLU08 44.8
LU-7 34.1
NLUEPA19-TX 24.0
NLU07 198.4
NLU51-TX 4826
NLU51 4323
NLU05 195
NLU06 47.3
527 88.6
NLUEPA5-TX 15.7
NLU69-TX 9.2
NLU04 32.0
NLU55-TX 1064.4
NLU73-TX 77.5
NLU81-TX 10.1
NLU76 66.5
NLU02 39.7
NLU01 131.2
NLU82-TX 35.6

CLEANUP STANDARD DETERMINATION GAS WORKS SEDIMENT AREA PSE10-18628-610			**GWSA BOUNDARY**
DATE: 8/9/05	DWN. BY: KBL/ftc		**FIGURE: 5-2**

FILE: T:/LakeUnion_N83/Projects/NLU/TPAHCleanUp_SD2005/GWSA_AreaBound_5_2.mxd

Figure 5-3a. TPAH Concentration vs. Distance from Shoreline
Eastern Study Area – East

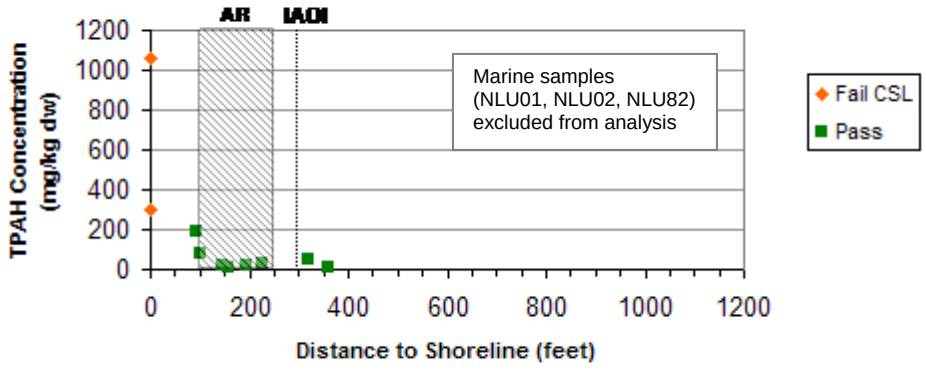


Figure 5-3b. TPAH Concentration vs. Distance from Shoreline
Eastern Study Area – South

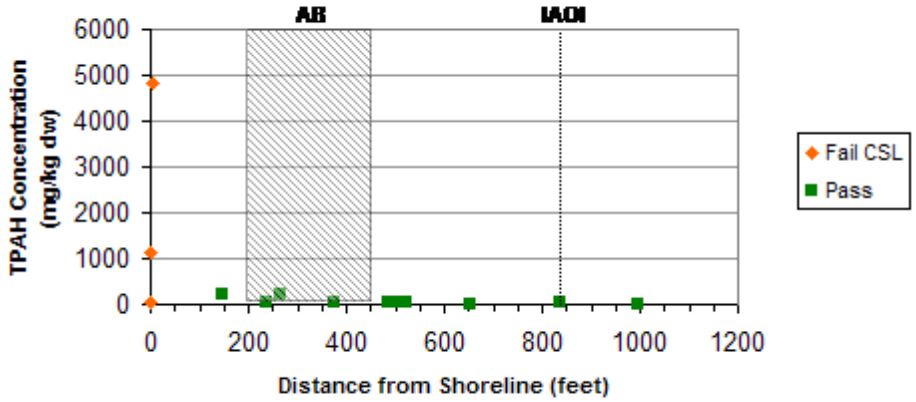
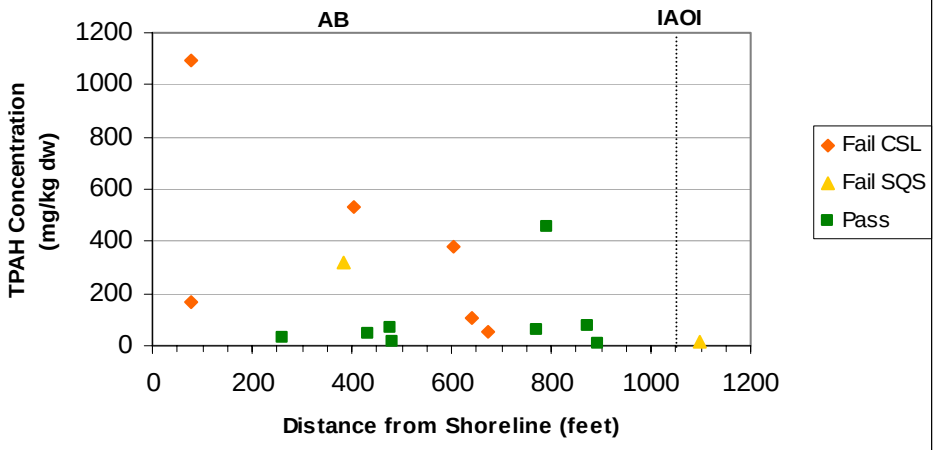


Figure 5-3c. TPAH Concentration vs. Distance from Shoreline
Western Study Area



Notes:

1. Distance from shoreline for surface sediment bioassay results (2002 - 2005)
2. Pass/Fail results based on Ecology's draft decision criteria for freshwater sediment bioassays
3. AB = GWSA Boundary
4. AOI = Area of Interest

RETEC

GWSA CLEANUP STANDARD DETERMINATION GAS WORKS SEDIMENT AREA	BIOASSAY RESULTS RELATIVE TO DISTANCE FROM SHORE
Date: 08/16/05 File: PSE\8628\GW1\5	FIGURE 5-3

Appendix A

Field Summary Tables

Table A-1. Field Parameters Measured during North Lake Union Phase 3 Bioassay Sample Collection

Station ID	Sampling Date	Overlying Water Field Parameters*						Sediment Field Parameters	
		Temperature ºC	Dissolved Oxygen mg/L	pH	ORP in water mV	Salinity ppt	Conductivity µmho/cm	ORP in sediment (@ 3 cm) mV	ORP in sediment (@ 12 cm) mV
NLU13-TX-0010	4/13/2005	10.85	11.50	7.63	106.7	0	16.92	279	-32
NLU41-TX-0010	4/13/2005	10.65	15.50	7.78	72.3	0	18.32	-53	-116
NLU51-TX-0010	4/14/2005	11.17	10.63	6.93	231.8	0	14.56	34	-23
NLU55-TX-0010	4/15/2005	n/a	n/a	n/a	n/a	0	n/a	-90	-152
NLU64-TX-0010	4/14/2005	10.95	12.15	7.35	145.0	0	14.52	201	143
NLU66-TX-0010	4/14/2005	9.65	1.24	6.86	152.0	0	15.38	173	142
NLU69-TX-0010	4/14/2005	10.89	10.72	6.97	122.5	0	15.35	68	-23
NLU73-TX-0010	4/14/2005	10.73	11.16	6.86	137.2	0	15.46	191	162
NLU76-TX-0010	4/13/2005	11.30	11.59	6.06	143.6	0	18.17	142	-38
NLU81-TX-0010	4/13/2005	11.01	9.90	6.10	140.0	0	45.55	228	189
NLU82-TX-0010	4/13/2005	11.03	11.37	6.19	138.9	0	16.01	32	-17
NLU83-TX-0010	4/13/2005	10.60	9.62	6.50	96.2	0	19.95	118	-70
NLU84-TX-0010	4/14/2005	10.77	7.45	6.04	258.4	0	14.22	-151	-154
NLU85-TX-0010	4/13/2005	11.01	9.79	6.09	163.4	0	15.98	175	-73
NLU86-TX-0010	4/14/2005	11.10	8.65	6.71	221.0	0	14.49	-25	-11
NLU87-TX-0010	4/13/2005	11.03	11.26	6.38	152.1	0	15.66	224	164
NLU117-TX-0010	4/14/2005	10.84	11.78	7.61	240.3	0	14.58	117	-132
NLU-EPA5-TX-0010	4/14/2005	10.64	11.62	7.31	128.3	0	14.77	254	192
NLU-EPA19-TX-0010	4/14/405	9.93	11.48	6.67	151.8	0	16.88	121	-3
NLU-Ref1-TX-0010 Grab 1	4/15/2005	9.42	13.35	7.14	194.3	0	12.58	218	158
NLU-Ref1-TX-0010 Grab 2	4/15/2005	9.53	12.36	6.40	220.9	0	12.17	184	184
NLU-Ref2-TX-0010	4/15/2005	9.40	12.40	7.20	214.2	0	12.84	130	90

Notes:

n/a – not analyzed. Sheen was observed on water.

*Water directly (2 cm depth over) overlying the sediment was collected with a pipette for analysis in Horiba U-22 Flow-Thru Cell.

Table A-2 Phase 3 Bioassay Surface Sediment Grain Size (PSEP) – April 2005

Percent Retained in Each Size Fraction	Gravel	Sand						Silt				Clay			% Fines (sum of all silt and clay)
		Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Total Sand	Coarse Silt	Medium Silt	Fine Silt	Very Fine Silt				
Phi Size	> -1	-1 to 0	0 to 1	1 to 2	2 to 3	3 to 4		4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	< 10	
Sieve Size (microns)	> #10 (2000)	10 to 18 (2000-1000)	18-35 (1000-500)	35-60 (500-250)	60-120 (250-125)	120-230 (125-62)		62.5-31.0	31.0-15.6	15.6-7.8	7.8-3.9	3.9-2.0	2.0-1.0	<1.0	
NLU13-TX-0010	0.8	1	6.4	5.3	6.2	5	23.9	1.8	12.2	16.2	18.2	9.8	6.7	10.4	75.3
NLU41-TX-0010	< 0.01	0.2	11.1	8.7	8.7	10.2	38.9	4.6	14.2	12.4	13.7	7.0	3.3	5.8	61
NLU51-TX-0010	3.7	2.4	6.9	16.1	23.2	13.2	61.8	4.1	6.1	7.6	5.4	3.6	1.5	6.1	34.4
NLU55-TX-0010	17.4	5.4	8.8	13.6	27.7	17.1	72.6	2.4	1.8	1.4	1.7	1.2	0.7	0.8	10
NLUD55-TX-0010	8.3	5.4	8.2	12.6	22.6	16.7	65.5	5.5	5.8	4.9	3.9	2.7	1.6	1.7	26.1
NLU64-TX-0010	0.1	1.1	14.3	10.0	11.3	10.8	47.5	5.8	12.9	11.3	9.1	5.7	3.3	4.3	52.4
NLU66-TX-0010	< 0.01	0.4	12.2	8.3	8.3	9.4	38.6	4.0	14.9	14.0	12.4	6.7	3.7	5.9	61.6
NLU69-TX-0010	< 0.01	0.9	13.4	7.1	7.5	9.4	38.3	5.8	16.0	13.6	11.9	6.0	3.3	5.1	61.7
NLU73-TX-0010	0.3	0.6	8.8	10.6	16.4	17.9	54.3	10.3	9.8	9.0	7.5	4.2	2.0	2.7	45.5
NLU173-TX-0010	1.0	0.6	8.6	10.1	15.4	18.0	52.7	9.6	11.2	8.1	7.8	4.2	2.6	2.8	46.3
NLU76-TX-0010	< 0.01	0.3	9.7	9.2	13.4	14.8	47.4	8.3	14.3	11.2	8.6	4.6	2.9	2.8	52.7
NLU81-TX-0010	0.1	0.5	11.9	8.1	8.7	10.7	39.9	7.3	16.1	11.3	10.9	5.9	3.7	4.9	60.1
NLU82-TX-0010	0.1	0.3	6.5	12.9	23.5	15.9	59.1	8.0	11.1	7.4	6.0	3.4	2.2	2.8	40.9
NLU83-TX-0010	< 0.01	1.0	12.8	7.6	7.8	8.5	37.7	3.2	14.0	13.5	13.6	7.3	3.9	6.8	62.3
NLU84-TX-0010	< 0.01	0.5	12.2	7.4	8.3	11.2	39.6	4.4	14.5	12.9	12.4	7.2	4.0	5.1	60.5
NLU85-TX-0010	0.5	0.4	10.5	7.6	8.0	9.8	36.3	3.8	12.8	13.9	12.9	8.3	5.0	6.5	63.2
NLU86-TX-0010	< 0.01	0.4	10.5	8.4	9.2	6.9	35.4	3.9	8.5	11.6	11.2	7.9	5.8	15.6	64.5
NLU87-TX-0010	< 0.01	0.4	10.6	6.9	8.8	8.0	34.7	3.8	10.8	14.3	13.3	9.0	5.3	8.9	65.4
NLU117-TX-0010	0.8	1.6	10.1	13.2	17.0	10.5	52.4	2.8	7.9	8.9	7.6	5.7	3.5	10.2	46.6
NLUD117-TX-0010	4.2	2.5	7.7	11.3	14.5	12.2	48.2	8.5	11.1	8.3	7.8	4.9	3.2	3.8	47.6
NLUEPA19-TX-0010	5.6	0.8	12.7	10.4	10.6	11.3	45.8	2.7	10.3	10.6	11.4	6.0	2.8	4.9	48.7
NLUEPA5-TX-0010	< 0.01	0.7	12.9	7.3	7.7	10.1	38.7	10.4	13.2	10.9	11.0	6.6	3.8	5.5	61.4
NLUREF1-TX-0010	10.1	3.3	6.6	13.2	16.7	14.7	54.5	15.9	8.7	4	2.6	1.7	1	1.5	35.4
NLUREF2-TX-0010	1.4	0.9	6.8	6.3	6.9	7.5	28.4	7.5	16.6	14.9	14.8	7.7	3.6	5.2	70.3

Note:
All grain size results are considered J-flagged as estimated values because of the apparent influence of organic material on sieving results
Grain size analysis by PSEP method.

Table A-3. Phase 2 Surface Sediment Grain Size – October 2002

Percent Retained in Each Size Fraction	Gravel	Sand						Silt				Clay			Total Fines
		Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Total Sand	Coarse Silt	Medium Silt	Fine Silt	Very Fine Silt				
Phi Size	>-1	-1 to 0	0 to 1	1 to 2	2 to 3	3 to 4		4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	<10	
Sieve Size (microns)	>#10 (2000)	10 to 18 (2000-1000)	18-35 1000-500)	35-60 (500-250)	60-120 (250-125)	120-230 (125-62)		62.5-31.0	31.0-15.6	15.6-7.8	7.8-3.9	3.9-2.0	2.0-1.0	<1.0	
NLU01-SS-0010A	2.3	3.1	5.6	21.8	21.2	7.9	59.7	6.5	9.4	8.1	7.2	3.0	1.4	2.4	38.0
NLU01-SS-0010B	1.6	3.5	6.2	21.3	21.2	8.0	60.2	6.8	9.4	8.0	6.7	2.8	1.8	2.7	38.2
NLU01-SS-0010C	1.5	3.4	6.2	22.5	21.1	8.1	61.3	5.2	9.8	7.9	6.8	3.0	2.0	2.5	37.2
NLU02-SS-0010	6.2	8.2	4.0	6.2	13.5	9.2	41.1	17.2	10.2	7.0	7.8	4.2	2.3	3.9	52.7
NLU04-SS-0010	1.9	11.4	8.4	4.9	4.5	5.7	35.0	20.4	10.9	8.4	9.7	5.0	2.5	6.2	63.1
NLU05-SS-0010	27.5	8.2	17.3	31.1	13.2	1.5	71.3	0.8	0.1	0.1	0.1	0.0	0.0	0.1	1.2
NLU06-SS-0010	0.1	12.4	14.2	10.8	9.6	9.4	56.3	5.6	10.6	7.7	8.2	4.5	2.8	4.1	43.6
NLU07-SS-0010	0.1	1.1	18.1	13.8	12.8	11.3	57.0	3.6	10.3	8.2	8.0	4.8	3.1	4.9	42.9
NLU08-SS-0010	2.8	16.6	8.2	5.1	5.1	5.5	40.5	6.4	15.3	10.9	9.5	5.0	3.0	6.5	56.7
NLU100-SS-0010	4.4	5.3	6.7	8.9	16.2	13.0	50.1	5.3	11.6	8.9	8.4	4.9	2.3	4.0	45.5
NLU10-SS-0010	1.0	7.8	9.7	7.7	7.4	7.9	40.6	4.2	16.3	11.4	10.3	5.7	2.5	8.0	58.4
NLU12-SS-0010	0.6	15.6	9.6	6.2	6.2	6.8	44.4	3.1	13.3	12.3	11.4	5.4	2.2	7.3	55.0
NLU13-SS-0010	0.1	1.2	1.5	2.4	7.3	5.8	18.2	2.7	16.3	15.8	17.3	12.1	7.8	9.7	81.7
NLU14-SS-0010	1.6	6.4	8.0	7.3	8.4	5.9	35.9	12.6	8.5	10.0	12.1	6.0	4.8	8.4	62.5
NLU15-SS-0010	0.3	2.1	10.3	7.6	8.5	11.2	39.6	5.3	17.5	12.8	10.0	4.8	3.5	6.4	60.1
NLU16-SS-0010	0.5	10.2	9.2	6.9	8.5	8.3	43.1	2.3	10.4	12.8	13.1	5.8	3.9	8.1	56.4
NLU17-SS-0010	0.2	0.4	0.7	1.1	7.0	7.6	16.9	4.0	12.4	17.1	17.6	12.0	7.1	12.8	83.0
NLU21-SS-0010	21.3	12.4	11.8	19.8	14.6	4.7	63.3	-3.2	3.5	3.9	4.5	2.9	1.4	2.5	15.3
NLU22-SS-0010	25.5	16.6	11.9	12.9	9.2	3.9	54.4	-0.3	3.6	4.1	5.5	3.2	1.2	2.7	20.0

Notes:

Results are for samples collected by RETEC in October 2002 and analyzed by RETEC (using Rosa).

Grain size analysis by PSEP method.

Table A-4. Phase 2 Surface Sediment Grain Size, Solids and TOC – March 2002

Sample ID	Ecology Analyses						RETEC Analyses	
	% Gravel	% Sand	% Silt	% Clay	Solids	% TOC	Solids	% TOC
	>2,000 µm	2,000 < X < 62.5 µm	62.5 < X < 4 µm	<4 µm	%	(104°C)	%	(104°C)
LU-1	8.1	27.8	38.8	25.2	16.9	15.5	16.2	5.8
LU-2	1.8	42.6	43.6	12.0	19.6	14.2	18.2	9.3
LU-3	8.8	12.8	48.9	29.5	15.1	13.7	14.3	6.6
LU-4	5.8	8.0	52.7	33.6	14.8	10.6	14.0	6.7
LU-5	10.0	16.8	48.6	24.6	11.0	13.6	12.4	6.7
LU-6	3.6	8.5	68.5	19.4	10.8	15.3	10.5	8.3
LU-7	17.8	6.7	51.4	24.0	10.9	15.3	10.4	9.1
LU-8	4.9	8.0	50.7	36.4	14.8	10.1	15.3	8.1
LU-9	3.0	6.7	62.8	27.4	12.1	12.6	12.4	8.8
LU-10	4.4	10.0	64.9	20.6	12.0	13.8	11.2	8.4
LU-11	10.1	11.4	57.8	20.7	11.8	13.5	12.3	7.1
Ref-1	10.2	60.5	24.8	4.6	33.2	4.2	34.7	4.2
Ref-2	17.6	51.4	26.0	5.0	10.4	25.5	10.6	13.0

Notes:

Results are for samples collected by Ecology in March 2002 and analyzed by Ecology (using Manchester and Rosa) and analyzed by RETEC (using ARI and Rosa).

Grain size analyses conducted according to methods specified in Table 2-1.

TOC analyzed according to PSEP (1996) for Ecology analysis and according to Plumb, 1981 for RETEC analysis.

Ref - Reference samples collected from Webster Point.

Appendix B

Summary Tables for Synoptic Chemistry (2002 and 2005)

Table B-1. Phase 3 Bioassay Surface Sediment Sample Data Summary

Analyte	Screening Criteria (mg/kg unless otherwise indicated)[1] LAET (SQS)	Screening Criteria (mg/kg unless otherwise indicated)[1] 2LAET (CSL)	Sample Name: NLU13-TX	NLU41-TX	NLU51-TX	NLU55-TX	NLUD55-TX0010	NLU64-TX	NLU66-TX	NLU69-TX	NLU73-TX	NLU173-TX	NLU76-TX	NLU81-TX	NLU82-TX	NLU83-TX	NLU84-TX	NLU85-TX	NLU86-TX	NLU87-TX	NLU117-TX	NLUD117-TX0010	NLUEPA5-TX	NLUEPA19-TX	NLURef1-TX	NLURef2-TX
			Sample ID: NLU13-TX-0010	NLU41-TX-0010	NLU51TX0010	NLU55-TX0010	NLUD55-TX0010	NLU64TX0010	NLU66TX0010	NLU69TX0010	NLU73TX0010	NLU173TX0010	NLU76-TX-0010	NLU81-TX-0010	NLU82-TX-0010	NLU83-TX-0010	NLU84TX0010	NLU85-TX-0010	NLU86TX0010	NLU87-TX-0010	NLU117TX0010	NLUD117-TX0010	NLUEPA5TX0010	NLUEPA19TX0010	NLUREF1-TX0010	NLUREf2-TX0010
			Sample Date: 4/13/2005	4/13/2005	4/14/2005	4/15/2005	4/28/2005	4/14/2005	4/14/2005	4/14/2005	4/14/2005	4/14/2005	4/13/2005	4/13/2005	4/13/2005	4/13/2005	4/14/2005	4/13/2005	4/14/2005	4/13/2005	4/14/2005	4/28/2005	4/14/2005	4/14/2005	4/15/2005	4/15/2005
			Depth Interval (ft): 0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33
							Diluted sample of NLU55-TX					*Duplicate of NLU73-TX-0010*										*Diluted sample of NLU117-TX*					
Conventionals/Misc.																										
Sulfide (mg/kg)	702	941	140	710	150	270	250	370	2000	2400	220 J	640 J	240	3600	560	1600	3000	2300	590	90	1800	470	160	1500	< 7.1	130
N-Ammonia (mg-N/kg)	NA	NA	76.1	58.8	28.2	41.7	37.8	22.9	59.3	150	60.7	62.2	69.3	28.1	82.8	64.9	63.2	25.5	68.0	59.7	49.0	33.1	54.4	67.8	18.7	38.4
Total Organic Carbon (%) - ARI	9.82%	NA	10.4	12.3	35.3	11.6	6.97	16.8	12.5	15.7	17.5 J	98.4 J	13.5	17.8	7.82	14.0	10.0	11.5	9.93	8.30	54.4	9.41	20.6	20.5	3.77	5.04
Total Organic Carbon (%) - WH	9.82%	NA	4.90	5.00	16.0	20.0	--	9.50	6.00	4.50	8.90	7.80	5.90	6.60	5.60	4.40	4.80	5.10	4.30	4.80	16.0	--	4.20	5.60	2.50	3.90
Soot Carbon as % TOC (%)	NA	NA	41	11	120	48	--	140	43	20	37	21	85	26	4.8	5.2	25	27	35	19	81	--	48	30	7.6	8.5
Total Solids (%)	NA	NA	15.0	9.40	30.9	37.9	40.1	11.4	9.50	9.00	13.7	14.1	11.7	9.90	17.6	9.50	10.3	10.6	14.0	12.4	17.4	28.0	10.8	10.2	32.4	23.1
Total Cyanide (mg/kg)	NA	NA	< 1.4	< 2.5	14	38	13 J	< 2.1	< 2.2	6.5	12 J	4.0 J	1.9	< 2.4	13	< 2.3	< 2.3	< 2.1	< 1.7	< 1.2	3.9	< 0.89	2.0	2.9	< 0.72	< 1.1
Metals (mg/kg dry weight)																										
Arsenic	31.4	50.9	100	< 60	30	70	--	< 40	< 50	< 60	70	70	< 40	< 50	40	< 50	< 50	< 50	360	130	60	--	< 50	< 50	< 20	< 20
Cadmium	2.39	2.9	3.0 J	< 2.0	0.90	0.60	--	< 2.0	< 2.0	< 2.0	< 1.0	3.0	< 2.0	< 2.0	1.0 J	< 2.0	< 2.0	< 2.0	2.0	2.0 J	2.0	--	< 2.0	< 2.0	< 0.60	0.90
Chromium	95	133	62	53	26	24	--	57	53	49	51	52	52	48	57	52	56	56	93	69	48	--	50	50	29	54
Copper	619	829	396	307	70.7	95.0	--	324	291	246	273	274	314	223	233	313	574	290	639	541	333	--	204	253	25.0	64.3
Iron	NA	NA	33700	30500	11000	15300	--	24600	26700	24900	21900	22400	28200	24700	30500	29700	33600	30600	47700	32700	28500	--	26500	26500	14700	30400
Lead	335	431	380	220	97	97 J	--	230	220	170	210	250	180	180	200	210	280	220	810	550	300	--	190	220	30 J	110 J
Mercury	0.8	3.04	2.2	< 0.50	0.40	0.50 J	--	0.60	< 0.50	< 0.50	0.50	0.70	< 0.40	< 0.50	0.40	< 0.50	1.1	0.70	2.5	1.1	1.6	--	< 0.40	< 0.50	< 0.10	0.20 J
Silver	0.545	3.5	< 2	< 3	< 1.0	< 0.7	--	< 3	< 3	< 3	< 2	< 2	< 3	< 3	< 2	< 3	< 3	< 3	3	2	2	--	< 3	< 3	< 1	2
Zinc	683	1080	662	395	153	245	--	445	423	377	399	429	412	338	542	389	528	378	1490	787	474	--	348	366	55.0	176
TBT - ion	0.260	6.65	0.63	0.42 J	0.010	0.25	--	0.87	0.54	0.28	0.39	0.37	0.53	0.29	0.62	0.45	1.3	0.52	2.3	2.1	0.57	--	0.29	0.53	0.020	0.029
LPAH (mg/kg dry weight)																										
Naphthalene	0.529	1.31	0.54	< 0.16	24	98	31	1.5	0.20	0.092 J	3.0	3.8	0.21	< 0.15	4.2	< 0.15	0.25	< 0.15	0.83	0.30	7.0	1.1	0.14 J	0.21	< 0.020	< 0.099
Acenaphthylene	0.47	0.64	2.8	< 0.16	14	16	3.6	1.8	0.18	0.15 J	1.3	1.9	0.36	< 0.15	0.41	< 0.15	0.44	< 0.15	1.6	1.4	7.8	1.2	0.18	0.18	< 0.020	< 0.099
Acenaphthene	1.06	1.32	0.95	< 0.16	58	40	12	2.5	1.0	< 0.16	1.7	2.3	0.18	< 0.15	0.31	< 0.15	0.38	< 0.15	0.91	0.40	27	5.8	0.13 J	0.18	< 0.020	0.20
Fluorene	1.07	3.85	0.78	< 0.16	36	20	5.4	1.1	0.28	< 0.16	0.83	1.1	0.18	< 0.15	0.37	< 0.15	0.22	< 0.15	0.91	0.38	20	4.2	< 0.14	0.098 J	< 0.020	< 0.099
Phenanthrene	6.10	7.57	4.8	0.52	570	120	40	6.5	1.3	0.47	6.4	7.1	1.4	0.67	2.6	0.51	1.8	0.21	1.8	1.2	48	7.4	0.75	1.2	0.062	0.29
Anthracene	1.23	1.58	3.5	0.18	180	45	10	2.3	0.43	0.18	2.0	2.3	0.46	0.21	0.80	0.16	0.69	< 0.15	1.2	0.70	19	3.8	0.23	0.32	< 0.020	0.23
2-Methylnaphthalene	0.469	0.555	< 0.53	< 0.16	4.8	32	9.9	0.32	< 0.15	< 0.16	0.74	0.90	< 0.13	< 0.15	0.14	< 0.15	0.12 J	< 0.15	0.28 J	0.17	4.9	0.66	< 0.14	< 0.15	< 0.020	< 0.099
Total LPAH [3]	6.59	9.20	13	0.70	880	340	100	16	3.4	0.89	15	18.5	2.8	0.88	8.7	0.67	3.8	0.21	7.3	4.4	130	24	1.4	2.2	0.062	0.72
HPAH (mg/kg dry weight)																										
Fluoranthene	11.1	15.0	26	1.9	970	140	49	41	5.4	1.8	12	14	3.5	1.8	5.7	1.9	5.1	0.73	20	8.5	180	32	3.0	4.6	0.10	1.3
Pyrene	8.79	16.0	33	2.0 J	1000	150	46	44	4.7	1.4	13	16	3.4	1.6	4.5	2.0	4.8	0.77	20	10	210	36	2.4	3.6	0.11	0.77
Benzo(a)anthracene	4.26	5.80	16	0.74	270	60	20	14	1.8	0.62	4.8	6.3	1.4	0.70	2.7	0.73	1.9	0.30	8.1	5.4	65	10	1.0	1.6	0.034	1.0
Chrysene	5.94	6.40	20	0.94	310	68	22	15	2.0	0.76	5.4	6.9	1.8	0.94	2.7	0.94	2.1	0.40	9.6	6.1	77	13	1.2	1.7	0.041	1.3
Benzo(b)fluoranthene [2]	5.50	6.90	14	1.4	300	58	16	23	2.3	0.98	8.0	10	2.1	1.1	3.2	1.3	3.3	0.58	11	7.2	76	13	1.8	2.4	0.045	2.1
Benzo(k)fluoranthene [2]	5.50	6.90	10	1.1	270	47	4.0	17	2.0	0.98	4.3	6.0	2.2	0.99	2.9	1.1	2.6	0.50	10	6.1	34	5.3	1.5	2.0	0.035	1.3
Benzo(a)pyrene	3.30	4.81	19	1.5	430	77	27	29	3.5	1.1	8.7	13	2.3	1.1	2.9	1.5	3.8	0.61	14	8.1	110	22	2.0	3.4	0.054	1.6
Indeno(1,2,3-cd)pyrene	4.12	5.30	11	0.79	190	60	6.5	8.4	1.4	0.32	2.6	4.0	0.94	0.52	1.1	0.92	1.2	0.31	3.9	3.4 J	95	6.6	0.57	1.1	0.038	0.90
Dibenzo(a,h)anthracene	0.800	0.839	3.8	0.18	24	8.4	2.3	1.7	0.27	< 0.16	0.69	0.97	0.22	< 0.15 J	0.30	0.19	0.28	< 0.15	0.95	0.44 J	9.8	1.6	0.14 J	0.23	< 0.020	0.39
Benzo(g,h,i)perylene	4.02	5.20	10	0.80	180	57	6.4	10	1.5	0.35	2.8	4.3	0.92	0.46	0.89	0.87	1.4	0.30	4.4	3.3 J	110	7.2	0.64	1.2	0.034	0.80
Total HPAH [4]	31.6	54.8	160	11	3900	730	200	200	25	8.3	62	81	19	9.2	27	11	27	4.5	100	59	970	150	14	22	0.49	11
TPAH (Calculated) [5]	38.23	64	180	12	4800	1060	300	220	28	9.2	78	100	22	10	36	12	30	4.7	110	63	1100	170	16	24	0.55	12
Phthalates (mg/kg dry weight)																										
Dimethylphthalate	0.311	0.436	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	0.096 J	< 0.15	< 0.16	0.073 J	0.12	0.17	< 0.15	0.18	< 0.15	0.1 J	< 0.15	< 0.34	0.13	< 0.44	< 0.13	< 0.14	0.084 J	< 0.020	< 0.099
Diethylphthalate	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
Di-n-Butylphthalate	0.103	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	0.089 J	< 0.13	< 0.15	< 0.11	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
Butylbenzylphthalate	0.260	0.366	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	0.097 J	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	0.11 J	< 0.15	< 0.34	0.12 J	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
bis(2-Ethylhexyl)phthalate	2.52	6.38	< 0.53	1.1	< 1.0	0.72	0.48	1.1	0.59	1.0	0.90	1.4	2.0	1.3	0.97	1.2	1.1	0.47	2.2	2.3	1.3	0.26	0.81	0.84	< 0.020	0.13
Di-n-Octyl phthalate	0.011	0.201	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
Phenols (mg/kg dry weight)																										
Phenol	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
2-Methylphenol	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
4-Methylphenol	0.760	2.36	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
2,4-Dimethylphenol	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
Pentachlorophenol	NA	NA	< 2.6	< 0.81	< 5.1	< 1.5	< 0.50	< 0.69	< 0.75	< 0.79	< 0.55	< 0.56	< 0.64	< 0.75	< 0.50	< 0.77	< 0.74	< 0.73	< 1.7	< 0.62	< 2.2	< 0.64	< 0.72	< 0.75	< 0.099	< 0.50

Table B-1. Phase 3 Bioassay Surface Sediment Sample Data Summary

Analyte	LAET (SQS)	2LAET (CSL)	NLU13-TX NLU13-TX-0010 4/13/2005 0- .33	NLU41-TX NLU41-TX-0010 4/13/2005 0- .33	NLU51-TX NLU51TX0010 4/14/2005 0- .33	NLU55-TX NLU55-TX0010 4/15/2005 0- .33	NLUD55-TX0010 NLUD55-TX0010 4/28/2005 0- .33 *Diluted sample of NLU55-TX*	NLU64-TX NLU64TX0010 4/14/2005 0- .33	NLU66-TX NLU66TX0010 4/14/2005 0- .33	NLU69-TX NLU69TX0010 4/14/2005 0- .33	NLU73-TX NLU73TX0010 4/14/2005 0- .33	NLU173-TX NLU173TX0010 4/14/2005 0- .33 *Duplicate of NLU73-TX-0010*	NLU76-TX NLU76-TX-0010 4/13/2005 0- .33	NLU81-TX NLU81-TX-0010 4/13/2005 0- .33	NLU82-TX NLU82-TX-0010 4/13/2005 0- .33	NLU83-TX NLU83-TX-0010 4/13/2005 0- .33	NLU84-TX NLU84TX0010 4/14/2005 0- .33	NLU85-TX NLU85-TX-0010 4/13/2005 0- .33	NLU86-TX NLU86TX0010 4/14/2005 0- .33	NLU87-TX NLU87-TX-0010 4/13/2005 0- .33	NLU117-TX NLU117TX0010 4/14/2005 0- .33	NLUD117-TX0010 NLUD117-TX0010 4/28/2005 0- .33 *Diluted sample of NLU117-TX*	NLUEPA5-TX NLUEPA5TX0010 4/14/2005 0- .33	NLUEPA19-TX NLUEPA19TX0010 4/14/2005 0- .33	NLURef1-TX NLUREF1-TX0010 4/15/2005 0- .33	NLURef2-TX NLURef2-TX0010 4/15/2005 0- .33
Misc. Extractables (mg/kg dry weight)																										
Benzyl Alcohol	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
Benzoic Acid	2.91	3.79	< 5.3 J	< 1.6 J	< 10 J	< 3.0 J	< 0.99	< 1.4 J	< 1.5 J	< 1.6 J	< 1.1 J	< 1.1 J	< 1.3 J	< 1.5 J	< 0.99 J	< 1.5 J	< 1.5 J	< 1.5 J	< 3.4 J	< 1.2 J	< 4.4 J	< 1.3	< 1.4 J	< 1.5 J	< 0.20 J	< 0.99 J
Carbazole	0.923	NA	< 0.53	< 0.16	**3.1**	**5.5**	**1.3**	**0.30**	< 0.15	< 0.16	**0.23**	**0.34**	< 0.13	< 0.15	**0.15**	< 0.15	**0.088 J**	< 0.15	**0.19 J**	**0.12**	**2.0**	**0.35**	< 0.14	< 0.15	< 0.020	< 0.099
Dibenzofuran	0.399	0.443	< 0.53	< 0.16	**3.9**	**4.7**	**1.1**	< 0.14	< 0.15	< 0.16	**0.16**	**0.21**	< 0.13	< 0.15	**0.12**	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	**5.6**	**1.0**	< 0.14	< 0.15	< 0.020	< 0.099
Hexachlorobutadiene	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
N-Nitrosodiphenylamine	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30 J	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12 J	< 0.44 J	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
Retene	6.02	NA	**0.81**	< 0.16	**6.2**	< 2.0 J	**0.34 J**	< 0.34	< 0.15	< 0.16	< 0.20	< 0.32	**0.13**	< 0.15	**0.40**	< 0.15	< 0.15	< 0.15	< 0.36	**0.41 J**	**9.8**	**2.1**	< 0.14	< 0.15	**0.22**	**4.9**
Hexachlorobenzene	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
1,2-Dichlorobenzene	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
1,3-Dichlorobenzene	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
1,4-Dichlorobenzene	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
1,2,4-Trichlorobenzene	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
Bis-(2-Chloroethyl) Ether	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
2-Chlorophenol	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
2,2'-Oxybis(1-Chloropropane)	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
N-Nitroso-Di-N-Propylamine	NA	NA	< 2.6	< 0.81	< 5.1	< 1.5	< 0.50	< 0.69	< 0.75	< 0.79	< 0.55	< 0.56	< 0.64	< 0.75	< 0.50	< 0.77	< 0.74	< 0.73	< 1.7	< 0.62	< 2.2	< 0.64	< 0.72	< 0.75	< 0.099	< 0.50
Hexachloroethane	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
Nitrobenzene	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020 J	< 0.099
Isophorone	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
2-Nitrophenol	NA	NA	< 2.6	< 0.81	< 5.1	< 1.5	< 0.50	< 0.69	< 0.75	< 0.79	< 0.55	< 0.56	< 0.64	< 0.75	< 0.50	< 0.77	< 0.74	< 0.73	< 1.7	< 0.62	< 2.2	< 0.64	< 0.72	< 0.75	< 0.099	< 0.50
Bis(2-Chloroethoxy) Methane	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
2,4-Dichlorophenol	NA	NA	< 2.6	< 0.81	< 5.1	< 1.5	< 0.50	< 0.69	< 0.75	< 0.79	< 0.55	< 0.56	< 0.64	< 0.75	< 0.50	< 0.77	< 0.74	< 0.73	< 1.7	< 0.62	< 2.2	< 0.64	< 0.72	< 0.75	< 0.099	< 0.50
4-Chloroaniline	NA	NA	< 2.6	< 0.81	< 5.1	< 1.5	< 0.50	< 0.69	< 0.75	< 0.79	< 0.55	< 0.56	< 0.64	< 0.75	< 0.50	< 0.77	< 0.74	< 0.73	< 1.7	< 0.62	< 2.2	< 0.64	< 0.72	< 0.75	< 0.099	< 0.50
4-Chloro-3-methylphenol	NA	NA	< 2.6	< 0.81	< 5.1	< 1.5	< 0.50	< 0.69	< 0.75	< 0.79	< 0.55	< 0.56	< 0.64	< 0.75	< 0.50	< 0.77	< 0.74	< 0.73	< 1.7	< 0.62	< 2.2	< 0.64	< 0.72	< 0.75	< 0.099	< 0.50
Hexachlorocyclopentadiene	NA	NA	< 2.6	< 0.81	< 5.1	< 1.5 J	< 0.50	< 0.69	< 0.75	< 0.79	< 0.55	< 0.56	< 0.64	< 0.75 J	< 0.50	< 0.77	< 0.74	< 0.73	< 1.7	< 0.62	< 2.2 J	< 0.64	< 0.72	< 0.75	< 0.099 J	< 0.50 J
2,4,6-Trichlorophenol	NA	NA	< 2.6	< 0.81	< 5.1	< 1.5	< 0.50	< 0.69	< 0.75	< 0.79	< 0.55	< 0.56	< 0.64	< 0.75	< 0.50	< 0.77	< 0.74	< 0.73	< 1.7	< 0.62	< 2.2	< 0.64	< 0.72	< 0.75	< 0.099	< 0.50
2,4,5-Trichlorophenol	NA	NA	< 2.6	< 0.81	< 5.1	< 1.5	< 0.50	< 0.69	< 0.75	< 0.79	< 0.55	< 0.56	< 0.64	< 0.75	< 0.50	< 0.77	< 0.74	< 0.73	< 1.7	< 0.62	< 2.2	< 0.64	< 0.72	< 0.75	< 0.099	< 0.50
2-Chloronaphthalene	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
2-Nitroaniline	NA	NA	< 2.6	< 0.81	< 5.1	< 1.5	< 0.50	< 0.69	< 0.75	< 0.79	< 0.55	< 0.56	< 0.64	< 0.75	< 0.50	< 0.77	< 0.74	< 0.73	< 1.7	< 0.62	< 2.2	< 0.64	< 0.72	< 0.75	< 0.099	< 0.50
3-Nitroaniline	NA	NA	< 2.6	< 0.81	< 5.1	< 1.5	< 0.50	< 0.69	< 0.75	< 0.79	< 0.55	< 0.56	< 0.64	< 0.75	< 0.50	< 0.77	< 0.74	< 0.73	< 1.7	< 0.62	< 2.2	< 0.64	< 0.72	< 0.75	< 0.099	< 0.50
2,4-Dinitrophenol	NA	NA	< 5.3	< 1.6	< 10	< 3.0 J	< 0.99	< 1.4	< 1.5	< 1.6	< 1.1	< 1.1	< 1.3	< 1.5 J	< 0.99	< 1.5	< 1.5	< 1.5	< 3.4	< 1.2	< 4.4 J	< 1.3	< 1.4	< 1.5	< 0.20 J	< 0.99 J
4-Nitrophenol	NA	NA	< 2.6 J	< 0.81 J	< 5.1 J	< 1.5 J	< 0.50	< 0.69 J	< 0.75 J	< 0.79 J	< 0.55 J	< 0.56 J	< 0.64 J	< 0.75 J	< 0.50 J	< 0.77 J	< 0.74 J	< 0.73 J	< 1.7 J	< 0.62 J	< 2.2 J	< 0.64	< 0.72 J	< 0.75 J	< 0.099 J	< 0.50 J
2,6-Dinitrotoluene	NA	NA	< 2.6	< 0.81	< 5.1	< 1.5	< 0.50	< 0.69	< 0.75	< 0.79	< 0.55	< 0.56	< 0.64	< 0.75	< 0.50	< 0.77	< 0.74	< 0.73	< 1.7	< 0.62	< 2.2	< 0.64	< 0.72	< 0.75	< 0.099	< 0.50
2,4-Dinitrotoluene	NA	NA	< 2.6	< 0.81	< 5.1	< 1.5	< 0.50	< 0.69	< 0.75	< 0.79	< 0.55	< 0.56	< 0.64	< 0.75	< 0.50	< 0.77	< 0.74	< 0.73	< 1.7	< 0.62	< 2.2	< 0.64	< 0.72	< 0.75	< 0.099	< 0.50
4-Chlorophenyl-phenylether	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
4-Nitroaniline	NA	NA	< 2.6	< 0.81	< 5.1	< 1.5	< 0.50	< 0.69	< 0.75	< 0.79	< 0.55	< 0.56	< 0.64	< 0.75	< 0.50	< 0.77	< 0.74	< 0.73	< 1.7	< 0.62	< 2.2	< 0.64	< 0.72	< 0.75	< 0.099	< 0.50
4,6-Dinitro-2-Methylphenol	NA	NA	< 5.3 J	< 1.6 J	< 10 J	< 3.0 J	< 0.99	< 1.4 J	< 1.5 J	< 1.6 J	< 1.1 J	< 1.1 J	< 1.3 J	< 1.5 J	< 0.99 J	< 1.5 J	< 1.5 J	< 1.5 J	< 3.4 J	< 1.2 J	< 4.4 J	< 1.3	< 1.4 J	< 1.5 J	< 0.20 J	< 0.99 J
4-Bromophenyl-phenylether	NA	NA	< 0.53	< 0.16	< 1.0	< 0.30	< 0.099	< 0.14	< 0.15	< 0.16	< 0.11	< 0.11	< 0.13	< 0.15	< 0.099	< 0.15	< 0.15	< 0.15	< 0.34	< 0.12	< 0.44	< 0.13	< 0.14	< 0.15	< 0.020	< 0.099
3,3'-Dichlorobenzidine	NA	NA	< 2.6	< 0.81	< 5.1	< 1.5	< 0.50	< 0.69	< 0.75	< 0.79	< 0.55	< 0.56	< 0.64	< 0.75	< 0.50	< 0.77	< 0.74	< 0.73	< 1.7	< 0.62	< 2.2	< 0.64	< 0.72	< 0.75	< 0.099	< 0.50
Pesticides/PCBs (mg/kg dry weight)																										
Chlordane [6]	NA	NA	< 0.00099	< 0.0018	**0.15 J**	< 0.020	--	< 0.0038	< 0.0042	< 0.0029	< 0.00099	< 0.0033	< 0.0019	< 0.0020	< 0.00098	< 0.002	**0.0042**	< 0.00099	< 0.042	< 0.0054	< 0.058	--	**0.0020**	< 0.0031	< 0.00097	< 0.0028
4,4'-DDD	0.096	NA	**0.0097**	**0.0024**	< 0.033	< 0.040	--	**0.011**	**0.0056**	**0.0029**	**0.0090**	**0.014**	**0.0021 J**	**0.0028**	**0.0022 J**	**0.0029**	**0.0070**	< 0.0020	< 0.075	**0.010**	**0.043 J**	--	**0.0043**	**0.0048**	**0.0042**	**0.0028**
4,4'-DDE	0.021	NA	< 0.0048	< 0.0020	< 0.020	< 0.040	--	< 0.010	< 0.0040	< 0.0020	< 0.0099	< 0.0020	< 0.0020	< 0.0020	< 0.0020	< 0.002	< 0.0028	< 0.0020	< 0.040	< 0.0073	< 0.020	--	< 0.0020	< 0.0020	< 0.0020	< 0.0020
4,4'-DDT	0.019	NA	< 0.0082	< 0.0020	< 0.020 J	< 0.040 J	--	< 0.0074 J	< 0.0020 J	< 0.0020 J	< 0.0074 J	< 0.0088 J	< 0.0020	< 0.00014	< 0.0020	< 0.002	< 0.0028 J	< 0.0020	< 0.11 J	< 0.0020	< 0.036 J	--	< 0.0035	< 0.0020	< 0.0020	< 0.0020
Aroclor 1254	0.23	0.294	< 0.022	**0.023 J**	< 0.078	< 0.18	--	< 0.059	**0.042**	< 0.039	**0.072 J**	**0.068**	< 0.020	**0.022 J**	< 0.020	**0.023**	< 0.056	< 0.020	**0.37**	**0.056 J**	< 0.14	--	< 0.040	< 0.040	< 0.020	< 0.040
Total PCB (Calculated)	0.062	0.354	**0.041**	**0.045**	< 0.078	< 0.20	--	**0.090**	**0.10**	**0.036**	**0.15**	**0.17**	< 0.020	**0.041**	< 0.020	**0.045**	< 0.085	< 0.020	**0.73**	**0.10**	< 0.14	--	**0.035**	**0.033**	< 0.020	**0.033**

NOTES

ARI = Analytical Resources, Inc., Tukwila, Washington

WH = Woods Hole Group, Raynham, Massachusetts

LAET = Lowest Apparent Effects Threshold. Proposed Washington State Department of Ecology Draft Freshwater Screening Criteria. Values exceeding LAET are highlighted **blue**.

SQS = Sediment Quality Standard

2LAET = Second Lowest Apparent Effects Threshold. Proposed Washington State Department of Ecology Draft Freshwater Screening Criteria. Values exceeding 2LAET are highlighted **pink**.

CSL = Cleanup Screening Level

Underline = detection limits are above screening levels

bold = detected value

-- = No value reported.

J = Estimated concentration when value is less than calculated reporting limit.

J- = Estimate biased low.

< = value was undetected at the reported concentration

[1] From Ecology, 2003, *Development of Freshwater Sediment Quality Values for Use in Washington State, Phase II Report* (Pub. No. 03-09-088). Significant digits match those presented in that document.

[2] A single LAET is given for benzo(b,k)fluoranthenes. This LAET was divided in half to give the LAET value for each isomer.

[3] LPAH was calculated using six LPAHs (all those listed except 2-Methylnaphthalene). If all 6 were non-detects, the highest individual detection limit was used as the total. If only some were non-detects, only detected values were used to calculate LPA

[4] HPAH is the sum of ten HPAHs (listed above). If all 10 were non-detects, the highest individual detection limit was used as the total. If only some were non-detects, only detected values were used to calculate HPAH.

[5] TPAH was calculated using 16 PAH (all those listed except 2-Methylnaphthalene). If all 16 were non-detects, the highest individual detection limit was used as the total. If only some were non-detects, only detected values were used to calculate TPAH.

[6] Chlordane is the sum of the alpha and beta forms. If both values were non-detects, the highest individual detection limit (and its qualifier) was used as the total. All detected values were computed into the total.

Table B-2. Phase 3 Porewater Water Sample Data Summary

Sample Name	NLU13-TX-0010	NLU41-TX-0010	NLU51TX0010	NLU55-TX0010	NLU64TX0010	NLU66TX0010	NLU69TX0010	NLU73TX0010	NLU173TX0010	NLU76-TX-0010	NLU81-TX-0010	NLU82-TX-0010	NLU83-TX-0010	NLU84TX0010	NLU85-TX-0010	NLU86TX0010	NLU87-TX-0010	NLU117TX0010	NLUEPA5TX0010	NLUEPA19TX0010	NLUREF1-TX0010
Sample ID	NLU13-TX-0010-W	NLU41-TX-0010-W	NLU51TX0010-W	NLU55-TX0010-W	NLU64TX0010-W	NLU66TX0010-W	NLU69TX0010-W	NLU73TX0010-W	NLU173TX0010-W	NLU76-TX-0010-W	NLU81-TX-0010-W	NLU82-TX-0010-W	NLU83-TX-0010-W	NLU84TX0010-W	NLU85-TX-0010-W	NLU86TX0010-W	NLU87-TX-0010-W	NLU117TX0010-W	NLUEPA5TX0010-W	NLUEPA19TX0010-W	NLUREF1-TX0010-W
Sample Date	4/19/2005	4/19/2005	4/22/2005	4/22/2005	4/21/2005	4/21/2005	4/21/2005	4/21/2005	4/21/2005	4/19/2005	4/19/2005	4/19/2005	4/19/2005	4/22/2005	4/19/2005	4/21/2005	4/19/2005	4/22/2005	4/21/2005	4/21/2005	4/22/2005
Depth Interval (ft)	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33	0- .33
Analyte																					
Conventionals/Misc.																					
Sulfide (mg/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total Organic Carbon (%)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dissolved Organic Carbon (%)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total Suspended Solids (mg/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total Cyanide (mg/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
WAD Cyanide (mg/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
pH	**7.23**	**7.08**	**7.47 J**	**6.94**	**7.03**	**7.23**	**7.28**	**7.26**	**6.92**	**6.98**	**6.94**	**7.44**	**7.26**	**7.04 J**	**7.25**	**7.20**	**7.14**	**7.97 J**	**7.07**	**7.36**	**7.04**
Conductivity (umhos/cm)	**332**	**469**	**519 J**	**226**	**188**	**239**	**283**	**184**	**206**	**157**	**129**	**287**	**476**	**320 J**	**186**	**342**	**372**	**1010 J**	**149**	**625**	**108**
Turbidity (NTU)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dissolved Oxygen (mg/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Metals (mg/L)																					
Antimony	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Arsenic	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cadmium	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chromium	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Copper	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lead	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mercury	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nickel	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Silver	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Zinc	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TBT - ion	< 0.022	--	--	--	--	--	--	--	--	< 0.022	< 0.022	**0.049**	--	--	--	**0.17**	**0.17**	--	--	--	--
Volatile Organics (mg/L)																					
Benzene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ethylbenzene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Toluene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total Xylenes (Calculated)[1]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
LPAH (mg/L)																					
Naphthalene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Acenaphthylene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Acenaphthene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Fluorene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Phenanthrene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Anthracene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2-Methylnaphthalene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total LPAH [2]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
HPAH (mg/L)																					
Fluoranthene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pyrene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Benzo(a)anthracene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chrysene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Benzo(b)fluoranthene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Benzo(k)fluoranthene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Benzo(a)pyrene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Indeno(1,2,3-cd)pyrene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dibenzo(a,h)anthracene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Benzo(g,h,i)perylene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total HPAH [3]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TPAH (Calculated) [4]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Phthalates (mg/L)																					
Dimethylphthalate	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Diethylphthalate	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Di-n-Butylphthalate	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Butylbenzylphthalate	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
bis(2-Ethylhexyl)phthalate	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Di-n-Octyl phthalate	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Phenols (mg/L)																					
Phenol	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2-Methylphenol	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4-Methylphenol	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2,4-Dimethylphenol	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pentachlorophenol	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Misc. Extractables (mg/L)																					
Benzyl Alcohol	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Benzoic Acid	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Carbazole	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dibenzofuran	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hexachlorobutadiene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
N-Nitrosodiphenylamine	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Retene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hexachlorobenzene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1,2-Dichlorobenzene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1,4-Dichlorobenzene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1,2,4-Trichlorobenzene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

NOTES
-- = No value reported.
bold - detected value
J = Estimated concentration when value is less than calculated reporting limit.
J- = Estimate biased low.
< = Value was undetected at the reported concentration.
[1] Total Xylenes are the sum of the m,p-Xylenes and the o-Xylene. If both values were non-detects, the highest individual detection limit (and its qualifier) was used as the total. All detected values were computed into the
[2] LPAH was calculated using six LPAHs (all those listed except 2-Methylnaphthalene). If all 6 were non-detects, the highest individual detection limit was used as the total. If only some were non-detects, only detected values were used to calculate t
[3] HPAH is the sum of ten HPAHs (listed above). If all 10 were non-detects, the highest individual detection limit was used as the total. If only some were non-detects, only detected values were used to calculate HF
[4] TPAH was calculated using 16 PAH (all those listed except 2-Methylnaphthalene). If all 16 were non-detects, the highest individual detection limit was used as the total. If only some were non-detects, only detected values were used to calculate T

Table B-3. Ecology/TAMU Surface Sediment Chemistry Results (RETEC Split Samples, March 2002)

Analyte	LU-1 3/14/2002	LU-2 3/14/2002	LU-3 3/14/2002	LU-4 3/14/2002	LU-5 3/14/2002	LU-6 3/14/2002	LU-7 3/13/2002	LU-8 3/13/2002	LU-9 3/13/2002	LU-10 3/13/2002	LU-11 3/13/2002	Ref-1 3/13/2002	Ref-2 3/13/2002
Conventionals													
Ammonia (NH_3) (mg-N/kg)	**94**	**79**	**99**	**100**	**85**	**72**	**100**	**100**	**89**	**100**	**83**	**34**	**74**
Sulfide (mg/kg)	**800**	**130**	**590**	**320**	**1400**	**2200**	**380** J	**430** J	**290** J	**700** J	**1500** J	ND J	ND J
TOC (%) at 104° C	**5.8**	**9.3**	**6.6**	**6.7**	**6.7**	**8.3**	**9.1**	**8.1**	**8.8**	**8.4**	**7.1**	**4.2**	**13**
Total Solids (%)	**16.2**	**18.2**	**14.3**	**14**	**12.4**	**10.5**	**10.4**	**15.3**	**12.4**	**11.2**	**12.3**	**34.7**	**10.6**
Preserved Total Solids (%)	**14.9**	**12.1**	**14.2**	**15.7**	**11.4**	**11.7**	**12**	**13.8**	**12.3**	**12.1**	**12**	**40.4**	**9.8**
Total Volatile Solids (%)	**21**	**22**	**22**	**20**	**25**	**27**	**28**	**19**	**24**	**26**	**25**	**9.6**	**46**
LPAH (mg/kg dry weight)													
Naphthalene	**3.4** E	**5.9** E	**2.3**	**0.47**	**0.12**	**0.16**	**0.27**	**0.17**	**0.12**	**0.16**	**0.1**	0.015 U	0.041 U
2-Methylnaphthalene	**1.1**	**1.1**	**0.54**	**0.11**	**0.035**	**0.041**	**0.056**	**0.043**	**0.029**	**0.044**	**0.036**	0.015 U	0.041 U
Acenaphthylene	**2.7** E	**3.9**	**1.7**	**0.44**	**0.14**	**0.13**	**0.33**	**0.16**	**0.094**	**0.28**	**0.21**	0.015 U	0.041 U
Acenaphthene	**9.4** E	**60** E	**1.7**	**0.89**	**0.096**	**0.17**	**0.22**	**0.11**	**0.068**	**0.13**	**0.11**	0.015 U	0.041 U
Fluorene	**5.0** E	**18** E	**0.95**	**0.29**	**0.07**	**0.1**	**0.14**	**0.07**	**0.044**	**0.092**	**0.12**	0.015 U	0.041 U
Phenanthrene	**27** E	**140** E	**14** E	**1.1**	**0.54**	**1.2**	**1.6**	**0.39**	**0.34**	**0.93**	**0.77**	**0.036**	**0.057**
Anthracene	**9.4** E	**30** E	**6.6** E	**0.59**	**0.20**	**0.31**	**0.58**	**0.18**	**0.12**	**0.31**	**0.26**	0.015 U	0.041 U
Total LPAH	**58**	**259**	**28**	**3.89**	**1.20**	**2.11**	**3.20**	**1.12**	**0.82**	**1.95**	**1.61**	**0.13**	**0.30**
HPAH (mg/kg dry weight)													
Fluoranthene	**90** E	**190** E	**84** E	**9.4** E	**2.1**	**3.7** E	**5.4** E	**2.2** E	**1.4**	**3.1** E	**2.8**	**0.16**	**0.11**
Pyrene	**120** E	**220** **	**120** E	**12** E	**2.6**	**4.2** E	**6.7** E	**3.1** E	**1.6**	**3.7** E	**2.7**	**0.13**	**0.094**
Benzo(a)anthracene	**31** E	**58** E	**28** E	**3.3** E	**0.99**	**1.4**	**2.7**	**1.1**	**0.64**	**1.6**	**1.0**	**0.038**	**0.086**
Chrysene	**34** E	**58** E	**34** E	**3.8** E	**1.1**	**1.5**	**2.5** E	**1.3**	**0.71**	**1.9**	**1.3**	**0.051**	**0.14**
Benzo(b)fluoranthene	**34** E	**59** E	**26** E	**4.1** E	**1.8**	**1.4**	**2.5** E	**1.3**	**0.82**	**2.2**	**1.5**	**0.044**	**0.074**
Benzo(k)fluoranthene	**29** E	**56** E	**24** E	**3.6** E	**1.3**	**1.2**	**2.6** E	**1.3**	**0.78**	**1.8**	**1.2**	**0.042**	**0.11**
Benzo(a)pyrene	**49** E	**98** E	**41** E	**6.2** E	**2.2**	**2.5**	**3.9** E	**2.1**	**1.3**	**3.3**	**2.1**	**0.067**	**0.094**
Dibenzo(a,h)anthracene	**6.8** E	**11** E	**6.4** E	**0.48**	**0.19**	**0.35**	**0.4**	**0.2**	**0.15**	**0.34**	**0.23**	0.015 U	0.041 U
Benzo(g,h,i)perylene	**46** E	**83** E	**36** E	**2.4**	**0.74**	**2.3**	**2.2**	**1.2**	**0.77**	**1.8**	**1.2**	**0.052**	0.041 U
Indeno(1,2,3-cd)pyrene	**31** E	**58** E	**26** E	**2.2**	**0.75**	**1.7**	**2.1**	**0.98**	**0.65**	**1.6**	**1.0**	**0.045**	0.041 U
Total HPAH	**471**	**891**	**425**	**47**	**14**	**20**	**31**	**15**	**9**	**21**	**15**	**0.64**	**0.83**
Total PAH (TPAH)	**529**	**1,150**	**453**	**51**	**15**	**22**	**34**	**16**	**9.6**	**23**	**17**	**0.77**	**1.13**
Total PAH mg/kg_{oc}	**9,117**	**12,365**	**6,867**	**767**	**223**	**269**	**376**	**196**	**109**	**277**	**234**	**18**	**9**
Misc. Extractables (mg/kg dry weight)													
d10-2-Methylnaphthalene	**0.0787**	**0.0763**	**0.0723**	**0.066**	**0.0577**	**0.072**	**0.0553**	**0.0577**	**0.0733**	**0.0587**	**0.0473**	**0.061**	**0.040**
d14-Dibenzo(a,h)anthracene	**0.0187**	**0.0347**	**0.048**	**0.044**	**0.0467**	**0.088**	**0.056**	**0.0587**	**0.064**	**0.062**	**0.0697**	**0.0667**	**0.050**
Dibenzofuran	**0.52**	**2.4**	**0.23**	**0.062**	0.032 U	0.031 U	0.031 U	0.027 U	0.029 U	0.037 U	**0.036**	0.015 U	0.041 U

Notes:

Results are for samples collected by Ecology in March 2002 and analyzed by RETEC (using ARI lab).

Bold font indicates that the compound was detected.

E - Value shown is the result of a dilution.

J - Estimated value

U - Value shown is the reported detection limit due to analyte being undetected in sample.

ND - Non detect

** - Value shown is the result of a reextraction.

Metals were not analyzed

Data presented has been validated by an independent data validator.

Table B-4. Ecology/TAMU Surface Sediment Chemistry Results (TAMU March 2002)

Station	LU-1	LU-2	LU-3	LU-4	LU-5	LU-6	LU-7	LU-8	LU-9	LU-10	LU-11	Ref-1	Ref-2
TOC, % [1]	**15.5**	**14.2**	**13.7**	**10.6**	**13.6**	**15.3**	**15.3**	**10.1**	**12.6**	**13.8**	**13.5**	**4.16**	**25.5**
Metals (mg/kg dry weight) [2]													
Silver	**2.20**	**1.39**	**2.00**	**3.44**	**1.23**	**0.98**	**0.86**	**3.24**	**1.50**	**1.11**	**1.00**	<0.199	**0.24**
Arsenic	**38.6**	**24.1**	**40.1**	**41.3**	**28.0**	**26.6**	**23.4**	**52.6**	**45.5**	**32.9**	**36.7**	**7.8**	**21.4**
Cadmium	**2.07**	**1.65**	**2.55**	**2.48**	**1.91**	**1.81**	**1.78**	**2.77**	**2.49**	**2.13**	**2.04**	**0.53**	**1.42**
Chromium	**50.7**	**48.8**	**60.8**	**67.0**	**51.2**	**48.1**	**44.2**	**66.4**	**55.8**	**48.4**	**47.4**	**36.6**	**32.9**
Copper	**251**	**182**	**349**	**291**	**310**	**238**	**198**	**276**	**304**	**246**	**233**	**28**	**52**
Mercury	**0.850**	**0.578**	**1.370**	**1.260**	**0.656**	**0.629**	**0.588**	**1.560**	**0.869**	**0.781**	**0.760**	**0.094**	**0.277**
Lead	**298**	**219**	**313**	**368**	**300**	**253**	**220**	**438**	**468**	**341**	**333**	**27**	**104**
Zinc	**413**	**326**	**455**	**480**	**412**	**399**	**349**	**516**	**484**	**383**	**399**	**57**	**122**
LPAH (mg/kg dry weight) [2]													
Naphthalene	**0.15**	**0.12**	**0.03 J**	**0.02 J**	**0.01 J**	**0.03 J**	**0.03 J**	**0.01 J**	**0.04 J**	< 0.105 U	**0.11**	**0.00 J**	**0.09 J**
2-Methylnaphthalene	**0.18**	**0.10**	**0.03 J**	**0.03 J**	**0.01 J**	**0.01 J**	**0.01 J**	**0.01 J**	**0.03 J**	**0.009 J**	**0.10**	**0.00 J**	**0.09**
Acenaphthylene	**4.08**	**4.55**	**5.82**	**0.83**	**0.70**	**0.57**	**0.61**	**0.72**	**0.46**	**0.48**	**0.30**	**0.01**	**0.04**
Acenaphthene	**1.86**	**4.30**	**0.36**	**0.28**	**0.07**	**0.77**	**0.10**	**0.06**	**0.14**	**0.05**	**0.21**	**0.02**	**0.25**
Fluorene	**3.12**	**4.16**	**0.66**	**0.58**	**0.35**	**1.18**	**0.41**	**0.24**	**0.60**	**0.25**	**0.68**	**0.15**	**0.64**
Phenanthrene	**34.94**	**36.72**	**8.99**	**7.54**	**5.90**	**17.92**	**6.09**	**3.55**	**5.84**	**3.46**	**4.80**	**1.92**	**4.59**
Anthracene	**11.60**	**11.67**	**10.03**	**2.04**	**1.40**	**2.55**	**1.28**	**1.25**	**1.08**	**0.84**	**0.70**	**0.09**	**0.42**
Total LPAH	**56**	**62**	**26**	**11**	**8**	**23**	**9**	**6**	**8**	**5**	**7**	**2**	**6**
HPAH (mg/kg dry weight) [2]													
Fluoranthene	**105.21**	**98.68**	**33.31**	**10.33**	**8.26**	**22.46**	**8.65**	**8.88**	**4.69**	**4.76**	**2.96**	**0.56**	**1.24**
Pyrene	**109.87**	**120.61**	**40.60**	**13.30**	**11.17**	**25.52**	**11.75**	**11.66**	**5.76**	**6.01**	**3.30**	**0.41**	**1.05**
Benz(a)anthracene	**38.31**	**42.97**	**17.73**	**5.01**	**4.30**	**6.35**	**4.84**	**4.10**	**2.19**	**2.33**	**1.17**	**0.05**	**0.16**
Chrysene	**44.91**	**48.19**	**18.87**	**5.43**	**4.83**	**6.59**	**5.23**	**5.18**	**2.57**	**2.39**	**1.41**	**0.08**	**0.24**
Benzo(b)fluoranthene	**39.47**	**53.55**	**13.92**	**6.45**	**6.04**	**6.06**	**6.07**	**4.78**	**3.31**	**3.37**	**1.94**	**0.06**	**0.18**
Benzo(k)fluoranthene	**27.69**	**26.39**	**14.17**	**5.09**	**3.39**	**5.84**	**3.31**	**2.68**	**1.74**	**1.64**	**0.89**	**0.04**	**0.09**
Benzo(a)pyrene	**52.93**	**64.00**	**24.02**	**8.87**	**6.83**	**9.61**	**7.15**	**5.02**	**3.58**	**3.96**	**1.77**	**0.05**	**0.14**
Dibenzo(a,h)anthracene	**5.47**	**8.71**	**2.39**	**0.75**	**0.47**	**0.93**	**0.49**	**0.56**	**0.22**	**0.36**	**0.19**	**0.01**	**0.02 J**
Benzo(g,h,i)perylene	**47.49**	**62.22**	**17.01**	**8.19**	**6.94**	**7.62**	**6.89**	**5.21**	**3.67**	**3.45**	**1.67**	**0.06**	**0.12**
Indeno(1,2,3-c,d)pyrene	**53.71**	**57.37**	**20.01**	**9.04**	**7.60**	**7.48**	**7.78**	**5.72**	**4.10**	**3.88**	**1.91**	**0.06**	**0.11**
Total HPAH	**525**	**583**	**202**	**72**	**60**	**98**	**62**	**54**	**32**	**32**	**17**	**1**	**3**
Total PAH (TPAH)	**581**	**644**	**228**	**84**	**68**	**121**	**71**	**60**	**40**	**37**	**24**	**4**	**9**
Total PAH mg/kg$_{oc}$	**3748**	**4537**	**1664**	**790**	**502**	**794**	**462**	**590**	**318**	**270**	**179**	**86**	**37**

Notes

[1] TOC measured in March 2002 Ecology split samples by Rosa.

[2] Results are for samples collected by Ecology in March 2002 and analyzed by TAMU.

Bold font indicates that the compound was detected.

J - Estimated value

U - Value shown is the reported detection limit due to analyte being undetected in sample.

Table B-5. Ecology/TAMU Surface Sediment Chemistry Results (TAMU July 2002)

Station	LU-1	LU-2	LU-3	LU-4	LU-5	LU-6	LU-7	LU-8	LU-9	LU-10	LU-11	Ref-1	Ref-2
TOC, % [1]	**15.5**	**14.2**	**13.7**	**10.6**	**13.6**	**15.3**	**15.3**	**10.1**	**12.6**	**13.8**	**13.5**	**4.16**	**25.5**
LPAH *(mg/kg dry weight)*													
Naphthalene	**0.39**	**0.24**	**0.17**	**0.049**	**0.016**	**0.016**	**0.020**	**0.090**	**0.015**	**0.16**	**0.035**	**0.001 J**	**0.029**
2-Methylnaphthalene	**0.13**	**0.15**	**0.083**	**0.021**	**0.013**	**0.01**	**0.014**	**0.051**	**0.01**	**0.16**	**0.019**	**0.0003 J**	**0.037**
Acenaphthylene	**8.26**	**6.03**	**2.00**	**1.15**	**0.65**	**0.84**	**0.94**	**0.531**	**0.42**	**0.413**	**0.667**	**0.022**	**0.13**
Acenaphthene	**8.45**	**0.26**	**0.11**	**0.076**	**0.17**	**0.24**	**0.29**	**0.020**	**0.017**	**0.017**	**0.028**	**0.001**	**0.12**
Fluorene	**9.38**	**0.99**	**0.25**	**0.17**	**0.23**	**0.39**	**0.45**	**0.031**	**0.024**	**0.023**	**0.048**	**0.001**	**0.26**
Phenanthrene	**259**	**47**	**4.4**	**3.9**	**2.8**	**4.8**	**4.7**	**0.81**	**1.31**	**0.40**	**2.96**	**0.082**	**3.29**
Anthracene	**57**	**17**	**3.5**	**2.3**	**1.2**	**1.8**	**2.3**	**0.69**	**0.72**	**0.53**	**1.08**	**0.055**	**0.55**
Total LPAH	**343**	**72**	**11**	**8**	**5**	**8**	**9**	**2**	**3**	**2**	**5**	**0**	**4**
HPAH *(mg/kg dry weight)*													
Fluoranthene	**386**	**126**	**57**	**22**	**8.5**	**11.4**	**16.3**	**5.79**	**5.18**	**4.28**	**8.15**	**0.45**	**2.60**
Pyrene	**454**	**183**	**80**	**32**	**10.7**	**15.7**	**26.7**	**8.86**	**6.02**	**5.47**	**8.89**	**0.52**	**2.85**
Benz(a)anthracene	**200**	**73**	**33**	**10**	**4.31**	**6.52**	**8.84**	**4.28**	**2.57**	**2.68**	**3.46**	**0.16**	**0.82**
Chrysene	**193**	**84**	**42**	**13**	**4.93**	**7.07**	**11.2**	**5.72**	**2.99**	**3.19**	**4.37**	**0.22**	**1.08**
Benzo(b)fluoranthene	**108**	**80**	**26**	**12**	**6.01**	**8.15**	**10.5**	**3.87**	**3.56**	**2.48**	**4.60**	**0.12**	**0.84**
Benzo(k)fluoranthene	**88**	**42**	**20**	**5.1**	**2.30**	**2.93**	**6.16**	**3.29**	**1.81**	**2.58**	**2.22**	**0.12**	**0.61**
Benzo(a)pyrene	**170**	**94**	**35**	**13**	**6.37**	**9.17**	**13.3**	**4.27**	**3.73**	**3.49**	**5.16**	**0.16**	**0.94**
Indeno(1,2,3-c,d)pyrene	**144**	**84**	**33**	**13**	**6.46**	**8.94**	**13.3**	**5.92**	**4.65**	**4.39**	**6.08**	**0.19**	**0.97**
Dibenzo(a,h)anthracene	**22**	**12**	**5**	**2.0**	**0.91**	**1.31**	**2.19**	**0.73**	**0.62**	**0.57**	**0.79**	**0.02**	**0.14**
Benzo(g,h,i)perylene	**126**	**75**	**30**	**12**	**5.85**	**8.26**	**12.3**	**5.80**	**4.50**	**4.35**	**5.88**	**0.18**	**0.89**
Total HPAH	**1890**	**853**	**362**	**136**	**56**	**79**	**121**	**49**	**36**	**33**	**50**	**2**	**12**
Total PAH (TPAH)	**2234**	**925**	**373**	**143**	**61**	**88**	**130**	**51**	**38**	**35**	**54**	**2**	**16**
Total PAH mg/kg$_{oc}$	**14410**	**6513**	**2722**	**1351**	**452**	**572**	**847**	**503**	**303**	**255**	**403**	**55**	**63**

Notes:

[1] TOC measured in March 2002 Ecology split samples by Rosa

Results are for samples collected by Ecology in July 2002 and analyzed by TAMU.

Bold font indicates that the compound was detected.

J - Estimated value

Table B-6. RETEC Phase 2 Surface Sediment Chemistry Results (October 2002)

Sample ID / Sample Date / Analyte	NLU01-SS-0010 10/14/2002	NLU02-SS-0010 10/15/2002	NLU04-SS-0010 10/15/2002	NLU05-SS-0010 10/15/2002	NLU06-SS-0010 10/14/2002	NLU07-SS-0010 10/14/2002	NLU08-SS-0010 10/15/2002	NLU10-SS-0010 10/15/2002	NLU12-SS-0010 10/15/2002	NLU13-SS-0010 10/14/2002	NLU14-SS-0010 10/14/2002	NLU15-SS-0010 10/14/2002	NLU16-SS-0010 10/15/2002	NLU17-SS-0010 10/14/2002	NLU21-SS-0010 10/15/2002	NLU22-SS-0010 10/15/2002
Conventionals																
N-Ammonia (mg-N/kg)	**42**	**88**	**100**	**3.8**	**49**	**52**	**120**	**110**	**120**	**120**	**150**	**140**	**150**	**160**	**43**	**95**
Sulfide (mg/kg)	**160**	**890**	**3700**	**4.1**	**970**	**120**	**2300**	**1700**	**1500**	**1100**	**1000**	**1200**	**4200**	**1900**	**45**	**700**
Total Organic Carbon (%)	**5.1**	**9.2**	**9.1**	**4.5**	**7.4**	**10**	**9.5**	**10**	**8.1**	**7.4**	**7.4**	**8.6**	**10**	**8.2**	**8.7**	**10**
pH (std units)	**6.11**	**5.65**	**6.00**	**5.68**	**6.04**	**6.04**	**6.10**	**6.14**	**6.22**	**6.54**	**6.32**	**6.34**	**6.57**	**6.51**	**6.18**	**5.64**
Total Solids (%)	**39.4**	**14.2**	**10.2**	**81.6**	**9.9**	**9.6**	**9.7**	**10.4**	**9.9**	**19.6**	**14**	**11.3**	**12.9**	**14.1**	**16.9**	**12.5**
Preserved Total Solids (%)	**46.6**	**13.9**	**9.3**	**74.7**	**10**	**11.5**	**10.4**	**10.9**	**10.1**	**16.3**	**13.2**	**11**	**11.5**	**15**	**12.5**	**12.7**
Metals (mg/kg)																
Antimony	**8**	**4**	**3**	**0.3**	**4**	**4**	**2**	**3**	**3**	**5**	**19**	**16**	**65**	**5**	< 1 U	**2**
Arsenic	**30**	< 40 U	< 50 U	< 6 U	< 50 U	< 50 U	< 50 U	< 50 U	< 50 U	**50**	**110**	**80**	**140**	**70**	< 30 U	< 50 U
Cadmium	**1.5**	**2**	**2**	**0.3**	**3**	**3**	< 2 U	< 2 U	**3**	**3**	**3**	**3**	**4**	**3**	**1**	< 2 U
Chromium	**50**	**56**	**53**	**20.1**	**54**	**56**	**52**	**54**	**61**	**57**	**73**	**76**	**71**	**72**	**30**	**60**
Copper	**159**	**286**	**215**	**15.8**	**215**	**266**	**243**	**298**	**456**	**259**	**1050**	**723**	**860**	**538**	**36**	**54**
Lead	**252**	**250**	**200**	**18**	**210**	**280**	**210**	**240**	**290**	**390**	**560**	**450**	**1150**	**430**	**40**	**100**
Mercury	**0.8**	**0.7**	**0.5**	**0.14**	**0.5**	**0.6**	**0.5**	**0.6**	**0.8**	**1.7**	**1.3**	**1.3**	**1.5**	**1.9**	< 0.3 U	< 0.3 U
Nickel	**71**	**57**	**51**	**36**	**54**	**61**	**53**	**50**	**53**	**61**	**65**	**61**	**68**	**85**	**34**	**34**
Tributyl Tin	**0.96 J**	NA	**0.16 B**	NA	**0.15 B**	NA	NA	**0.15 B**	**0.31 B**	NA	NA	NA	NA	**0.31 B**	NA	NA
Zinc	**405**	**469**	**359**	**56.7**	**372**	**438**	**377**	**388**	**460**	**402**	**956**	**766**	**1200**	**684**	**83**	**188**
LPAH (mg/kg dry weight)																
Naphthalene	**3.1**	**0.54**	**0.39**	**2.4**	**0.32 J**	**1.5**	< 0.39 U	< 0.39 U	**0.56**	**0.64**	**0.62**	**0.54**	**3.1**	**1.6**	< 0.097 U	< 0.098 U
2-Methylnaphthalene	**0.88**	< 0.38 U	< 0.39 U	< 0.9 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.39 U	< 0.39 U	**2.5**	**1.2**	< 0.097 U	< 0.098 U
Acenaphthylene	**1.9**	**1.00**	**0.78**	**2.6**	**0.53**	**2.1**	**0.51**	**0.55**	**0.68**	**0.85**	**2.0**	**0.89**	**7.2**	**9.4**	< 0.097 U	< 0.098 U
Acenaphthene	**5.5**	**0.50**	< 0.39 U	**1.4**	**0.28 J**	**1.6**	< 0.39 U	< 0.39 U	< 0.39 U	**0.6**	**1.6**	< 0.39 U	**12**	**9.5**	< 0.097 U	< 0.098 U
Fluorene	**3.2**	**0.40**	< 0.39 U	**1.0**	< 0.39 U	**0.89**	< 0.39 U	< 0.39 U	< 0.39 U	**0.47**	**1.4**	< 0.39 U	**13**	**9.8**	< 0.097 U	< 0.098 U
Phenanthrene	**19**	**3.00**	**1.6**	**7.7**	**1.7**	**7.0**	**1.9**	**1.2**	**1.9**	**1.4**	**1.9**	**1.8**	**24**	**22**	< 0.097 U	< 0.098 U
Anthracene	**5.2**	**1.4**	**1.0**	**3.2**	**0.83**	**3.0**	**0.84**	**0.69**	**0.98**	**0.94**	**2.0**	**1.2**	**14**	**15**	< 0.097 U	< 0.098 U
LPAH (Calculated)	**37.9**	**6.84**	**4.55**	**18.3**	**4.05**	**16.09**	**4.42**	**3.61**	**4.9**	**4.9**	**9.52**	**5.21**	**73.3**	**67.3**	< 0.582	< 0.588
HPAH (mg/kg dry weight)																
Fluoranthene	**16**	**5.8**	**4.0**	**31**	**5.8**	**30**	**6.4**	**3.8**	**5.6**	**9.9**	**7.8**	**7.0**	**49**	**61**	< 0.097 U	**0.19**
Pyrene	**19**	**5.7**	**4.6**	**35**	**6.7**	**38**	**7.5**	**4.5**	**6.8**	**12**	**9.5**	**8.2**	**62**	**84**	**0.097 J**	**0.19**
Benzo(a)anthracene	**5.7**	**2.4**	**1.9**	**12**	**2.5**	**12**	**2.6**	**1.7**	**2.5**	**3.3**	**4.4**	**3.2**	**20**	**28**	< 0.097 U	**0.18**
Chrysene	**6.7**	**2.8**	**2.4**	**11**	**2.6**	**11**	**2.7**	**1.9**	**2.8**	**4.1**	**5.2**	**4.2**	**23**	**31**	< 0.097 U	**0.26**
Benzo(b)fluoranthene	**5.4**	**2.8**	**2.4**	**12**	**3.0**	**14**	**3.1**	**2.3**	**3.3**	**3.8**	**4.8**	**4.5**	**15**	**17**	< 0.097 U	**0.18**
Benzo(k)fluoranthene	**4.5**	**2.2**	**2.1**	**11**	**2.6**	**11**	**3.0**	**2.1**	**3.3**	**3.0**	**4.7**	**3.7**	**14**	**19**	< 0.097 U	**0.15**
Benzo(a)pyrene	**8.0**	**3.3**	**3.1**	**20**	**4.5**	**23**	**4.9**	**3.2**	**5.1**	**5.8**	**7.7**	**6.5**	**25**	**32**	< 0.097 U	**0.14**
Dibenzo(a,h)anthracene	**3.0**	**1.4**	**1.1**	**5.7**	**1.5**	**8.3 M**	**1.4**	**0.89**	**1.7**	**2.3**	**3.6**	**3.1**	**4.4**	**7.7 M**	< 0.097 U	< 0.098 U
Benzo(g,h,i)perylene	**14**	**3.3**	**3.4**	**21**	**8.3**	**20**	**5.2**	**3.2**	**7.0**	**10**	**12**	**12**	**20**	**18**	< 0.097 U	< 0.098 U
Indeno(1,2,3-cd)pyrene	**11**	**3.2**	**3.2**	**18**	**6.1**	**15**	**4.7**	**2.9**	**5.4**	**7.5**	**9.6**	**8.7**	**15**	**18**	< 0.097 U	< 0.098 U
HPAH (Calculated)	**93**	**33**	**28**	**177**	**44**	**182**	**42**	**26**	**44**	**62**	**69**	**61**	**247**	**316**	**0.97**	**1.584**
TPAH (Calculated)	**131**	**40**	**33**	**195**	**48**	**198**	**46**	**30**	**48**	**67**	**79**	**66**	**321**	**383**	**1.552**	**2.172**
TPAH mg/kg$_{oc}$	**2,573**	**432**	**360**	**4,333**	**644**	**1,984**	**483**	**301**	**598**	**900**	**1,065**	**771**	**3,207**	**4,671**	**18**	**22**
Other Organics (mg/kg dw)																
1,2,4-Trichlorobenzene	< 0.37 U	< 0.38 U	< 0.39 U	< 0.9 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.097 U	< 0.098 U
1,2-Dichlorobenzene	< 0.37 U	< 0.38 U	< 0.39 U	< 0.9 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.097 U	< 0.098 U
1,4-Dichlorobenzene	< 0.37 U	< 0.38 U	< 0.39 U	< 0.9 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.097 U	< 0.098 U
2,4-Dimethylphenol	< 0.37 U	< 0.38 U	< 0.39 U	< 0.9 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.097 U	< 0.098 U
2-Methylphenol	< 0.37 U	< 0.38 U	< 0.39 U	< 0.9 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.097 U	< 0.098 U
4-Methylphenol	< 0.37 U	< 0.38 U	< 0.39 U	< 0.9 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.39 U	< 0.39 U	**0.45**	< 0.38 U	**0.11**	**0.27**
Benzoic Acid	< 3.7 U	< 3.8 U	< 3.9 U	< 9 U	< 3.9 U	< 3.9 U	< 3.9 U	< 3.9 U	< 3.9 U	< 3.8 U	< 3.9 U	< 3.9 U	< 3.9 U	< 3.8 U	< 0.97 U	< 0.98 U
Benzyl Alcohol	< 0.37 U	< 0.38 U	< 0.39 U	< 0.9 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.097 U	< 0.098 U
bis(2-Ethylhexyl)phthalate	**1.0 B**	**2.2 B**	**2.4 B**	< 0.9 U	**2.1 B**	**1.9 B**	**1.1 B**	**2.1**	**2.3 B**	**0.55 B**	**1.4 B**	**2.2 B**	**3.7 B**	**0.76 B**	**0.20 B**	**0.30 B**
Butylbenzylphthalate	< 0.37 U	< 0.38 U	< 0.39 U	< 0.9 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.097 U	< 0.098 U
Dibenzofuran	**0.28 J**	< 0.38 U	< 0.39 U	< 0.9 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.39 U	< 0.39 U	**2.1**	**1.1**	< 0.097 U	< 0.098 U
Diethylphthalate	< 0.37 U	< 0.38 U	< 0.39 U	< 0.9 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.097 U	< 0.098 U
Dimethylphthalate	< 0.37 U	< 0.38 U	< 0.39 U	< 0.9 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.097 U	< 0.098 U
Di-n-Butylphthalate	**0.52 B**	< 0.38 U	< 0.39 U	< 0.9 U	**0.37 JB**	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.39 U	**0.44 B**	< 0.39 U	< 0.38 U	< 0.097 U	< 0.098 U
Di-n-Octyl phthalate	< 0.37 U	< 0.38 U	< 0.39 U	< 0.9 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	**0.48 BM**	< 0.39 U	< 0.39 U	< 0.38 U	< 0.097 U	< 0.098 U
Hexachlorobenzene	< 0.37 U	< 0.38 U	< 0.39 U	< 0.9 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.097 U	< 0.098 U
Hexachlorobutadiene	< 0.37 U	< 0.38 U	< 0.39 U	< 0.9 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.097 U	< 0.098 U
N-Nitrosodiphenylamine	< 0.37 U	< 0.38 U	< 0.39 U	< 0.9 U	**0.26 J**	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.39 U	< 0.39 U	< 0.39 U	**2.4**	< 0.097 U	< 0.098 U
Pentachlorophenol	< 1.9 U	< 1.9 U	< 1.9 U	< 4.5 U	< 2 U	< 2 U	< 2 U	< 2 U	< 1.9 U	< 1.9 U	< 1.9 U	< 1.9 U	< 2 U	< 1.9 U	< 0.49 U	< 0.49 U
Phenol	< 0.37 U	< 0.38 U	< 0.39 U	< 0.9 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.097 U	< 0.098 U
Hexachlorobutadiene	< 0.37 U	< 0.38 U	< 0.39 U	< 0.9 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.39 U	< 0.39 U	< 0.39 U	< 0.38 U	< 0.097 U	< 0.098 U
PCB (mg/kg dry weight)																
Aroclor 1016	< 0.02 U	NA	< 0.02 U	NA	< 0.02 U	NA	NA	< 0.02 U	< 0.02 U	NA	NA	NA	NA	< 0.02 U	NA	NA
Aroclor 1221	< 0.039 U	NA	< 0.04 U	NA	< 0.04 U	NA	NA	< 0.04 U	< 0.04 U	NA	NA	NA	NA	< 0.039 U	NA	NA
Aroclor 1232	< 0.02 U	NA	< 0.02 U	NA	< 0.02 U	NA	NA	< 0.02 U	< 0.02 U	NA	NA	NA	NA	< 0.02 U	NA	NA
Aroclor 1242	< 0.02 U	NA	< 0.02 U	NA	< 0.02 U	NA	NA	< 0.02 U	< 0.02 U	NA	NA	NA	NA	< 0.02 U	NA	NA
Aroclor 1248	< 0.085 Y	NA	< 0.02 U	NA	< 0.02 U	NA	NA	< 0.02 Y	< 0.02 U	NA	NA	NA	NA	< 0.11 Y	NA	NA
Aroclor 1254	**0.24**	NA	**0.068**	NA	**0.069**	NA	NA	**0.069**	**0.078**	NA	NA	NA	NA	**0.26**	NA	NA
Aroclor 1260	**0.12**	NA	**0.054**	NA	**0.038**	NA	NA	**0.055**	**0.063**	NA	NA	NA	NA	**0.14**	NA	NA
Total PCB (Calculated)	**0.544**	NA	**0.242**	NA	**0.227**	NA	NA	**0.244**	**0.261**	NA	NA	NA	NA	**0.609**	NA	NA

Notes:

Results are for samples collected by RETEC in October 2002 and analyzed by RETEC (using ARI).

Bold font indicates that the compound was detected.

J , M - Estimated value

U - Value shown is the reported detection limit due to analyte being undetected in sample.

NA = not available

Appendix C

Phase 3 Bioassay Results

Appendix Table C-1. *Hyalella azteca 10-day Survival*
Preliminary Data
Gas Works Sediments - Eastern Study Area
Test Initiation: April 29, 2005

		Survival						Survival			
Site	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	Site	Rep	# Alive	% Survival	Mean % Survival	St. Dev.
Control	1	20	100	98	2.7	85	1	20	100	95	3.5
	2	19	95				2	19	95		
	3	20	100				3	19	95		
	4	19	95				4	18	90		
	5	20	100				5	19	95		
Ref 1	1	16	80	84	5.5	87	1	20	100	94	8.2
	2	16	80				2	20	100		
	3	16	80				3	16	80		
	4	18	90				4	19	95		
	5	18	90				5	19	95		
Ref 2	1	19	95	86	5.5	66	1	18	90	92	10.4
	2	17	85				2	20	100		
	3	17	85				3	20	100		
	4	16	80				4	19	95		
	5	17	85				5	15	75		
55	1	11	55	51	6.5	19	1	20	100	97	4.5
	2	8	40				2	19	95		
	3	11	55				3	20	100		
	4	11	55				4	20	100		
	5	10	50				5	18	90		
13	1	17	85	84	9.6	73	1	16	80	89	8.2
	2	16	80				2	20	100		
	3	18	90				3	17	85		
	4	14	70				4	19	95		
	5	19	95				5	17	85		
83	1	16	80	94	8.9	69	1	17	85	87	8.4
	2	20	100				2	16	80		
	3	18	90				3	18	90		
	4	20	100				4	20	100		
	5	20	100				5	16	80		
76	1	17	85	82	4.5	5	1	18	90	88	7.6
	2	17	85				2	16	80		
	3	17	85				3	19	95		
	4	15	75				4	19	95		
	5	16	80				5	16	80		
81	1	17	85	90	7.1	64	1	17	85	89	6.5
	2	17	85				2	19	95		
	3	17	85				3	18	90		
	4	20	100				4	16	80		
	5	19	95				5	19	95		
82	1	16	80	79	8.9	84	1	20	100	98	2.7
	2	16	80				2	19	95		
	3	13	65				3	19	95		
	4	18	90				4	20	100		
	5	16	80				5	20	100		

		Survival			
Site	Rep	# Alive	% Survival	Mean % Survival	St. Dev.
51	1	0	0	0	0.0
	2	0	0		
	3	0	0		
	4	0	0		
	5	0	0		
117	1	0	0	0	0.0
	2	0	0		
	3	0	0		
	4	0	0		
	5	0	0		
86	1	18	90	87	13.0
	2	18	90		
	3	18	90		
	4	13	65		
	5	20	100		
Diluted 55	1	18	90	74	11.9
	2	12	60		
	3	16	80		
	4	13	65		
	5	15	75		
Diluted 117	1	4	20	30	10.0
	2	5	25		
	3	7	35		
	4	9	45		
	5	5	25		

Table C-2. GWSA Phase 3 Site-Wide *Hyalella azteca* Results and Statistics

Site	TPAH (mg/kg dw)	Most Similar Reference [1]	Ave. % Survival	QUALITY CONTROL [2]			DATA QUALITY ANALYSIS						Decision Criteria [5]
				Control	REF1	REF2	Endpoint Analysis [2,3]			t-Test Analysis (p Value) [4]			
				C > 80% survival	R1 > 75% survival	R2 > 75% survival	C - T	R1 - T	R2 - T	Sample vs Control	Sample vs R1	Sample vs R2	
Control	—	—	98	Pass									
REF1	0.553	—	84		Pass								
REF2	12.2	—	86			Pass							
NLU13	176	REF2	84				14 (SQS)	0	**2**	< 0.01	0.50	**0.35**	Pass
NLU51	4826	REF1	0				98 (CSL)	**84 (CSL)**	86 (CSL)	< 0.01	**< 0.01**	< 0.01	CSL
NLU55	1064	REF1	51				47 (CSL)	**33 (CSL)**	35 (CSL)	< 0.01	**< 0.01**	< 0.01	CSL
NLUD55	301	REF1	74				24 (SQS)	**10**	12 (SQS)	< 0.01	**0.06**	0.04	Pass
NLU64	219	REF1	89				9	**-5**	-3	0.01	**NA**	NA	Pass
NLU66	28.3	REF2	92				6	-8	**-6**	0.12	NA	**NA**	Pass
NLU69	9.20	REF2	87				11 (SQS)	-3	**-1**	0.01	NA	**NA**	Pass
NLU73	77.5	REF1	89				9	**-5**	-3	0.02	**NA**	NA	Pass
NLU76	21.6	REF1	82				16 (SQS)	**2**	4	< 0.01	**0.27**	0.12	Pass
NLU81	10.1	REF2	90				8	-6	**-4**	0.02	NA	**NA**	Pass
NLU82	35.6	REF1	79				19 (SQS)	**5**	7	< 0.01	**0.16**	0.09	Pass
NLU83	12.1	REF2	94				4	-10	**-8**	0.18	NA	**NA**	Pass
NLU84	30.3	REF2	98				0	-14	**-12**	0.50	NA	**NA**	Pass
NLU85	4.71	REF2	95				3	-11	**-9**	0.09	NA	**NA**	Pass
NLU86	109	REF2	87				11	-3	**-1**	0.05	NA	**NA**	Pass
NLU87	62.9	REF2	94				4	-10	**-8**	0.17	NA	**NA**	Pass
NLU117	1096	REF1	0				98 (CSL)	**84 (CSL)**	86 (CSL)	< 0.01	**< 0.01**	< 0.01	CSL
NLUD117	170	REF1	30				68 (CSL)	**54 (CSL)**	56 (CSL)	< 0.01	**< 0.01**	< 0.01	CSL
NLUEPA5	15.7	REF2	88				10	-4	**-2.00**	0.01	NA	**NA**	Pass
NLUEPA19	24.0	REF1	97				1	**-13**	-11.00	0.34	**NA**	NA	Pass

NOTES

C = control; R1 = REF1; R2 = REF2; T = test (site)

NA = not applicable (test sample survival exceeded reference or control sample survival)

[1] Based upon grain size characteristics, with emphasis given in the following order of priority: % fines > % sand > % gravel

[2] red text = fail; **bold** = reference most similar to test site

[3] SQS: R - T > 10%; CSL: R - T > 25%

[4] Normality and homogeneity of variance were tested prior to t-testing using SPSS 10.0

[5] Ecology Draft Decision Criteria: test sediment has statistically significantly higher ($p \leq 0.05$) mean mortality than reference sediment AND average endpoint difference listed in Note 3

Appendix Table C-3. Phase 3 *Chironomus tentans* 20-day Survival and Growth
Preliminary Results-for discussion purposes only
Gas Works Sediments - Eastern Study Area
Test Initiated May 25, 2005

		Survival				Weight							
Site	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	Tare Weight (mg)	Total Weight (mg)	Ashed Weight (mg)	Total org Weight. (mg)	Weight per Org (mg)	Mean Growth per Org (mg)		St. Dev.
	1	9	90	82.0		71.04	82.26	71.98	10.28	1.14		1.54	
	2	5	50			70.25	80.97	71.56	9.41	1.88			
Control	3	10	100	82.0	19.2	72.14	92.08	74.38	17.70	1.77	1.54		0.29
	4	8	80			72.41	85.66	73.74	11.92	1.49			
	5	9	90			72.07	86.18	73.39	12.79	1.42			
	1	6	60	92.0		81.33	98.01	84.13	13.88	2.31		1.97	
	2	10	100			101.67	122.90	104.37	18.53	1.85			
Ref1	3	10	100	92.0	17.9	66.74	90.77	70.18	20.59	2.06	1.97		0.22
	4	10	100			76.20	97.32	79.22	18.10	1.81			
	5	10	100			67.49	89.16	71.24	17.92	1.79			
	1	8	80	80.0		79.93	99.22	83.67	15.55	1.94		2.46	
	2	10	100			91.36	110.04	94.63	15.41	1.54			
Ref2	3	7	70	80.0	12.2	92.14	113.90	95.37	18.53	2.65	2.46		0.70
	4	7	70			90.70	117.41	94.94	22.47	3.21			
	5	8	80			72.04	99.51	75.66	23.85	2.98			
	1	5	50	54.0		100.67	105.90	101.20	4.70	0.94		1.18	
	2	7	70			88.37	98.98	89.71	9.27	1.32			
NLU 13	3	4	40	54.0	11.4	75.45	80.13	76.00	4.13	1.03	1.18		0.22
	4	5	50			71.90	78.07	72.50	5.57	1.11			
	5	6	60			73.06	83.07	74.12	8.95	1.49			
	1	0	0	0.0		-	-	-	-	-		-	
	2	0	0			-	-	-	-	-			
NLU 51	3	0	0	0.0	0.0	-	-	-	-	-	-		-
	4	0	0			-	-	-	-	-			
	5	0	0			-	-	-	-	-			
	1	0	0	54.0		-	-	-	-	-		0.77	
	2	8	80			57.33	66.43	58.66	7.77	0.97			
NLU 55	3	6	60	54.0	32.9	80.19	86.42	80.70	5.72	0.95	0.77		0.23
	4	5	50			81.74	85.30	82.16	3.14	0.63			
	5	8	80			61.35	66.08	61.85	4.23	0.53			
	1	6	60	48.0		80.47	98.61	82.17	16.44	2.74		1.82	
	2	5	50			84.16	94.83	85.03	9.80	1.96			
D55	3	1	10	48.0	25.9	68.04	69.14	68.20	0.94	0.94	1.82		0.65
	4	4	40			64.48	73.07	65.63	7.44	1.86			
	5	8	80			62.55	77.28	64.63	12.65	1.58			
	1	10	100	86.0		85.00	105.47	86.98	18.49	1.85		2.34	
	2	5	50			79.02	93.92	80.35	13.57	2.71			
NLU 64	3	8	80	86.0	21.9	73.78	98.13	75.98	22.15	2.77	2.34		0.40
	4	10	100			78.22	104.09	81.18	22.91	2.29			
	5	10	100			107.33	130.11	109.58	20.53	2.05			
	1	9	90	72.0		76.99	100.80	79.35	21.45	2.38		2.57	
	2	8	80			56.98	80.82	58.97	21.85	2.73			
NLU 66	3	6	60	72.0	13.0	77.19	96.92	78.73	18.19	3.03	2.57		0.79
	4	6	60			75.54	97.70	77.44	20.26	3.38			
	5	7	70			67.52	77.53	68.38	9.15	1.31			
	1	9	90	96.0		95.42	119.58	98.01	21.57	2.40		2.30	
	2	10	100			86.01	119.58	89.05	30.53	3.05			
NLU 69	3	10	100	96.0	5.5	79.22	101.94	81.56	20.38	2.04	2.30		0.51
	4	10	100			86.25	105.20	88.41	16.79	1.68			
	5	9	90			81.10	104.20	83.42	20.78	2.31			
	1	10	100	92.0		89.48	115.42	92.24	23.18	2.32		1.94	
	2	7	70			78.11	95.24	79.79	15.45	2.21			
NLU 73	3	10	100	92.0	13.0	67.96	90.62	70.44	20.18	2.02	1.94		0.35
	4	9	90			71.40	87.03	73.66	13.37	1.49			
	5	10	100			85.87	104.87	88.05	16.82	1.68			
	1	10	100	94.0		101.55	121.70	103.72	17.98	1.80		1.71	
	2	9	90			88.49	113.14	90.75	22.39	2.49			
NLU 76	3	8	80	94.0	8.9	85.75	104.05	87.62	16.43	2.05	1.71		0.67
	4	10	100			88.60	96.68	89.57	7.11	0.71			
	5	10	100			66.26	84.04	68.98	15.06	1.51			
	1	9	90	82.0		85.67	111.95	88.18	23.77	2.64		2.64	
	2	10	100			81.66	107.34	84.63	22.71	2.27			
NLU 81	3	9	90	82.0	23.9	58.23	79.90	60.37	19.53	2.17	2.64		0.59
	4	9	90			72.48	97.32	74.99	22.33	2.48			
	5	4	40			73.23	89.33	74.72	14.61	3.65			
	1	7	70	76.0		84.51	99.42	86.11	13.31	1.90		2.25	
	2	6	60			73.94	94.48	76.05	18.43	3.07			
NLU 82	3	9	90	76.0	18.2	89.95	110.59	91.98	18.61	2.07	2.25		0.47
	4	6	60			67.72	81.82	69.30	12.52	2.09			
	5	10	100			111.71	135.02	113.95	21.07	2.11			
	1	8	80	84.0		82.08	101.46	84.38	17.08	2.14		2.33	
	2	7	70			55.95	78.70	57.94	20.76	2.97			
NLU 83	3	9	90	84.0	8.9	78.46	100.17	80.68	19.49	2.17	2.33		0.41
	4	9	90			76.88	101.94	79.56	22.38	2.49			
	5	9	90			79.83	99.15	81.95	17.20	1.91			

Appendix Table C-3. Phase 3 *Chironomus tentans* 20-day Survival and Growth
Preliminary Results-for discussion purposes only
Gas Works Sediments - Eastern Study Area
Test Initiated May 25, 2005

		Survival				Weight						
Site	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	Tare Weight (mg)	Total Weight (mg)	Ashed Weight (mg)	Total org Weight. (mg)	Weight per Org (mg)	Mean Growth per Org (mg)	St. Dev.
	1	8	80	88.0		77.39	95.28	79.91	15.37	1.92	2.18	
	2	10	100			85.46	105.60	87.84	17.76	1.78		
NLU 84	3	7	70	88.0	13.0	72.84	95.95	74.88	21.07	3.01	2.18	0.52
	4	9	90			102.02	126.73	105.45	21.28	2.36		
	5	10	100			68.91	90.16	71.69	18.47	1.85		
	1	10	100	82.0		73.85	96.36	76.55	19.81	1.98	2.36	
	2	10	100			74.83	104.09	78.76	25.33	2.53		
NLU 85	3	5	50	82.0	20.5	89.30	102.58	90.60	11.98	2.40	2.36	0.22
	4	8	80			72.18	93.84	74.10	19.74	2.47		
	5	8	80			78.17	99.59	80.09	19.50	2.44		
	1	8	80	62.0		73.07	83.16	74.53	8.63	1.08	1.25	
	2	6	60			80.01	85.43	80.70	4.73	0.79		
NLU 86	3	2	20	62.0	24.9	79.36	84.28	81.19	3.09	1.55	1.25	0.39
	4	8	80			67.72	83.77	69.80	13.97	1.75		
	5	7	70			74.90	83.58	75.94	7.64	1.09		
	1	11	110	88.0		68.56	86.52	71.67	14.85	1.35	2.25	
	2	10	100			80.19	116.08	83.59	32.49	3.25		
NLU 87	3	9	90	88.0	19.2	80.24	98.48	82.55	15.93	1.77	2.25	0.80
	4	6	60			73.94	86.80	75.01	11.79	1.97		
	5	8	80			81.26	107.29	83.96	23.33	2.92		
	1	3	30	34.0		110.93	114.80	111.36	3.44	1.15	1.62	
	2	3	30			79.86	87.04	80.50	6.54	2.18		
NLU 117	3	5	50	34.0	23.0	77.88	86.35	78.70	7.65	1.53	1.62	0.43
	4	0	0			-	-	-	-	-		
	5	6	60			70.16	81.44	71.63	9.81	1.64		
	1	8	80	40.0		103.42	120.65	105.23	15.42	1.93	1.90	
	2	6	60			79.71	90.40	81.01	9.39	1.57		
D117	3	1	10	40.0	29.2	87.47	88.39	87.58	0.81	0.81	1.90	0.81
	4	3	30			53.81	63.82	54.83	8.99	3.00		
	5	2	20			75.97	80.75	76.33	4.42	2.21		
	1	10	100	88.0		77.98	97.40	79.96	17.44	1.74	2.17	
	2	9	90			77.77	98.41	79.87	18.54	2.06		
EPA 5	3	10	100	88.0	13.0	76.17	99.18	78.52	20.66	2.07	2.17	0.32
	4	7	70			89.70	109.24	91.62	17.62	2.52		
	5	8	80			100.31	121.82	102.26	19.56	2.45		
	1	8	80	82.0		76.89	93.49	79.10	14.39	1.80	2.14	
	2	10	100			74.92	98.43	77.00	21.43	2.14		
EPA 19	3	10	100	82.0	17.9	92.10	110.03	94.15	15.88	1.59	2.14	0.46
	4	7	70			90.65	111.49	92.59	18.90	2.70		
	5	6	60			82.26	99.04	84.12	14.92	2.49		

Table C-4. GWSA Phase 3 Site-Wide *C. tentans* Survival Results and Statistics

Site	TPAH (mg/kg dw)	Most Similar Reference [1]	% Survival	QUALITY CONTROL			DATA QUALITY ANALYSIS [2]						Decision Criteria [5]
				Control	REF1	REF2	Endpoint Analysis [3]			t-Test Analysis (p Value) [4]			
				C > 68% survival	R1 > 65% survival	R2 > 65% survival	C - T	R1 - T	R2 - T	Sample vs Control	Sample vs R1	Sample vs R2	
Control	—	—	82	Pass									
REF1	0.553	—	92		Pass								
REF2	12.2	—	80			Pass							
NLU13	176	REF2	54				28 (CSL)	38 (CSL)	**26 (CSL)**	0.01	< 0.01	**0.01**	CSL
NLU51	4826	REF1	0				82 (CSL)	**92 (CSL)**	80 (CSL)	< 0.01	**< 0.01**	< 0.01	CSL
NLU55	1064	REF1	54				28 (CSL)	**38 (CSL)**	26 (CSL)	0.06	**0.01**	0.07	CSL
NLUD55	301	REF1	48				34 (CSL)	**44 (CSL)**	32 (CSL)	0.02	**< 0.01**	0.02	CSL
NLU64	219	REF1	86				-4	**6**	-6	NA	**0.30**	NA	Pass
NLU66	28.3	REF2	72				10	20 (SQS)	**8**	0.14	0.01	**0.17**	Pass
NLU69	9.20	REF2	96				-14	-4	**-16**	NA	NA	**NA**	Pass
NLU73	77.5	REF1	92				-10	**0**	-12	NA	**0.41**	NA	Pass
NLU76	21.6	REF1	94				-12	**-2**	-14	NA	**NA**	NA	Pass
NLU81	10.1	REF2	82				0	10	**-2**	0.48	0.14	**NA**	Pass
NLU82	35.6	REF1	76				6	**16 (SQS)**	4	0.35	**0.07**	0.42	Pass
NLU83	12.1	REF2	84				-2	8	**-4**	NA	0.05	**NA**	Pass
NLU84	30.3	REF2	88				-6	4	**-8**	NA	0.24	**NA**	Pass
NLU85	4.71	REF2	82				0	10	**-2**	0.43	0.17	**NA**	Pass
NLU86	109	REF2	62				20 (SQS)	30 (CSL)	**18 (SQS)**	0.07	0.01	**0.08**	Pass
NLU87	62.9	REF2	88				-6	4	**-8**	NA	0.22	**NA**	Pass
NLU117	1096	REF1	34				48 (CSL)	**58 (CSL)**	46 (CSL)	< 0.01	**< 0.01**	< 0.01	CSL
NLUD117	170	REF1	40				42 (CSL)	**52 (CSL)**	40 (CSL)	0.01	**< 0.01**	0.01	CSL
NLUEPA5	15.7	REF2	88				-6	4	**-8.00**	NA	0.24	**NA**	Pass
NLUEPA19	24.0	REF1	82				0	**10**	-2.00	0.43	**0.16**	NA	Pass

NOTES

C = control; R1 = REF1; R2 = REF2; T = test (site)

NA = not applicable (test sample survival exceeded reference or control sample survival)

[1] Based upon grain size characteristics, with emphasis given in the following order of priority: % fines > % sand > % gravel.

[2] red text = fail; **bold** = reference most similar to test site

[3] SQS: R - T > 15%; CSL: R - T > 25%

[4] Normality and homogeneity of variance were tested prior to t-testing using SPSS 10.0. Untransformed data was both normal and had homogenous variance, but the arsin(sqrt) transform improved the variance so was used for the t-testing (1-tailed).

[5] Ecology Draft Decision Criteria: test sediment has statistically significantly higher ($p \leq 0.05$) mean mortality than reference sediment AND average endpoint difference listed in Note 3

Table C-5. GWSA Phase 3 *C. tentans* Growth Results and Statistics

Site	TPAH (mg/kg dw)	Most Similar Reference [1]	growth (mg/org afdw)	QUALITY CONTROL			DATA QUALITY ANALYSIS [2]						Decision Criteria [5]
				Control	REF1	REF2	Endpoint Analysis [3]			t-Test Analysis (p Value) [4]			
				C > 0.48 mg/ind afdw	RF/CF > 0.8	RF/CF > 0.8	T/C	T/R1	T/R2	Sample vs Control	Sample vs R1	Sample vs R2	
Control	—	—	1.54	Pass									
REF1	0.553	—	1.97		Pass								
REF2	12.2	—	2.46			Pass							
NLU13	176	REF2	1.18				0.77 (SQS)	0.60 (CSL)	**0.48 (CSL)**	0.03	< 0.01	**< 0.01**	CSL
NLU51	4826	REF1	NA				--	**--**	--	--	**--**	--	--
NLU55	1064	REF1	0.77				0.50 (CSL)	**0.39 (CSL)**	0.31 (CSL)	< 0.01	**< 0.01**	< 0.01	CSL
NLUD55	301	REF1	1.82				1.18	**0.92**	0.74 (SQS)	NA	**0.32**	0.08	Pass
NLU64	219	REF1	2.34				1.52	**1.19**	0.95	NA	**NA**	0.37	Pass
NLU66	28.3	REF2	2.57				1.67	1.31	**1.04**	NA	NA	**NA**	Pass
NLU69	9.20	REF2	2.30				1.49	1.17	**0.93**	NA	NA	**0.34**	Pass
NLU73	77.5	REF1	1.94				1.26	**0.99**	0.79 (SQS)	NA	**0.45**	0.09	Pass
NLU76	21.6	REF1	1.71				1.11	**0.87**	0.69 (CSL)	NA	**0.22**	0.06	Pass
NLU81	10.1	REF2	2.64				1.72	1.34	**1.07**	NA	NA	**NA**	Pass
NLU82	35.6	REF1	2.25				1.46	**1.14**	0.91	NA	**NA**	0.29	Pass
NLU83	12.1	REF2	2.33				1.51	1.19	**0.95**	NA	NA	**0.36**	Pass
NLU84	30.3	REF2	2.18				1.42	1.11	**0.89**	NA	NA	**0.25**	Pass
NLU85	4.71	REF2	2.36				1.53	1.20	**0.96**	NA	NA	**0.38**	Pass
NLU86	109	REF2	1.25				0.81 (SQS)	0.64 (CSL)	**0.51 (CSL)**	0.11	< 0.01	**< 0.01**	CSL
NLU87	62.9	REF2	2.25				1.46	1.14	**0.91**	NA	NA	**0.33**	Pass
NLU117	1096	REF1	1.62				1.05	**0.83 (SQS)**	0.66 (CSL)	NA	**0.08**	0.04	Pass
NLUD117	170	REF1	1.90				1.23	**0.97**	0.77 (SQS)	NA	**0.43**	0.14	Pass
NLUEPA5	15.7	REF2	2.17				1.41	1.10	**0.88**	NA	NA	**0.21**	Pass
NLUEPA19	24.0	REF1	2.14				1.39	**1.09**	0.87	NA	**NA**	0.21	Pass

NOTES

C = control; R1 = REF1; R2 = REF2; T = test (site)

-- = all organisms died; no growth to report

NA = not applicable (test sample survival exceeded reference or control sample survival)

[1] Based upon grain size characteristics, with emphasis given in the following order of priority: % fines > % sand > % gravel

[2] red text = fail; **bold** = reference most similar to test site

[3] SQS: R - T > 15%; CSL: R - T > 25%

[4] Normality and homogeneity of variance were tested prior to t-testing using SPSS 10.0. Untransformed data was both normal and had homogenous variance.

[5] Ecology Draft Decision Criteria: test sediment has statistically significantly higher ($p \leq 0.05$) mean mortality than reference sediment AND average endpoint difference listed in Note 3

Table C-6. Revisiting RETEC Split Sample Microtox® Results and Statistics (from Ecology/TAMU stations – March, 2002)

Site	TPAH (mg/kg dw)	Time	Mean Light Reading	p-Value: Control vs Sample	p-Value: Ref Sed. vs Sample	RD [2]	SQS or CSL Failure [3]	*test ok?* Fc(mean)/ Ic(mean) ≥ 72%	*ref pass?* F_{R1}(mean)/ Fc(mean) ≥ 80%	Marine: *use test I(0)?* I(0) / Ci(0) ≥ 80%	Marine: mean Δ I(15)	Marine: RD: T/C	Marine: RD: T/R	Freshwater: mean Δ I(15) (final/initial)	Freshwater: RD (15 min): T/C	Freshwater: RD (15 min): T/R
Control	-	$I_{(0)}$	90.03 (100%)													
		$I_{(5)}$	76.74 (85.2%)													
		$I_{(15)}$	64.28 (71.4%)					0.71			0.714			0.71	—	
Ref-1	0.77	$I_{(0)}$	81.37							0.90						
		$I_{(5)}$	70.13	0.038							*R1 to R1 init*			*R1 to R1 initial*		
		$I_{(15)}$	56.79	0.106					0.88		0.698			0.70	—	
LU-1	529	$I_{(0)}$	61.82							0.69						
		$I_{(5)}$	53.55	<0.001	0.005 [1]	23.6	SQS				*T to C init*	*CSL*	*CSL*	*T to T initial*		
		$I_{(15)}$	39.53	<0.001	0.003 [1]	30.4	CSL				0.439	0.61	0.63	0.64	—	0.92
LU-2	1150	$I_{(0)}$	45.78							0.51						
		$I_{(5)}$	42.12	<0.001	<0.001	39.9	CSL				*T to C init*	*CSL*	*CSL*	*T to T initial*		
		$I_{(15)}$	38.21	<0.001	<0.001 [1]	32.7	CSL				0.424	0.59	0.61	0.83	—	1.20
LU-3	453	$I_{(0)}$	73.17							0.81						
		$I_{(5)}$	63.24	0.001	0.003	9.8					*T to T init*			*T to T initial*		
		$I_{(15)}$	52.63	0.001	0.011	7.3					0.719	1.01	1.03	0.72	—	1.03
Control	-	$I_{(0)}$	102.14 (100%)													
		$I_{(5)}$	115.91 (113.5%)													
		$I_{(15)}$	119.6 (117.1%)					1.17			1.171			1.17		
Ref-1	0.77	$I_{(0)}$	91.18							0.89						
		$I_{(5)}$	102.09	0.075							*R1 to R1 init*			*R1 to R1 initial*		
		$I_{(15)}$	103.18	0.049					0.86		1.132			1.13		
LU-4	51	$I_{(0)}$	69.54							0.68						
		$I_{(5)}$	70.72	0.001	0.018	30.7	CSL				*T to C init*	*CSL*	*CSL*	*T to T initial*	SQS	SQS
		$I_{(15)}$	61.36	<0.001	0.004	40.5	CSL				0.601	0.51	0.53	0.88	0.75	0.78
LU-5	15	$I_{(0)}$	84.92							0.83						
		$I_{(5)}$	93.10	0.002	0.165	8.8					*T to T init*			*T to T initial*		
		$I_{(15)}$	95.84	0.001	0.204	7.1					1.129	0.96	1.00	1.13	0.96	1.00
LU-6	22	$I_{(0)}$	85.05							0.83						
		$I_{(5)}$	92.82	0.004	0.175	9.1					*T to T init*			*T to T initial*		
		$I_{(15)}$	93.35	0.002	0.157	9.5					1.098	0.94	0.97	1.10	0.94	0.97
LU-7	34	$I_{(0)}$	12.33							0.12						
		$I_{(5)}$	10.89	<0.001 [1]	<0.001 [1]	89.3	CSL				*T to C init*	*CSL*	*CSL*	*T to T initial*		
		$I_{(15)}$	13.93	<0.001 [1]	<0.001 [1]	86.5	CSL				0.136	0.12	0.12	1.13	0.96	1.00
Control	-	$I_{(0)}$	95.77 (100%)													
		$I_{(5)}$	84.65 (88.4%)													
		$I_{(15)}$	73.61 (76.9%)					0.77			0.769			0.77		
Ref-1	0.77	$I_{(0)}$	75.05							0.78						
		$I_{(5)}$	65.10	0.022							*R1 to R1 init*			*R1 to R1 initial*		
		$I_{(15)}$	55.20	0.016					0.75		NA			0.74		—
LU-8	16	$I_{(0)}$	83.83							0.88	0.851	1.11				
		$I_{(5)}$	71.38	0.195	0.347	-9.6	—				*T to T init*	*SQS*		*T to T initial*	SQS	
		$I_{(15)}$	48.17	0.060 [1]	0.317	12.7	—				0.575	0.75		0.57	0.75	—
LU-9	9.6	$I_{(0)}$	81.71							0.85						
		$I_{(5)}$	72.68	0.038	0.212	-11.6	—				*T to T init*			*T to T initial*		
		$I_{(15)}$	66.17	0.104	0.104	-19.9	—				0.810	1.05		0.81	1.05	—
LU-10	23	$I_{(0)}$	79.22							0.83						
		$I_{(5)}$	68.42	0.003 [1]	0.343 [1]	-5.1	—				*T to T init*			*T to T initial*		
		$I_{(15)}$	60.39	0.032	0.28	-9.4	—				0.762	0.99		0.76	0.99	—

Notes

Results are for samples collected by Ecology in March 2002 and analyzed by RETEC (using AMEC).

[1] Unequal variance. Welch's correction applied to t-test.

[2] RD is the relative difference between the reference site (R) and the test site (T) light readings.
RD = [100-(T/R)*100]
T = Mean (5 pseudo-replicates) test output results
R = Mean (5 pseudo-replicates) reference output results

[3] SQS failure = RD ≥ 15%
CSL failure = RD ≥ 25%

$I_{(0)}$ = Initial reading
$I_{(5)}$ = 5 minute reading
$I_{(15)}$ = 15 minute reading
= outcome changed from original analysis

Table C-7. GWSA Phase 3 Site-Wide Microtox® Results and Statistics: Using Marine QA/QC Criteria

Site	TPAH (mg/kg dw)	Most Similar Reference [1]	Time [2,3]	Mean Light Reading	QUALITY CONTROL [4,5]			DATA ANALYSIS						Decision Criteria [8]
								Endpoint Analysis [4,6]			t-Test Analysis (p Value) [7]			
					F_{R1}(mean)/ Ic(mean) ≥ 80%	F_{R2}(mean)/ Ic(mean) ≥ 80%	Fc(mean)/ Ic(mean) ≥ 72%	$T_{(mean\Delta)}$/ $R1_{(mean\Delta)}$	$T_{(mean\Delta)}$/ $R2_{(mean\Delta)}$	$T_{(mean\Delta)}$/ $C_{(mean\Delta)}$	Sample versus $R1_{(mean\Delta)}$	Sample versus $R2_{(mean\Delta)}$	Sample versus $C_{(mean\Delta)}$	
Control	—	—	$I_{(0)}$	93										
			$I_{(15)}$	79										
			$T_{(mean\Delta)}$	0.84			0.84							
REF1	0.553	—	$I_{(0)}$	89										
			$I_{(15)}$	62	0.78									
			$T_{(mean\Delta)}$	0.70										
REF2	12.18	—	$I_{(0)}$	82										
			$I_{(15)}$	59		0.75								
			$T_{(mean\Delta)}$	0.72										
NLU73	77.52	REF1	$I_{(0)}$	90										Pass
			$I_{(15)}$	71										
			$T_{(mean\Delta)}$	0.78				**NA**	NA	0.93	**NA**	NA	0.003	
Control	—	—	$I_{(0)}$	94										
			$I_{(15)}$	69										
			$T_{(mean\Delta)}$	0.73			0.73							
REF1	0.553	—	$I_{(0)}$	83										
			$I_{(15)}$	59	0.86									
			$T_{(mean\Delta)}$	0.71										
REF2	12.18	—	$I_{(0)}$	74										
			$I_{(15)}$	53		0.77								
			$T_{(mean\Delta)}$	0.56										
NLU51	4826	REF1	$I_{(0)}$	58										SQS
			$I_{(15)}$	50										
			$T_{(mean\Delta)}$	0.53				**0.75 (SQS)**	NA	0.72 (CSL)	0.000	NA	0.000	
NLUD55	301.2	REF1	$I_{(0)}$	37										CSL
			$I_{(15)}$	32										
			$T_{(mean\Delta)}$	0.34				**0.49 (CSL)**	NA	0.47 (CSL)	0.000	NA	0.000	
NLUD117	170.2	REF1	$I_{(0)}$	60										CSL
			$I_{(15)}$	46										
			$T_{(mean\Delta)}$	0.49				**0.70 (CSL)**	NA	0.68 (CSL)	0.000	NA	0.000	
Control	—	—	$I_{(0)}$	99										
			$I_{(15)}$	80										
			$T_{(mean\Delta)}$	0.81			0.81							
REF1	0.553	—	$I_{(0)}$	87										
			$I_{(15)}$	66	0.82									
			$T_{(mean\Delta)}$	0.76										
REF2	12.18	—	$I_{(0)}$	81										
			$I_{(15)}$	60		0.75								
			$T_{(mean\Delta)}$	0.74										
NLU55	1064	REF1	$I_{(0)}$	51										CSL
			$I_{(15)}$	44										
			$T_{(mean\Delta)}$	0.45				**0.60 (CSL)**	NA	0.56 (CSL)	**0.000**	NA	0.000	
NLU64	219	REF1	$I_{(0)}$	91										Pass
			$I_{(15)}$	72										
			$T_{(mean\Delta)}$	0.80				**1.05**	NA	0.98	**0.018**	NA	0.141	
NLU117	1096	REF1	$I_{(0)}$	64										CSL
			$I_{(15)}$	54										
			$T_{(mean\Delta)}$	0.55				**0.72 (CSL)**	NA	0.67 (CSL)	**0.000**	NA	0.000	
Control	—	—	$I_{(0)}$	101										
			$I_{(15)}$	100										
			$T_{(mean\Delta)}$	0.99			0.99							
REF1	0.553	—	$I_{(0)}$	94										
			$I_{(15)}$	86	0.86									
			$T_{(mean\Delta)}$	0.91										
REF2	12.18	—	$I_{(0)}$	100										
			$I_{(15)}$	100		1.00								
			$T_{(mean\Delta)}$	1.00										
NLUEPA5	15.68	REF2	$I_{(0)}$	96										Pass
			$I_{(15)}$	96										
			$T_{(mean\Delta)}$	0.99				1.09	**0.99**	1.00	0.000	**0.262**	1.000	
NLUEPA19	24.02	REF1	$I_{(0)}$	99										Pass
			$I_{(15)}$	101										
			$T_{(mean\Delta)}$	1.02				**1.11** [#]	1.02	1.02	**0.000**	0.065	0.009	
Control	—	—	$I_{(0)}$	97										
			$I_{(15)}$	78										
			$T_{(mean\Delta)}$	0.80			0.80							
REF1	0.553	—	$I_{(0)}$	89										
			$I_{(15)}$	71	0.92									
			$T_{(mean\Delta)}$	0.80										
REF2	12.18	—	$I_{(0)}$	81										
			$I_{(15)}$	61		0.79								
			$T_{(mean\Delta)}$	0.76										
NLU66	28.26	REF2	$I_{(0)}$	88										Pass
			$I_{(15)}$	72										
			$T_{(mean\Delta)}$	0.81				1.02	**NA**	1.02	0.309	**NA**	0.359	

Table C-7. GWSA Phase 3 Site-Wide Microtox® Results and Statistics: Using Marine QA/QC Criteria

Site	TPAH (mg/kg dw)	Most Similar Reference [1]	Time [2,3]	Mean Light Reading	QUALITY CONTROL [4,5]			DATA ANALYSIS						Decision Criteria [8]
								Endpoint Analysis [4,6]			t-Test Analysis (p Value) [7]			
					F_{R1}(mean)/ Ic(mean) ≥ 80%	F_{R2}(mean)/ Ic(mean) ≥ 80%	Fc(mean)/ Ic(mean) ≥ 72%	$T_{(mean\Delta)}$/ $R1_{(mean\Delta)}$	$T_{(mean\Delta)}$/ $R2_{(mean\Delta)}$	$T_{(mean\Delta)}$/ $C_{(mean\Delta)}$	Sample versus $R1_{(mean\Delta)}$	Sample versus $R2_{(mean\Delta)}$	Sample versus $C_{(mean\Delta)}$	
NLU69	9.20	REF2	$I_{(0)}$	86										Pass
			$I_{(15)}$	72										
			$T_{(mean\Delta)}$	0.84				1.05	**NA**	1.05	0.019	**NA**	0.037	
NLU76	21.57	REF1	$I_{(0)}$	90										Pass
			$I_{(15)}$	73										
			$T_{(mean\Delta)}$	0.81				**1.01**	NA	1.02	**0.376**	NA	0.417	
Control	—	—	$I_{(0)}$	88										
			$I_{(15)}$	68										
			$T_{(mean\Delta)}$	0.77			0.77							
REF1	0.553	—	$I_{(0)}$	82										
			$I_{(15)}$	63	0.93									
			$T_{(mean\Delta)}$	0.77										
REF2	12.18	—	$I_{(0)}$	88										
			$I_{(15)}$	67		0.98								
			$T_{(mean\Delta)}$	0.76										
NLU81	10.09	REF2	$I_{(0)}$	86										Pass
			$I_{(15)}$	68										
			$T_{(mean\Delta)}$	0.79				1.02	**1.03**	1.02	0.716	**0.294**	0.447	
NLU82	35.58	REF1	$I_{(0)}$	66										SQS
			$I_{(15)}$	56										
			$T_{(mean\Delta)}$	0.63				**0.82 (SQS)**	0.83 (SQS)	0.82 (SQS)	**0.000**	0.000	0.000	
NLU87	62.92	REF2	$I_{(0)}$	90										Pass
			$I_{(15)}$	71										
			$T_{(mean\Delta)}$	0.80				1.03	**1.05**	1.03	0.276	**0.070**	0.108	
Control	—	—	$I_{(0)}$	81										
			$I_{(15)}$	68										
			$T_{(mean\Delta)}$	0.84			0.84							
REF1	0.553	—	$I_{(0)}$	95										
			$I_{(15)}$	83	1.21									
			$T_{(mean\Delta)}$	0.87										
REF2	12.18	—	$I_{(0)}$	86										
			$I_{(15)}$	80		1.17								
			$T_{(mean\Delta)}$	0.95										
NLU13	176	REF2	$I_{(0)}$	71										Pass
			$I_{(15)}$	65										
			$T_{(mean\Delta)}$	0.91				1.04	**0.96**	1.08	0.310 *	**0.746 ***	0.024 *	
NLU83	12.12	REF2	$I_{(0)}$	75										Pass
			$I_{(15)}$	70										
			$T_{(mean\Delta)}$	0.93				1.07	**0.98**	1.10	.095 *	**0.977 ***	0.001 *	
Control	—	—	$I_{(0)}$	85										
			$I_{(15)}$	82										
			$T_{(mean\Delta)}$	0.96			0.96							
REF1	0.553	—	$I_{(0)}$	65										
			$I_{(15)}$	60	0.74									
			$T_{(mean\Delta)}$	0.71										
REF2	12.18	—	$I_{(0)}$	70										
			$I_{(15)}$	69		0.85								
			$T_{(mean\Delta)}$	0.99										
NLU84	30.26	REF2	$I_{(0)}$	96										Pass
			$I_{(15)}$	91										
			$T_{(mean\Delta)}$	0.95				NA	**0.96**	0.99	NA	**0.140**	0.712	
NLU85	4.71	REF2	$I_{(0)}$	107										Pass
			$I_{(15)}$	101										
			$T_{(mean\Delta)}$	0.95				NA	**0.96**	0.99	NA	**0.047**	0.249	
NLU86	109.2	REF2	$I_{(0)}$	84										Pass
			$I_{(15)}$	80										
			$T_{(mean\Delta)}$	0.95				NA	**0.96**	0.99	NA	**0.090**	0.619	

NOTES

C = control; R1 = REF1; R2 = REF2; T = test (site)

Nearshore Area
Eastern Study Area
Western Study Area

[1] Based upon grain size characteristics, with emphasis given in the following order of priority: % fines > % sand > % gravel.

[2] $I_{(0)}$ = light reading after the initial five minute incubation period; $I_{(15)}$ = light reading fifteen minutes after $I_{(0)}$

[3] Δ = change; calculated by dividing $I_{(15)}$ by $I_{(0)}$

[4] green text = pass; red text = fail; **bold** = reference most similar to test site

[5] A failure of the control indicates a re-test is required. A failure of a reference means the control values must be used in t-test calculations.

[6] SQS: T/R < 0.85; CSL: T/R < 0.75

[#] T_{mean}/C_{mean} > 1.10 and T_{mean}/R_{mean} > 1.10 are not interpretable (as per Ecology's Sediment Sampling and Analysis Plan Appendix Subappendix C, 2003)

[7] t-tests were calculated using SPSS 10. 0 (2-tail). Normality and homogeneity of variance were tested prior to t-testing using SPSS 10.0.
* Test used transformed data (inverse), which improved normality and homogeneity of variance.

[8] Ecology Draft Decision Criteria: test sediment has statistically significantly higher ($p \leq 0.05$) mean mortality than reference sediment AND average endpoint difference listed in Note 6

Appendix Table C-8a. Microtox 100 Percent Sediment Porewater Test
Preliminary Data: Site 73
Gas Works Sediments - Eastern Study Area
Test Initiation: April 28, 2005

Site	Reading	Light Reading Replicate 1	2	3	4	5	Mean	St.Dev.	$T_{(mean\Delta)}$/ $Ref1_{(mean\Delta)}$	$T_{(mean\Delta)}$/ $Ref2_{(mean\Delta)}$	$T_{(mean\Delta)}$/ $C_{(mean\Delta)}$	Change in light readings compared to initial control $I_{(t)(mean)}/I_{(0)C(mean)}$	Change in light readings compared to final control $I_{(t)(mean)}/I_{(t)C(mean)}$	Evaluation of initial light output $I_{(0)(mean)}/I_{(0)C(mean)}$
Control	$I_{(0)}$	94	90	100	88	95	93							
	$I_{(5)}$	96	93	103	88	96	95					1.02		
	$I_{(15)}$	79	78	86	72	79	79					0.84		
	$C_{(5)}$	1.02	1.03	1.03	1.00	1.01	1.02	0.01				*test OK*		
	$C_{(15)}$	0.84	0.87	0.86	0.82	0.83	**0.84**	0.02						
Ref 1	$I_{(0)}$	88	86	88	89	93	89							0.95
	$I_{(5)}$	83	84	87	83	88	85						0.89	*use R1 I(mean0)*
	$I_{(15)}$	63	59	64	58	65	62						0.78	
	$R_{(5)}$	0.89	0.90	0.93	0.89	0.94	0.91	0.03					*t-test = Cntrl*	
	$R_{(15)}$	0.67	0.63	0.69	0.62	0.70	**0.66**	0.03						
Ref 2	$I_{(0)}$	87	80	80	83	82	82							0.88
	$I_{(5)}$	80	73	74	76	76	76						0.80	*use R2 I(mean0)*
	$I_{(15)}$	62	57	58	60	58	59						0.75	
	$T_{(5)}$	0.92	0.91	0.93	0.92	0.93	0.92	0.01					*t-test = Cntrl*	
	$T_{(15)}$	0.71	0.71	0.73	0.72	0.71	**0.72**	0.01						
73	$I_{(0)}$	90	87	91	91	92	90							0.97
	$I_{(5)}$	83	80	86	87	86	84							*use 73 I(mean0)*
	$I_{(15)}$	69	67	70	73	75	71							
	$T_{(5)}$	0.92	0.92	0.95	0.96	0.93	0.94	0.02	1.03	1.02	0.92			
	$T_{(15)}$	0.77	0.77	0.77	0.80	0.82	**0.78**	0.02	**1.19**	**1.10**	**0.93**			

SQS: T/R < 0.85; CSL: T/R < 0.75

NLU73	Pass	Pass	Pass

$I_{(0)}$ is the light reading after the initial five minute incubation period

$I_{(5)}$ is the light reading five minutes after $I_{(0)}$

$I_{(15)}$ is the light reading fifteen minutes after $I_{(0)}$

$C_{(t)}$, $R_{(t)}$, and $T_{(t)}$ are the changes in light readings from the intial reading in each sample container for the control, reference sediment and test sites. I(t)/I(0)

Quality Control Steps:

1. Is control final mean output greater than or equal to 72% control initial mean output?

$I_{(5)}$:$F_{c(mean)}/I_{c(mean)}$: **102%** **YES**

$I_{(15)}$:$F_{c(mean)}/I_{c(mean)}$: **84%** **YES**

YES: Control results are acceptable

NO: Control results are unacceptable (retest required)

2. Does the reference final mean meet or exceed 80% of control final mean?

Ref 1 $I_{(5)}$:$F_{R(mean)}/F_{C(mean)}$: **89%** **YES** Ref 2 $I_{(5)}$:$F_{R(mean)}/F_{C(mean)}$: **80%** **YES**

$I_{(15)}$:$F_{R(mean)}/F_{C(mean)}$: **78%** **NO** $I_{(15)}$:$F_{R(mean)}/F_{C(mean)}$: **75%** **NO**

YES: Use reference data for t-test calculation

NO: Use control data for t-test calculation

3. Is the reference initial mean greater than or equal to 80% of control initial mean?

Ref 1:$I_{R(mean)}/I_{C(mean)}$: **95%** **YES** Ref 2:$I_{R(mean)}/I_{C(mean)}$: **88%** **YES**

YES: Use reference initial mean to calculate change in final light readings **<-- this was a mistake; Naut calc Ref1 using Ic**

NO: Use control initial mean to calculate change in final light readings

4. Are test initial mean values greater than or 80% of control initial mean values?

Site 73 $I_{T(mean)}/I_{C(mean)}$: **97%** **YES**

YES: Use site initial mean to calculate change in final light readings

NO: Use control initial mean to calculate change in final light readings **<-- checks out fine**

Appendix Table C-8b. Microtox 100 Percent Sediment Porewater Test
Preliminary Data: Sites D117, D55, 51
Gas Works Sediments - Eastern Study Area
Test Initiation: April 28, 2005

Site	Reading	Light Reading Replicate 1	2	3	4	5	Mean	St.Dev.	$T_{(mean\Delta)}/Ref1_{(mean\Delta)}$	$T_{(mean\Delta)}/Ref2_{(mean\Delta)}$	$T_{(mean\Delta)}/C_{(mean\Delta)}$	Change in light readings compared to initial control $I_{(t)(mean)}/I_{(0)C(mean)}$	Change in light readings compared to final control $I_{(t)(mean)}/I_{(t)C(mean)}$	Evaluation of initial light output $I_{(0)(mean)}/I_{(0)C(mean)}$
Control	$I_{(0)}$	92	91	96	96	97	94							
	$I_{(5)}$	75	78	79	79	75	77					0.82		
	$I_{(15)}$	70	69	67	69	68	69					0.73		
	$C_{(5)}$	0.82	0.86	0.82	0.82	0.77	0.82	0.03				test OK		
	$C_{(15)}$	0.76	0.76	0.70	0.72	0.70	0.73	0.03						
Ref 1	$I_{(0)}$	84	84	83	81	85	83							0.88
	$I_{(5)}$	69	70	67	68	70	69						0.89	use R1 I(mean0)
	$I_{(15)}$	59	61	56	59	59	59						0.86	
	$R_{(5)}$	0.73	0.74	0.71	0.72	0.74	0.73	0.01					t-test = Ref1	
	$R_{(15)}$	0.70	0.73	0.67	0.73	0.69	0.71	0.02						
Ref 2	$I_{(0)}$	76	71	73	74	76	74							0.78
	$I_{(5)}$	61	59	60	58	61	60						0.77	use C I(mean0)
	$I_{(15)}$	54	53	52	52	53	53						0.77	
	$T_{(5)}$	0.80	0.83	0.82	0.78	0.80	0.81	0.02					t-test = Cntrl	
	$T_{(15)}$	0.71	0.75	0.71	0.70	0.70	0.71	0.02						
D117	$I_{(0)}$	59	59	61	58	61	60							0.63
	$I_{(5)}$	51	50	53	51	51	51							use C I(mean0)
	$I_{(15)}$	48	45	48	45	46	46							
	$T_{(5)}$	0.54	0.53	0.56	0.54	0.54	0.54	0.01	0.74	0.67	0.66			
	$T_{(15)}$	0.81	0.76	0.79	0.78	0.75	0.78	0.02	**1.10**	**1.09**	**1.07**			
D55	$I_{(0)}$	36	36	37	39	39	37							0.40
	$I_{(5)}$	32	34	33	37	37	35							use C I(mean0)
	$I_{(15)}$	29	33	32	35	33	32							
	$T_{(5)}$	0.34	0.36	0.35	0.39	0.39	0.37	0.02	0.50	0.50	0.45			
	$T_{(15)}$	0.31	0.35	0.34	0.37	0.35	0.34	0.02	**0.49**	**0.48**	**0.47**			
51	$I_{(0)}$	58	58	56	60	60	58							0.62
	$I_{(5)}$	52	56	54	53	53	54							use C I(mean0)
	$I_{(15)}$	49	52	50	49	48	50							
	$T_{(5)}$	0.55	0.59	0.57	0.56	0.56	0.57	0.02	0.78	0.70	0.69			
	$T_{(15)}$	0.52	0.55	0.53	0.52	0.51	0.53	0.02	**0.75**	**0.74**	**0.72**			

SQS: T/R < 0.85; CSL: T/R < 0.75

NLUD117	CSL	Pass	CSL
NLUD55	CSL	CSL	CSL
NLU51	SQS	Pass	CSL

Quality Control Steps:

1. Is control final mean output greater than or equal to 72% control initial mean output?

$I_{(5)}$:$F_{c(mean)}/I_{c(mean)}$: **82%** **YES**

$I_{(15)}$:$F_{c(mean)}/I_{c(mean)}$: **73%** **YES**

YES: Control results are acceptable
NO: Control results are unacceptable (retest required)

2. Does the reference final mean meet or exceed 80% of control final mean?

Ref 1 $I_{(5)}$:$F_{R(mean)}/F_{C(mean)}$: **89%** **YES** Ref 2 $I_{(5)}$:$F_{R(mean)}/F_{C(mean)}$: **77%** **NO**

$I_{(15)}$:$F_{R(mean)}/F_{C(mean)}$: **86%** **YES** $I_{(15)}$:$F_{R(mean)}/F_{C(mean)}$: **77%** **NO**

YES: Use reference data for t-test calculation
NO: Use control data for t-test calculation **<-- will depend upon which Ref is most appropriate for ea sample**

3. Is the reference initial mean greater than or equal to 80% of control initial mean?

Ref 1:$I_{R(mean)}/I_{C(mean)}$: **88%** **YES** Ref 2:$I_{R(mean)}/I_{C(mean)}$: **78%** **NO**

YES: Use reference initial mean to calculate change in final light readings
NO: Use control initial mean to calculate change in final light readings **<-- this was a mistake; Naut calc Ref1 using Ic and calc Ref2 using IR2**

4. Are test initial mean values greater than or 80% of control initial mean values?

Site D117 $I_{T(mean)}/I_{C(mean)}$: **63%** **NO**

Site D55 $I_{T(mean)}/I_{C(mean)}$: **40%** **NO**

Site 51 $I_{T(mean)}/I_{C(mean)}$: **62%** **NO**

YES: Use site initial mean to calculate change in final light readings
NO: Use control initial mean to calculate change in final light readings **<-- checks out fine**

Appendix Table C-8c. Microtox 100 Percent Sediment Porewater Test
Preliminary Data: Sites 64, 55, 117
Gas Works Sediments - Eastern Study Area
Test Initiation: April 28, 2005

Site	Reading	Light Reading Replicate 1	2	3	4	5	Mean	St.Dev.	$T_{(mean)}/Ref1_{(mean)}$	$T_{(mean)}/Ref2_{(mean)}$	$T_{(mean)}/C_{(mean)}$	Change in light readings compared to initial control $I_{(t)(mean)}/I_{(0)C(mean)}$	Change in light readings compared to final control $I_{(t)(mean)}/I_{(t)C(mean)}$	Evaluation of initial light output $I_{(0)(mean)}/I_{(0)C(mean)}$
Control	$I_{(0)}$	95	100	101	99	98	99							
	$I_{(5)}$	94	96	97	95	100	96					0.98		
	$I_{(15)}$	78	79	82	79	81	80					0.81		
	$C_{(5)}$	0.99	0.96	0.96	0.96	1.02	0.98	0.03				*test OK*		
	$C_{(15)}$	0.82	0.79	0.81	0.80	0.83	0.81	0.02						
Ref 1	$I_{(0)}$	94	82	84	87	88	87							0.88
	$I_{(5)}$	93	79	85	84	87	86						0.89	*use R1 I(mean0)*
	$I_{(15)}$	74	61	64	63	67	66						0.82	
	$R_{(5)}$	0.94	0.80	0.86	0.85	0.88	0.87	0.05					*t-test = Ref1*	
	$R_{(15)}$	0.79	0.74	0.76	0.72	0.76	0.76	0.02						
Ref 2	$I_{(0)}$	83	77	78	81	84	81							0.82
	$I_{(5)}$	78	74	74	78	80	77						0.80	*use R2 I(mean0)*
	$I_{(15)}$	62	57	59	60	62	60						0.75	
	$T_{(5)}$	0.94	0.96	0.95	0.96	0.95	0.95	0.01					*t-test = Cntrl*	
	$T_{(15)}$	0.75	0.74	0.76	0.74	0.74	0.74	0.01						
64	$I_{(0)}$	87	92	91	89	95	91							0.92
	$I_{(5)}$	87	91	90	87	92	89							*use 64 I(mean0)*
	$I_{(15)}$	70	74	72	72	73	72							
	$T_{(5)}$	1.00	0.99	0.99	0.98	0.97	0.98	0.01		1.03	1.01			
	$T_{(15)}$	0.80	0.80	0.79	0.81	0.77	0.80	0.02	**1.05**	**1.07**	**0.98**			
55	$I_{(0)}$	51	52	48	53	51	51							0.52
	$I_{(5)}$	50	51	47	51	47	49							*use C I(mean0)*
	$I_{(15)}$	45	47	43	44	43	44							
	$T_{(5)}$	0.51	0.52	0.48	0.52	0.48	0.50	0.02		0.57	0.51			
	$T_{(15)}$	0.46	0.48	0.44	0.45	0.44	0.45	0.02	**0.60**	**0.60**	**0.56**			
117	$I_{(0)}$	64	63	65	64	65	64							0.65
	$I_{(5)}$	63	61	60	61	62	61							*use C I(mean0)*
	$I_{(15)}$	54	53	54	54	54	54							
	$T_{(5)}$	0.64	0.62	0.61	0.62	0.63	0.62	0.01		0.65	0.64			
	$T_{(15)}$	0.55	0.54	0.55	0.55	0.55	0.55	0.00	**0.72**	**0.73**	**0.67**			

SQS: T/R < 0.85; CSL: T/R < 0.75

NLU64	Pass	Pass	Pass
NLU55	CSL	CSL	CSL
NLU117	CSL	CSL	CSL

Quality Control Steps:

1. Is control final mean output greater than or equal to 72% control initial mean output?

$I_{(5)}:F_{C(mean)}/I_{C(mean)}$: **98%** **YES**

$I_{(15)}:F_{C(mean)}/I_{C(mean)}$: **81%** **YES**

YES: Control results are acceptable
NO: Control results are unacceptable (retest required)

2. Does the reference final mean meet or exceed 80% of control final mean?

Ref 1 $I_{(5)}:F_{R(mean)}/F_{C(mean)}$: **89%** **YES** Ref 2 $I_{(5)}:F_{R(mean)}/F_{C(mean)}$: **80%** **YES**

$I_{(15)}:F_{R(mean)}/F_{C(mean)}$: **82%** **YES** $I_{(15)}:F_{R(mean)}/F_{C(mean)}$: **75%** **NO**

YES: Use reference data for t-test calculation
NO: Use control data for t-test calculation **<-- will depend upon which Ref is most appropriate for ea sample**

3. Is the reference initial mean greater than or equal to 80% of control initial mean?

Ref 1:$I_{R(mean)}/I_{C(mean)}$: **88%** **YES** Ref 2:$I_{R(mean)}/I_{C(mean)}$: **82%** **YES**

YES: Use reference initial mean to calculate change in final light readings
NO: Use control initial mean to calculate change in final light readings **<-- this was a mistake; Naut calc Ref1 using Ic and calc Ref2 using IR2**

4. Are test initial mean values greater than or 80% of control initial mean values?

Site 64 $I_{T(mean)}/I_{C(mean)}$: **92%** **YES**

Site 55 $I_{T(mean)}/I_{C(mean)}$: **52%** **NO**

Site 117 $I_{T(mean)}/I_{C(mean)}$: **65%** **NO**

YES: Use site initial mean to calculate change in final light readings
NO: Use control initial mean to calculate change in final light readings

Appendix Table C-8d. Microtox 100 Percent Sediment Porewater Test
Preliminary Data: Sites 66, 69, 76
Gas Works Sediments - Eastern Study Area
Test Initiation: April 28, 2005

Site	Reading	Light Reading Replicate 1	2	3	4	5	Mean	St.Dev.	$T_{(mean)}/Ref1_{(mean)}$	$T_{(mean)}/Ref2_{(mean)}$	$T_{(mean)}/C_{(mean)}$	Change in light readings compared to initial control $I_{(t)(mean)}/I_{(0)C(mean)}$	Change in light readings compared to final control $I_{(t)(mean)}/I_{(t)C(mean)}$	Evaluation of initial light output $I_{(0)(mean)}/I_{(0)C(mean)}$
Control	$I_{(0)}$	94	97	98	99	99	97							
	$I_{(5)}$	85	90	87	90	93	89					0.91		
	$I_{(15)}$	76	76	74	78	84	78					0.80		
	$C_{(5)}$	0.90	0.93	0.89	0.91	0.94	0.91	0.02				*test OK*		
	$C_{(15)}$	0.81	0.78	0.76	0.79	0.85	0.80	0.03						
Ref 1	$I_{(0)}$	91	88	87	88	92	89							0.92
	$I_{(5)}$	79	80	80	82	86	81						0.91	*use R1 I(mean0)*
	$I_{(15)}$	69	71	70	73	74	71						0.92	
	$R_{(5)}$	0.81	0.82	0.82	0.84	0.88	0.84	0.03					*t-test = Ref1*	
	$R_{(15)}$	0.76	0.81	0.80	0.83	0.80	0.80	0.03						
Ref 2	$I_{(0)}$	77	81	81	82	82	81							0.83
	$I_{(5)}$	67	71	73	71	72	71						0.80	*use R2 I(mean0)*
	$I_{(15)}$	58	62	63	60	62	61						0.79	
	$T_{(5)}$	0.87	0.88	0.90	0.87	0.88	0.88	0.01					*t-test = Cntrl*	
	$T_{(15)}$	0.75	0.77	0.78	0.73	0.76	0.76	0.02						
66	$I_{(0)}$	86	91	87	88	89	88							0.91
	$I_{(5)}$	79	88	82	79	84	82							*use 66 I(mean0)*
	$I_{(15)}$	69	75	72	72	71	72							
	$T_{(5)}$	0.92	0.97	0.94	0.90	0.94	0.93	0.03		1.06	1.02			
	$T_{(15)}$	0.80	0.82	0.83	0.82	0.80	0.81	0.01	**1.02**	**1.08**	**1.02**			
69	$I_{(0)}$	89	87	86	85	83	86							0.88
	$I_{(5)}$	81	81	78	79	76	79							*use 69 I(mean0)*
	$I_{(15)}$	77	71	71	72	70	72							
	$T_{(5)}$	0.91	0.93	0.91	0.93	0.92	0.92	0.01		1.10	1.01			
	$T_{(15)}$	0.87	0.82	0.83	0.85	0.84	0.84	0.02	**1.05**	**1.11**	**1.05**			
76	$I_{(0)}$	87	90	89	89	94	90							0.92
	$I_{(5)}$	80	82	82	83	84	82							*use 76 I(mean0)*
	$I_{(15)}$	71	72	72	74	75	73							
	$T_{(5)}$	0.92	0.91	0.92	0.93	0.89	0.92	0.01		1.04	1.00			
	$T_{(15)}$	0.82	0.80	0.81	0.83	0.80	0.81	0.01	**1.01**	**1.07**	**1.02**			

SQS: T/R < 0.85; CSL: T/R < 0.75

NLU64	Pass	Pass	Pass
NLU55	Pass	Pass	Pass
NLU117	Pass	Pass	Pass

Quality Control Steps:

1. Is control final mean output greater than or equal to 72% control initial mean output?

$I_{(5)}$:$F_{c(mean)}/I_{c(mean)}$: **91%** **YES**

$I_{(15)}$:$F_{c(mean)}/I_{c(mean)}$: **80%** **YES**

YES: Control results are acceptable
NO: Control results are unacceptable (retest required)

2. Does the reference final mean meet or exceed 80% of control final mean?

Ref 1 $I_{(5)}$:$F_{R(mean)}/F_{C(mean)}$: **91%** **YES** Ref 2 $I_{(5)}$:$F_{R(mean)}/F_{C(mean)}$: **80%** **YES**

$I_{(15)}$:$F_{R(mean)}/F_{C(mean)}$: **92%** **YES** $I_{(15)}$:$F_{R(mean)}/F_{C(mean)}$: **79%** **NO**

YES: Use reference data for t-test calculation
NO: Use control data for t-test calculation **<-- will depend upon which Ref is most appropriate for ea sample**

3. Is the reference initial mean greater than or equal to 80% of control initial mean?

Ref 1:$I_{R(mean)}/I_{C(mean)}$: **92%** **YES** Ref 2:$I_{R(mean)}/I_{C(mean)}$: **83%** **YES**

YES: Use reference initial mean to calculate change in final light readings
NO: Use control initial mean to calculate change in final light readings **<-- this was a mistake; Naut calc Ref1 using Ic and calc Ref2 using IR2**

4. Are test initial mean values greater than or 80% of control initial mean values?

Site 66 $I_{T(mean)}/I_{C(mean)}$: **91%** **YES**

Site 69 $I_{T(mean)}/I_{C(mean)}$: **88%** **YES**

Site 76 $I_{T(mean)}/I_{C(mean)}$: **92%** **YES**

YES: Use site initial mean to calculate change in final light readings
NO: Use control initial mean to calculate change in final light readings

Appendix Table C-8e. Microtox 100 Percent Sediment Porewater Test
Preliminary Data: Sites NLU 84; NLU 85, NLU 86
Gas Works Sediments - Eastern Study Area
Test Initiation: April 19, 2005

Site	Light Reading Replicate								$T_{(mean)}/Ref1_{(mean)}$	$T_{(mean)}/Ref2_{(mean)}$	$T_{(mean)}/C_{(mean)}$	Change in light readings compared to initial control $I_{(t)(mean)}/I_{(0)C(mean)}$	Change in light readings compared to final control $I_{(t)(mean)}/I_{(t)C(mean)}$	Evaluation of initial light output $I_{(0)(mean)}/I_{(0)C(mean)}$
	Reading	1	2	3	4	5	Mean	St.Dev.						
Control	$I_{(0)}$	95	69	95	85	82	85							
	$I_{(5)}$	91	69	97	83	79	84					0.98		
	$I_{(15)}$	88	68	93	81	78	82					0.96		
	$C_{(5)}$	0.96	1.00	1.02	0.98	0.96	0.98	0.03				*test OK*		
	$C_{(15)}$	0.93	0.99	0.98	0.95	0.95	0.96	0.02						
Ref 1	$I_{(0)}$	46	72	72	71	63	65							0.76
	$I_{(5)}$	43	70	68	66	62	62						0.74	*use C I(mean0)*
	$I_{(15)}$	40	64	70	67	60	60						0.74	
	$R_{(5)}$	0.50	0.82	0.80	0.77	0.73	0.73	0.13					*t-test = Cntrl*	
	$R_{(15)}$	0.47	0.75	0.82	0.79	0.70	0.71	0.14						
Ref 2	$I_{(0)}$	49	78	78	69	78	70							0.83
	$I_{(5)}$	51	75	74	71	69	68						0.81	*use R2 I(mean0)*
	$I_{(15)}$	50	78	78	69	72	69						0.85	
	$T_{(5)}$	1.04	0.96	0.95	1.03	0.88	0.97	0.06					*t-test = Ref2*	
	$T_{(15)}$	1.02	1.00	1.00	1.00	0.92	0.99	0.04						
NLU 84	$I_{(0)}$	82	99	108	91	99	96							1.12
	$I_{(5)}$	76	94	105	91	100	93							*use 84 I(mean0)*
	$I_{(15)}$	79	92	100	90	95	91							
	$T_{(5)}$	0.93	0.95	0.97	1.00	1.01	0.97	0.03		1.00	0.99			
	$T_{(15)}$	0.96	0.93	0.93	0.99	0.96	0.95	0.03	**1.35**	**0.96**	**0.99**			
NLU 85	$I_{(0)}$	103	104	108	115	105	107							1.26
	$I_{(5)}$	100	100	104	112	99	103							*use 85 I(mean0)*
	$I_{(15)}$	98	98	104	109	97	101							
	$T_{(5)}$	0.97	0.96	0.96	0.97	0.94	0.96	0.01		1.33	0.98			
	$T_{(15)}$	0.95	0.94	0.96	0.95	0.92	0.95	0.01	**1.34**	**0.96**	**0.99**			
NLU 86	$I_{(0)}$	91	76	92	84	76	84							0.98
	$I_{(5)}$	86	74	90	81	73	81							*use 86 I(mean0)*
	$I_{(15)}$	86	72	88	80	73	80							
	$T_{(5)}$	0.95	0.97	0.98	0.96	0.96	0.96	0.01		0.99	0.98			
	$T_{(15)}$	0.95	0.95	0.96	0.95	0.96	0.95	0.01	**1.35**	**0.96**	**0.99**			

SQS: T/R < 0.85; CSL: T/R < 0.75

NLU84	Pass	Pass	Pass
NLU85	Pass	Pass	Pass
NLU86	Pass	Pass	Pass

Quality Control Steps:

1. Is control final mean output greater than or equal to 72% control initial mean output?

$I_{(5)}$:$F_{c(mean)}/I_{c(mean)}$: **98%** **YES**

$I_{(15)}$:$F_{c(mean)}/I_{c(mean)}$: **96%** **YES**

YES: Control results are acceptable
NO: Control results are unacceptable (retest required)

2. Does the reference final mean meet or exceed 80% of control final mean?

Ref 1 $I_{(5)}$:$F_{R(mean)}/F_{C(mean)}$: **74%** **NO** Ref 2 $I_{(5)}$:$F_{R(mean)}/F_{C(mean)}$: **81%** **YES**

$I_{(15)}$:$F_{R(mean)}/F_{C(mean)}$: **74%** **NO** $I_{(15)}$:$F_{R(mean)}/F_{C(mean)}$: **85%** **YES**

YES: Use reference data for t-test calculation
NO: Use control data for t-test calculation **<-- will depend upon which Ref is most appropriate for ea sample**

3. Is the reference initial mean greater than or equal to 80% of control initial mean?

Ref 1:$I_{R(mean)}/I_{C(mean)}$: **76%** **NO** Ref 2:$I_{R(mean)}/I_{C(mean)}$: **83%** **YES**

YES: Use reference initial mean to calculate change in final light readings
NO: Use control initial mean to calculate change in final light readings ^-- has been QCed against final data; OK

4. Are test initial mean values greater than or 80% of control initial mean values?

Site NLU 84 $I_{T(mean)}/I_{C(mean)}$: **112%** **YES**

Site NLU 85 $I_{T(mean)}/I_{C(mean)}$: **126%** **YES**

Site NLU 86 $I_{T(mean)}/I_{C(mean)}$: **98%** **YES**

YES: Use site initial mean to calculate change in final light readings
NO: Use control initial mean to calculate change in final light readings

Appendix Table C-8f. Microtox 100 Percent Sediment Porewater Test
Preliminary Data: Sites NLU 13, NLU 41, NLU 83
Gas Works Sediments - Eastern Study Area
Test Initiation: April 19, 2005

Site	Light Reading Replicate								$T_{(mean)}$/ $Ref1_{(mean)}$	$T_{(mean)}$/ $Ref2_{(mean)}$	$T_{(mean)}$/ $C_{(mean)}$	Change in light readings compared to initial control $I_{(t)(mean)}/I_{(0)C(mean)}$	Change in light readings compared to final control $I_{(t)(mean)}/I_{(t)C(mean)}$	Evaluation of initial light output $I_{(0)(mean)}/I_{(0)C(mean)}$
	Reading	1	2	3	4	5	Mean	St.Dev.						
Control	$I_{(0)}$	96	81	80	80	68	81							
	$I_{(5)}$	85	73	73	74	61	73					0.90		
	$I_{(15)}$	81	68	68	68	57	68					0.84		
	$C_{(5)}$	0.89	0.90	0.91	0.93	0.90	0.90	0.02				*test OK*		
	$C_{(15)}$	0.84	0.84	0.85	0.85	0.84	0.84	0.01						
Ref 1	$I_{(0)}$	92	103	96	93	92	95							1.18
	$I_{(5)}$	86	95	89	86	87	89						1.21	*use R1 I(mean0)*
	$I_{(15)}$	80	86	81	78	90	83						1.21	
	$R_{(5)}$	1.06	1.17	1.10	1.06	1.07	1.09	0.05					*t-test = Ref1*	
	$R_{(15)}$	0.87	0.83	0.84	0.84	0.98	0.87	0.06						
Ref 2	$I_{(0)}$	98	101	78	84	69	86							1.06
	$I_{(5)}$	91	94	73	78	89	85						1.16	*use R2 I(mean0)*
	$I_{(15)}$	84	89	69	73	86	80						1.17	
	$T_{(5)}$	0.93	0.93	0.94	0.93	1.29	1.00	0.16					*t-test = Ref2*	
	$T_{(15)}$	0.86	0.88	0.88	0.87	1.25	0.95	0.17						
NLU 13	$I_{(0)}$	58	67	82	71	79	71							0.88
	$I_{(5)}$	52	60	74	73	73	66							*use 13 I(mean0)*
	$I_{(15)}$	50	59	74	72	71	65							
	$T_{(5)}$	0.90	0.90	0.90	1.03	0.92	0.93	0.06		0.93	1.03			
	$T_{(15)}$	0.86	0.88	0.90	1.01	0.90	0.91	0.06	**1.04**	**0.96**	**1.08**			
NLU 41	$I_{(0)}$	88	90	82	85	87	86							1.07
	$I_{(5)}$	82	85	76	80	83	81							*use 41 I(mean0)*
	$I_{(15)}$	81	83	76	79	82	80							
	$T_{(5)}$	0.93	0.94	0.93	0.94	0.95	0.94	0.01		0.86	1.04			
	$T_{(15)}$	0.92	0.92	0.93	0.93	0.94	0.93	0.01		1.06	1.10			
NLU 83	$I_{(0)}$	76	69	76	79	77	75							0.93
	$I_{(5)}$	72	66	73	74	73	72							*use 83 I(mean0)*
	$I_{(15)}$	70	70	70	71	70	70							
	$T_{(5)}$	0.95	0.96	0.96	0.94	0.95	0.95	0.01		0.95	1.05			
	$T_{(15)}$	0.92	1.01	0.92	0.90	0.91	0.93	0.05	**1.07**	**0.98**	**1.10**			

SQS: T/R < 0.85; CSL: T/R < 0.75

NLU13	Pass	Pass	Pass
NLU83	Pass	Pass	Pass

Quality Control Steps:

1. Is control final mean output greater than or equal to 72% control initial mean output?

$I_{(5)}$:$F_{c(mean)}/I_{c(mean)}$: **90%** **YES**

$I_{(15)}$:$F_{c(mean)}/I_{c(mean)}$: **84%** **YES**

YES: Control results are acceptable
NO: Control results are unacceptable (retest required)

2. Does the reference final mean meet or exceed 80% of control final mean?

Ref 1 $I_{(5)}$:$F_{R(mean)}/F_{C(mean)}$: **121%** **YES** Ref 2 $I_{(5)}$:$F_{R(mean)}/F_{C(mean)}$: **116%** **YES**

$I_{(15)}$:$F_{R(mean)}/F_{C(mean)}$: **121%** **YES** $I_{(15)}$:$F_{R(mean)}/F_{C(mean)}$: **117%** **YES**

YES: Use reference data for t-test calculation
NO: Use control data for t-test calculation

3. Is the reference initial mean greater than or equal to 80% of control initial mean?

Ref 1:$I_{R(mean)}/I_{C(mean)}$: **118%** **YES** Ref 2:$I_{R(mean)}/I_{C(mean)}$: **106%** **YES**

YES: Use reference initial mean to calculate change in final light readings
NO: Use control initial mean to calculate change in final light readings **<-- this was a mistake; Naut calc Ref1 using Ic and calc Ref2 using IR2**

4. Are test initial mean values greater than or 80% of control initial mean values?

Site NLU 13 $I_{T(mean)}/I_{C(mean)}$: **88%** **YES**

Site NLU 41 $I_{T(mean)}/I_{C(mean)}$: **107%** **YES**

Site NLU 83 $I_{T(mean)}/I_{C(mean)}$: **93%** **YES**

YES: Use site initial mean to calculate change in final light readings
NO: Use control initial mean to calculate change in final light readings

Appendix Table C-8g. Microtox 100 Percent Sediment Porewater Test
Preliminary Data: Sites 81, 82, 87
Gas Works Sediments - Eastern Study Area
Test Initiation: April 25, 2005

Site	Reading	Light Reading Replicate 1	2	3	4	5	Mean	St.Dev.	$T_{(mean)}$/ $Ref1_{(mean)}$	$T_{(mean)}$/ $Ref2_{(mean)}$	$T_{(mean)}$/ $C_{(mean)}$	Change in light readings compared to initial control $I_{(t)(mean)}/I_{(0)C(mean)}$	Change in light readings compared to final control $I_{(t)(mean)}/I_{(t)C(mean)}$	Evaluation of initial light output $I_{(0)(mean)}/I_{(0)C(mean)}$
Control	$I_{(0)}$	93	84	83	88	93	88							
	$I_{(5)}$	81	75	73	78	81	78					0.88		
	$I_{(15)}$	73	64	64	67	72	68					0.77		
	$C_{(5)}$	0.87	0.89	0.88	0.89	0.87	0.88	0.01				*test OK*		
	$C_{(15)}$	0.78	0.76	0.77	0.76	0.77	0.77	0.01						
Ref 1	$I_{(0)}$	90	85	67	80	88	82							0.93
	$I_{(5)}$	76	75	60	69	77	71						0.92	*use R1 I(mean0)*
	$I_{(15)}$	69	64	52	62	70	63						0.93	
	$R_{(5)}$	0.86	0.85	0.68	0.78	0.87	0.81	0.08					*t-test = Ref1*	
	$R_{(15)}$	0.77	0.75	0.78	0.78	0.80	0.77	0.02						
Ref 2	$I_{(0)}$	87	87	86	88	90	88							0.99
	$I_{(5)}$	76	77	76	77	78	77						0.99	*use R2 I(mean0)*
	$I_{(15)}$	66	66	66	69	66	67						0.98	
	$T_{(5)}$	0.87	0.89	0.88	0.88	0.87	0.88	0.01					*t-test = Ref2*	
	$T_{(15)}$	0.76	0.76	0.77	0.78	0.73	0.76	0.02						
81	$I_{(0)}$	76	91	88	88	87	86							0.98
	$I_{(5)}$	65	80	77	75	77	75							*use 81 I(mean0)*
	$I_{(15)}$	57	71	67	76	67	68							
	$T_{(5)}$	0.86	0.88	0.88	0.85	0.89	0.87	0.01		0.99	0.99			
	$T_{(15)}$	0.75	0.78	0.76	0.86	0.77	0.79	0.05	**1.02**	**1.03**	**1.02**			
82	$I_{(0)}$	66	67	68	67	64	66							**0.75**
	$I_{(5)}$	61	65	60	61	60	61							*use C I(mean0)*
	$I_{(15)}$	54	61	53	55	56	56							
	$T_{(5)}$	0.69	0.74	0.68	0.69	0.68	0.70	0.02		0.86	0.79			
	$T_{(15)}$	0.61	0.69	0.60	0.62	0.63	0.63	0.04	**0.82**	**0.83**	**0.82**			
87	$I_{(0)}$	90	89	89	88	92	90							1.02
	$I_{(5)}$	79	83	79	77	81	80							*use 87 I(mean0)*
	$I_{(15)}$	72	72	69	74	69	71							
	$T_{(5)}$	0.88	0.93	0.89	0.88	0.88	0.89	0.02		1.02	1.01			
	$T_{(15)}$	0.80	0.81	0.78	0.84	0.75	0.80	0.03	**1.03**	**1.05**	**1.03**			

SQS: T/R < 0.85; CSL: T/R < 0.75

NLU81	Pass	Pass	Pass
NLU82	SQS	SQS	SQS
NLU87	Pass	Pass	Pass

Quality Control Steps:

1. Is control final mean output greater than or equal to 72% control initial mean output?

$I_{(5)}$:$F_{c(mean)}/I_{c(mean)}$: **88%** **YES**

$I_{(15)}$:$F_{c(mean)}/I_{c(mean)}$: **77%** **YES**

YES: Control results are acceptable
NO: Control results are unacceptable (retest required)

2. Does the reference final mean meet or exceed 80% of control final mean?

Ref 1 $I_{(5)}$:$F_{R(mean)}/F_{C(mean)}$: **92%** **YES** Ref 2 $I_{(5)}$:$F_{R(mean)}/F_{C(mean)}$: **99%** **YES**

$I_{(15)}$:$F_{R(mean)}/F_{C(mean)}$: **93%** **YES** $I_{(15)}$:$F_{R(mean)}/F_{C(mean)}$: **98%** **YES**

YES: Use reference data for t-test calculation
NO: Use control data for t-test calculation

3. Is the reference initial mean greater than or equal to 80% of control initial mean?

Ref 1:$I_{R(mean)}/I_{C(mean)}$: **93%** **YES** Ref 2:$I_{R(mean)}/I_{C(mean)}$: **99%** **YES**

YES: Use reference initial mean to calculate change in final light readings
NO: Use control initial mean to calculate change in final light readings

<-- this was a mistake; Naut calc Ref1 using Ic and calc Ref2 using IR2

4. Are test initial mean values greater than or 80% of control initial mean values?

Site 81 $I_{T(mean)}/I_{C(mean)}$: **98%** **YES**

Site 82 $I_{T(mean)}/I_{C(mean)}$: **75%** **NO**

Site 87 $I_{T(mean)}/I_{C(mean)}$: **102%** **YES**

YES: Use site initial mean to calculate change in final light readings
NO: Use control initial mean to calculate change in final light readings

Appendix Table C-8h. Microtox 100 Percent Sediment Porewater Test
Preliminary Data: Sites EPA 5, EPA 19
Gas Works Sediments - Eastern Study Area
Test Initiation: April 22, 2005

Site	Reading	Light Reading Replicate 1	2	3	4	5	Mean	St.Dev.	$T_{(mean)}/Ref1_{(mean)}$	$T_{(mean)}/Ref2_{(mean)}$	$T_{(mean)}/C_{(mean)}$	Change in light readings compared to initial control $I_{(t)(mean)}/I_{(0)C(mean)}$	Change in light readings compared to final control $I_{(t)(mean)}/I_{(t)C(mean)}$	Evaluation of initial light output $I_{(0)(mean)}/I_{(0)C(mean)}$
Control	$I_{(0)}$	93	107	107	91	105	101							
	$I_{(5)}$	94	109	110	94	106	103					1.02		
	$I_{(15)}$	92	105	106	90	106	100					0.99		
	$C_{(5)}$	1.01	1.02	1.03	1.03	1.01	1.02	0.01				*test OK*		
	$C_{(15)}$	0.99	0.98	0.99	0.99	1.01	0.99	0.01						
Ref 1	$I_{(0)}$	89	99	106	79	99	94							0.94
	$I_{(5)}$	89	100	109	81	100	96						0.93	*use R1 I(mean0)*
	$I_{(15)}$	81	91	95	74	90	86						0.86	
	$R_{(5)}$	0.88	0.99	1.08	0.81	0.99	0.95	0.11					*t-test = Ref1*	
	$R_{(15)}$	0.91	0.92	0.90	0.94	0.91	0.91	0.01						
Ref 2	$I_{(0)}$	103	104	99	95	100	100							1.00
	$I_{(5)}$	112	109	106	2	107	87						0.85	*use R2 I(mean0)*
	$I_{(15)}$	104	102	99	96	100	100						1.00	
	$T_{(5)}$	1.09	1.05	1.07	0.02	1.07	0.86	0.47					*t-test = Ref2*	
	$T_{(15)}$	1.01	0.98	1.00	1.01	1.00	1.00	0.01						
EPA 5	$I_{(0)}$	100	80	106	98	98	96							0.96
	$I_{(5)}$	104	84	111	104	105	102							*use EPA5 I(mean0)*
	$I_{(15)}$	99	80	104	97	98	96							
	$T_{(5)}$	1.04	1.05	1.05	1.06	1.07	1.05	0.01		1.23	1.03			
	$T_{(15)}$	0.99	1.00	0.98	0.99	1.00	0.99	0.01	**1.09**	**0.99**	**1.00**			
EPA 19	$I_{(0)}$	103	101	95	108	90	99							0.99
	$I_{(5)}$	109	106	101	113	94	105							*use EPA19 I(mean0)*
	$I_{(15)}$	105	103	96	108	93	101							
	$T_{(5)}$	1.06	1.05	1.06	1.05	1.04	1.05	0.01		1.11	1.03			
	$T_{(15)}$	1.02	1.02	1.01	1.00	1.03	1.02	0.01	**1.11**	**1.02**	**1.02**			

SQS: T/R < 0.85; CSL: T/R < 0.75

NLU81	Pass	Pass	Pass
NLU82	Pass	Pass	Pass

Quality Control Steps:

1. Is control final mean output greater than or equal to 72% control initial mean output?

$I_{(5)}$:$F_{c(mean)}/I_{c(mean)}$: **102%** **YES**

$I_{(15)}$:$F_{c(mean)}/I_{c(mean)}$: **99%** **YES**

YES: Control results are acceptable
NO: Control results are unacceptable (retest required)

2. Does the reference final mean meet or exceed 80% of control final mean?

Ref 1 $I_{(5)}$:$F_{R(mean)}/F_{C(mean)}$: **93%** **YES** Ref 2 $I_{(5)}$:$F_{R(mean)}/F_{C(mean)}$: **85%** **YES**

$I_{(15)}$:$F_{R(mean)}/F_{C(mean)}$: **86%** **YES** $I_{(15)}$:$F_{R(mean)}/F_{C(mean)}$: **100%** **YES**

YES: Use reference data for t-test calculation
NO: Use control data for t-test calculation

3. Is the reference initial mean greater than or equal to 80% of control initial mean?

Ref 1:$I_{R(mean)}/I_{C(mean)}$: **94%** **YES** Ref 2:$I_{R(mean)}/I_{C(mean)}$: **100%** **YES**

YES: Use reference initial mean to calculate change in final light readings
NO: Use control initial mean to calculate change in final light readings

^-- has been QCed against final data; OK

4. Are test initial mean values greater than or 80% of control initial mean values?

Site EPA 5 $I_{T(mean)}/I_{C(mean)}$: **96%** **YES**

Site EPA 19 $I_{T(mean)}/I_{C(mean)}$: **99%** **YES**

YES: Use site initial mean to calculate change in final light readings
NO: Use control initial mean to calculate change in final light readings

Appendix D

Bioassay Statistical Methodology

APPENDIX D
Bioassay Statistical Methodology

Statistical Tools and Applications
Phase 3 and Phase 2/3 Datasets
PSE10-18628-610
08-16-05

This appendix documents the various statistical tools used to determine a site-specific sediment bioassay TPAH cleanup level(s). Microsoft Excel and/or SPSS statistical software packages were used for all graphical and statistical analyses of the Gas Works Sediment Area (GWSA) bioassay and synoptic chemistry data. This memo is intended provide a background on these statistical tools and to assist those unfamiliar with SPSS output. Below are descriptions of the methodology and output used for data interpretations. The detail below is applicable to SPSS 10.0, which was used for analyses of GWSA Site-Wide Bioassay data; there may be slight modifications to both procedures and output in the newer versions.

I. Overview: Dataset and Statistical Process

The GWSA bioassay dataset spans three different sampling events: March 2002 and October 2002 (collectively referred to as "Phase 2") and April 2005 ("Phase 3"). GWSA bioassay data analysis was conducted in several iterations in an effort to identify the relationships between observed toxicity and the synoptic chemistry. Exploratory statistics (histograms and scatterplots) were used to evaluate data distributions (Appendix E). The initial screening (Appendix F) explored the relationships between variables and identified those parameters that best account for the variance observed in bioassay test results. These parameters were, in turn, carried forward into a more focused secondary screening (Appendix G). The secondary screening was designed to better describe the relationship between synoptic chemistry and observed toxicity, as well as to help establish which toxicity tests could be reliably used to derive a site-specific TPAH cleanup level. The outcomes of the initial and secondary screening were used in part to help derive a TPAH cleanup level (Appendix H).

II. Initial Exploration and Screening

The initial screening was conducted with the combined Phases 2 and 3 dataset, and then repeated with the Phase 3 dataset only (see Appendix F). Because the Phase 3 dataset has more chemical parameters (although it has fewer samples), it was used as a quality control check on the list of significant parameters derived using the combined dataset. The scope of this effort was to initially explore the relationships between variables and to identify those parameters that best account for the variance observed in bioassay test results.

A. Histogram

Histograms are a univariate statistical and exploratory graphical tool. A histogram displays the distribution of values in a quantitative variable by dividing the range into equally-spaced intervals and plotting the count of cases in each interval as a bar. Histograms are appropriate for continuous, quantitative variables (for example, sulfide concentration or percent

survival). In a histogram, the quantitative variable is graphed on the x-axis, while the frequency of observations (e.g., sulfide concentration) is plotted on the y-axis. In this way, the histogram provides information on the spread and shape of the dataset.

Dataset: SPSS treats rows as cases (individual sample results) and columns as parameters or variables. Histograms can be generated for any specified parameter.

Output: SPSS will generate a histogram in the Output window. If you want to change the number of bins (i.e., bars in the histogram), double click on the graph to open the Chart window, then single click on the x-axis. Go to the "Chart" menu and select "Axis." Under "Intervals," select "Custom" and click "Define." From here you can specify the number of bins, as well as the preferred range of values. Other customizations are available, but are outside the scope of this memorandum.

B. Scatterplot Matrix

Scatterplots highlight the relationship between two quantitative variables by plotting the actual values along two axes. Scatterplots can also be useful in identifying bivariate outliers. A scatterplot matrix combines simple scatterplots (those between only two variables) for multiple variables into a single graph.

Dataset: As with the histogram, each column represents a different variable, dependent or independent. The scatterplot matrix can be generated for any combination of these parameters. In the case of the GWSA bioassay dataset, the data were organized by sampling station. Thus, one column was a list of station IDs.

Output: SPSS will generate a scatterplot matrix in the Output window. The legend identifies which point on the graph corresponds with which case (e.g., station ID). Other customizations are available (e.g., placement of axis labels), but are not dealt with here.

C. Two Sample T-Testing

The t-test evaluates hypotheses about means of quantitative variables, the purpose being to draw conclusions about population characteristics observed in a sample. SPSS's "Independent-Samples t-test" procedure tests whether the mean of a single variable (e.g., mortality) for subjects in one group differs from the mean in another group (e.g., test station versus a control sample). SPSS was used for two-tailed hypothesis testing and Excel was used for one-tailed hypothesis testing. The hypothesis testing assumes that the means are equal and that the samples are from the same population. If the null hypothesis is rejected (alpha < 0.05), then it is concluded that the samples are from different populations and are significantly different.

Dataset: SPSS t-testing requires that the independent variable be entered categorically into a single column, with the dependent variable being entered into another column. For example, in the GWSA dataset, the independent variable "station ID" would be one column, while the dependent variable "*Hyalella azteca* survival" would be in another column. Each station was coded using a numerical value under the "Data View" tab; these coded values were married to their corresponding station ID labels under the "Variable View" tab. All output therefore provided the value labels (i.e., station IDs), which eased interpretation.

Output: The following is a description of the program output and subsequent interpretation:

- *Group Statistics*: The left column indicates what variable is being tested (e.g., mortality). The next column shows the samples being compared. "N" shows the number of replicates used in the analysis for each sample. Descriptive statistics (mean, standard deviation, standard error) comprise the remainder of the table.
- *Independent Samples Test*: "Levene's Test for Equality of Variances" is used to assess whether the two groups in question have equal population variances. If you reject the null hypothesis that the variances are equal (e.g., significance < 0.05), then you need to proceed using the "Equal Variances Not Assumed" row in the output table; if you accept the null hypothesis, use the values in the "Equal Variances Assumed" row. The "t-test for Equality of Means" presents the t-test results. Given are the t-statistic value, the degrees of freedom, and the significance, or p, value. If the p value is lower than the stated alpha, then the null hypothesis (group means are equal) is rejected. The remainder of the table assesses the difference between the group means.

D. Analysis of Variance (ANOVA) — Comparison of Means

Like the t-test, ANOVA tests hypotheses about means of quantitative variables, the purpose being to draw conclusions about population characteristics observed in a sample. Unlike t-tests, ANOVA compares the means of more than two samples. ANOVA examines the variability among the sample means relative to the spread of the observations within each group. ANOVA uses the F statistic (which computes the variation among the sample means divided by the variation within the samples) to evaluate samples.

ANOVA assumes that sample data are normally distributed and have equal variances, and that observations are independent. There are a variety of tests for normality and variance (e.g., Shapiro-Wilks and Levene, respectively); these should be evaluated prior to ANOVA.

Dataset: As with t-testing, SPSS ANOVA treats rows as cases (individual sample results) and columns as variables; the independent variable needs to be entered categorically into a single column, with the dependent variable being entered into another column. Each sample (independent variable) should be coded as described previously.

Output: The following is a description of the program output and subsequent interpretation:

- *Descriptives*: This table presents the summary statistics (e.g., mean and standard deviation) for each level of the independent variable (e.g., station ID).
- *Test of Homogeneity of Variance*: The computations of the Levene test use the deviation (with the sign discarded) from each case to its group mean. Provided in the output table are the F value, the degrees of freedom, and the significance of F. If the significance value is larger than the stated significance level (e.g., $\alpha = 0.05$), the sample variances are equal.
- *ANOVA*: This table presents the sum of squares, degrees of freedom, and mean square for both between-groups and within-groups measures. The F statistic (calculated as the between-groups mean square divided by the within-groups mean square) and its significance are also given. If the F value is significant (e.g., "Significance" is less than 0.05), that means there are levels of the independent variable that came from different populations than the rest. Running a post hoc test (e.g., Tukey test) would indicate which levels are the same or different.

E. Correlation: Pearson's Bivariate

Pearson's bivariate correlation is a measure of linear association. The correlation coefficient, which varies between -1.0 and 1.0, measures the strength of the association between two variables: the closer the value is to |1.0|, the stronger the association.

Dataset: Unlike t-testing or ANOVA, correlation can use a tabular, rather than coded, data structure wherein each column represents a different variable, independent or dependent.

Output: SPSS produces a table showing the correlation between all pairs of variables included in the analysis. Within each box in the table are three lines of data. The first is the Pearson correlation coefficient; the closer this value is to 1.0 or -1.0, the stronger the correlation. The second line shows whether the correlation is significant at the specified value of alpha. The third line, "N," shows how many samples were used in the correlation analysis.

F. Hierarchical Cluster Analysis

Cluster analysis is a multivariate tool for detecting groupings in data. The objects in these groups may be cases (e.g., station ID) or variables (e.g., TPAH). In the hierarchical clustering method, clustering begins by finding the closest pair of objects (cases or variables) according to a distance measure and combines them to form a cluster. The algorithm continues stepwise, joining pairs of objects, pairs of clusters, or an object with a cluster, until all data are in a cluster. "Hierarchical" signifies that once two objects or clusters are paired, they remain together until the final step. That is, a cluster formed in a later stage contains clusters from an earlier stage which in turn contains clusters from a still earlier stage. A "dendrogram" is a graphical display of the clustering steps.

Dataset: Hierarchical cluster analysis uses a tabular, rather than coded, data structure wherein each column represents a different variable, independent or dependent. Note, however, that if you are clustering cases, you must enter those coded into the spreadsheet if you wish to see their corresponding labels in the dendrogram. For example, in the GWSA dataset, we clustered by station ID. In order to see the station IDs in the dendrogram, the values had to first be given numerical values, the labels for which were entered under the "Variable View" tab, as was described previously for t-testing.

Output: The following is a description of the program output and subsequent interpretation:

- *Case Processing Summary*: This table summarizes the number of missing cases, the number of usable ("valid") cases, as well as the total number of cases.
- *Agglomeration Schedule*: From this table you can identify which cases or clusters are combined at each step. The clustering stages are listed in column 1. "Cluster Combined" identifies which cases or clusters are joined at a given stage. The "Coefficients" column is the distance (e.g., squared Euclidean) between the cases joined. Smaller coefficients are indicative of the joining of fairly homogenous cases or clusters, whereas larger coefficients are an indication that the members of the clusters are more dissimilar. The "Stage Cluster First Appears" identifies when a cluster is formed, as well as when a new case is added to an existing cluster. The "Next Stage" column indicates the stage at which a particular cluster increases in size.

- *Dendrogram*: This tree diagram more easily shows the cluster relationships depicted in tabular form by the agglomeration schedule. The cases are listed vertically along the left side of the dendrogram, with the "tree" branching horizontally to the right. Lines closer together (toward the left of the graph) indicate earlier joinings; lines toward the right of the graph indicate later joinings. Be mindful that this graphical presentation does not indicate the joining distance (see "Coefficients" in the agglomeration schedule). From this, you get a pictorial presentation of which cases are most similar or dissimilar.

III. Secondary Screening

The secondary screening used stepwise regression with two goals in mind:

1) To determine which chemical and physical parameters account for most of the variance observed in bioassay test results, and
2) To determine which toxicity tests can reliably be used to derive a site-specific TPAH cleanup level.

Statistical analyses, such as stepwise regression, can become "overfit" if too many variables are included; therefore, the smaller and more focused subset of data identified using the initial screening tools was utilized for the secondary screening (see Appendix G).

A. Stepwise Regression

Multiple linear stepwise regression helps determine the subset of independent (predictor) variables that explains the largest amount of variance in the dependent variable. Stepwise selection begins like forward stepping — variables are entered into the model one by one, starting with the variable with the strongest correlation to the dependent variable; unlike forward stepping, stepwise also tests variables already in the model for removal at each step. This is a commonly used method, particularly when there are correlations among the independent variables. Care must be taken not to "overfit" the model; that is, using too many variables reduces the model's performance.

Dataset: Stepwise regression uses a tabular, rather than coded, data structure wherein each column represents a different variable, independent or dependent.

Output: The following is a description of the program output and subsequent interpretation:

- *Variables Entered*: This table shows those parameters that are sequentially added or subtracted from the model. These models are additive, meaning that a given model includes (or excludes) any parameters entered (or removed) in the preceding models.
- *Model Summary*: The Model Summary provides estimates of the models' fit to the data. "R" is the correlation between the observed and model-predicted values of the dependent variable. "R^2" is the squared value of this correlation, and represents the proportion of the total variation in the dependent variable explained by the regression model. "Adjusted R^2" is a measure of goodness of fit; unlike R^2, which will increase whenever an independent variable is added to the model, the adjusted R^2 will increase only if the independent variable improves the fit of the regression equation to the data.
- *ANOVA*: The ANOVA table assesses the significance of the overall model; that is, ANOVA determines whether the slope of the regression model is significantly different from zero.

- *Coefficients*: This table provides the coefficients for all of the independent variables in the model and their significance values. In order to assess the usefulness of each predictor (independent variable), you cannot just compare the coefficients: Even if the independent variables are all measured in the same units, a comparison of their size might not be revealing. The beta coefficients attempt to make the regression coefficients more comparable. However, the t statistic and associated significance provide a better clue as to the relative importance of each independent variable in the model.
- *Excluded Variables*: The Excluded Variables table facilitates tracking of how SPSS selects a variable for entry or removal at the next step: Of the variables not currently included in the model, that with the highest t statistic (absolute value) is the likely candidate for inclusion in the next iteration. At each stage, SPSS uses the default entrance criterion of $F > 3.84$. The "t" value reported in the table is the square root of 3.84, so no variable enters the model if t is less than 1.96. When no remaining excluded variables have a t exceeding 1.96, no more models are generated. Using the stepwise method, SPSS concurrently reviews entered variables; these are removed when their t value drops below 1.65 (the square root of the default F removal criterion of 2.71).

IV. TPAH Cleanup Level

Based on the initial and secondary screenings, TPAH is a primary chemical of concern in the GWSA. A TPAH cleanup level will therefore be used to direct remedial actions in the GWSA. A ranking approach and concentration-response curves were used to derive the TPAH cleanup level (Appendix H).

A. TPAH Ranking Approach

A ranking approach is a non-parametric, non-continuous method of comparing concentration to biological response. The Apparent Effect Threshold (AET) approach, used to derive the Sediment Management Standard SQS and CSL screening levels for marine sediments, uses a ranking method. The concentration of the analyte interest is arrayed in order from lowest to highest, or vice-versa, and the corresponding biological response is arrayed in a parallel column next to the concentration. The biological responses are described as passes/failures or hit/no hit results when compared to Ecology's draft bioassay decision criteria. Because the data array is not continuous and linear (e.g., 5, 10, 15, 20), but is instead ranked by the actual concentration (e.g., 78, 109, 131, 301), biological "threshold" responses correspond to the highest concentration where no observed effect, or hit, is observed.

B. Concentration-Response Curves

In a concentration-response relationship, the concentration represents actual benthic exposure measured in the test media. Response of the biological performance of a test organism is measured as percent mortality or percent growth at the end of a test period. The relationships between concentration and response are plotted with the logarithmic concentration on the x-axis and percent response on the y-axis. For the GWSA bioassay dataset, the relationship was further described using a cubic regression line. We used a cubic polynomial trend line in order to fit a smooth and reasonably representative line through the scatter of points. The cubic regression line was the lowest order of polynomials that gave a plausible smooth line with an R-squared value of at least 0.6. The response data were normalized to the control or the reference sample as shown in Appendix H.

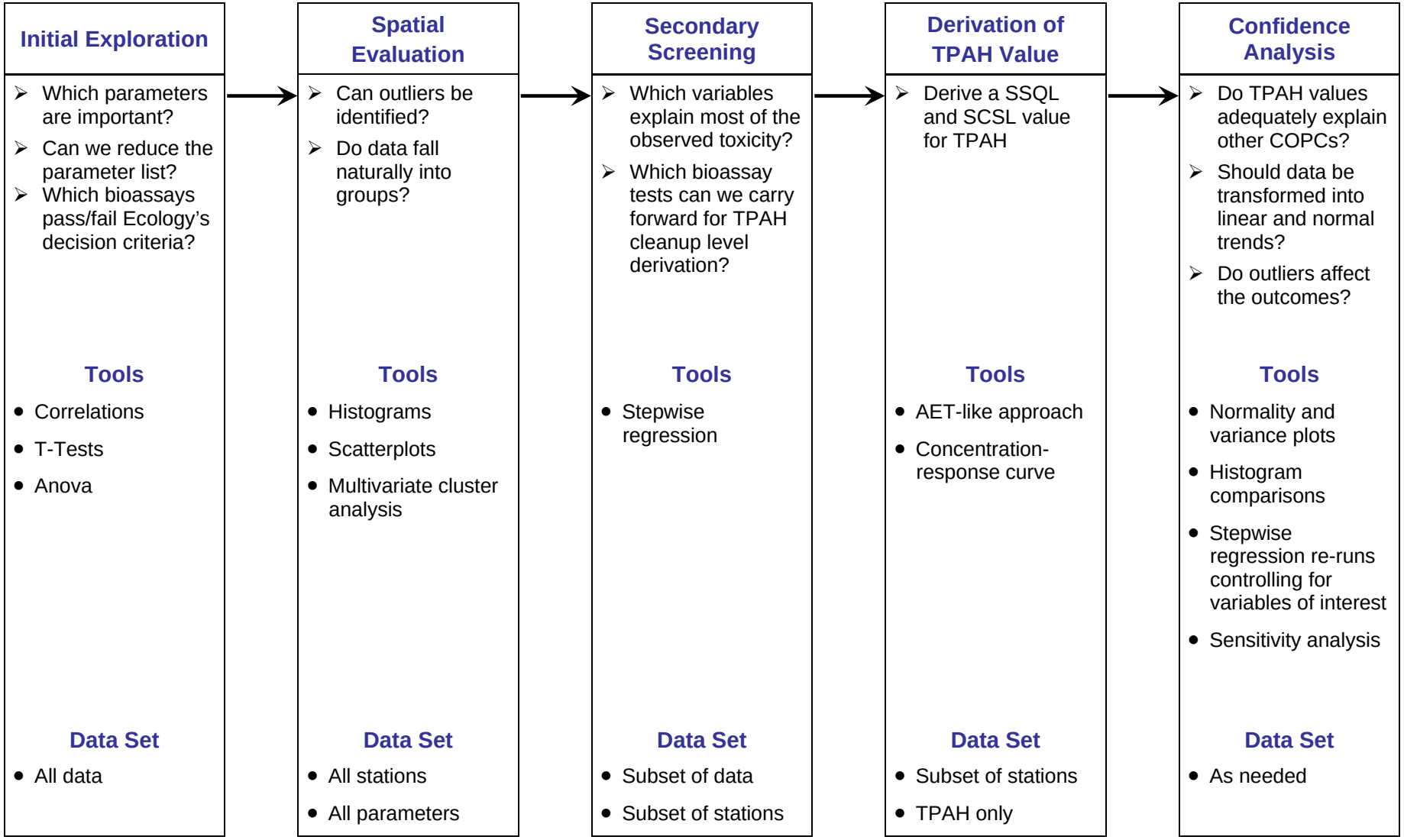
The Probit transformation can be helpful in developing a more linear relationship between the dependent and independent variables. The bioassay laboratory did concurrent concentration-response curves using Probit and Log transformations, which are also shown in Appendix H.

Dataset: The concentration-response curves are modified simple scatterplots; the dataset, therefore, is as described previously for scatterplots.

Output: SPSS will generate the scatterplot in the Output window. The graph can be customized as follows after double clicking the graph to open the Chart window:

- *Transformation*: It is often helpful in concentration-response curves to log-transform the analyte of interest. If the log-transformed values were not already input into the "X Axis" box, the transformation can occur from the graphical output. Single click on the X axis, then click the "Chart" menu. Under "Scale," select "Log" and click "OK."
- *Trendline*: To add a trendline, select "Options" under the "Chart" menu. Under "Fit Line," select "Total" and click "Fit Options." Select the type of regression visually appropriate for the data; for the GWSA dataset, we used the cubic regression. To plot the confidence intervals, click "Mean" in the "Regression Prediction Lines" box, and then specify the confidence interval (e.g., 95%). Under "Regression Options" you can choose to display the R-squared value on the graph. When finished, click "Continue" and then click "OK."

Appendix D
Gas Works Sediment Area
Statistical Analysis Flow Chart



Appendix E

Graphical Distribution Evaluation – Histograms and Scatterplots

APPENDIX E
Histograms, Distributions and Scatterplots

Phase 3 and Phase 2/3 Data Sets
PSE10-18628-610
07-12-05

This appendix summarizes the exploratory and visual examination of the Gas Works Sediment Area (GWSA) chemistry and bioassay data for both Phase 2 (2002) and Phase 3 (2005) sampling events. This analysis was conducted with the Phase 3 data set only, and then repeated as a combined data set (2002 and 2005). The scope of this effort was to initially explore the graphical relationships among variables and to identify outliers. These parameters will, in turn, be carried forward into more focused analyses (Appendices F and G). SPSS versions 10.0 and 13.0 were used for analysis.

I. HISTOGRAMS

Histograms are a univariate statistical and exploratory graphical tool. A histogram displays the distribution of values in a quantitative variable by dividing the range into equally-spaced intervals (the total number of which is referred to as "bin size") and plotting the count of cases in each interval as a bar. The bins (or bars) appear along the X axis and frequency appears on the Y axis. Each histogram has a normality curve superimposed on it in order to compare the parameter's distribution to a normal distribution. In addition to providing information on the spread and shape of a data set, histograms can also help identify outliers. All histograms generated for this analysis had a bin size of at least 10: the larger the bin size, the more clear each parameter's distribution curve is.

A) Phase 3 Data Set

The Phase 3 data set (2005) included the following parameters:

Conventionals: sulfide, ammonia, total organic carbon (TOC), cyanide

Metals: arsenic, cadmium, chromium, copper, iron, lead, mercury, silver, zinc, tributyltin (TBT)

Organics: total polycyclic aromatic hydrocarbons (TPAH), carbon-normalized TPAH (TPAH-oc), phenol, 2,4-dimethylphenol, carbazole, dibenzofuran, and total polychlorinated biphyenyls (PCBs)

Physical: percent fines, total solids

Bioassays: *Hyalella azteca* 10-day survival, Microtox® luminescence porewater test, *Chironomus tentans* 20-day survival and growth

The samples included: NLU13-TX, NLU51-TX, NLU55-TX, NLUD55-TX, NLU64-TX, NLU66-TX, NLU69-TX, NLU73-TX, NLU76-TX, NLU81-TX through NLU87-TX, NLU117-TX, NLUD117-TX, NLUEPA5-TX, and NLUEPA19-TX. The Phase 3 whole data set output is displayed in Table E-1.

B) Phase 2 + 3 Combined Data Set

The Phase 2 + 3 combined data set (2002 and 2005) included the following parameters:

Conventionals: sulfide, ammonia, TOC

Metals: arsenic, cadmium, chromium, copper, lead, mercury, zinc

Organics: TPAH

Physical: percent fines

Bioassays: *Hyalella azteca* 10-day survival, Microtox® luminescence porewater test, *Chironomus tentans* 20-day survival and growth

The locations included the following samples:

- *2005*: NLU13-TX, NLU51-TX, NLU55-TX, NLUD55-TX, NLU64-TX, NLU66-TX, NLU69-TX, NLU73-TX, NLU76-TX, NLU81-TX through NLU87-TX, NLU117-TX, NLUD117-TX, NLUEPA5-TX, NLUEPA19-TX
- *2002*: LU-1 through LU-11, NLU01, NLU02, NLU04, NLU05, NLU06, NLU07, NLU08, NLU10, NLU12, NLU13, NLU14, NLU15, NLU16, and NLU17

The Phase 3 data set is indicated by the suffix "–TX" and the Phase 2 data set has no suffix. The Phase 2 + 3 combined data set output is displayed in Table E-2.

C) Conclusions

The Phase 3 and Phase 2 + 3 combined data sets were non-normally distributed for some parameters. Outliers occurred in both the Phase 3 and Phase 2 + 3 combined data sets. For the Phase 3 data set, parameters TOC, cyanide, lead, and PCBs were log-transformed to improve data distribution and minimize the influence of outliers (Table E-3). For the Phase 2 + 3 combined data set, only TOC was log-transformed (Table E-4). Distributions for the other parameters did not improve upon transformation. Distributions were also visually checked using Q-Q plots for normality and scatterplots for outliers.

II. SCATTERPLOTS AND SCATTERPLOT MATRICES

Scatterplots and scatterplot matrices are a second type of statistical univariate and exploratory graphical tool. A scatterplot matrix produces a set of scatterplots tied to one another where colors encode the density of the points in the scatterplots and represent individual samples. Each scatterplot and scatterplot matrix has a color-coded sample key. Scatterplots and scatterplot matrices are best used to determine outliers in a data set. Due to the large amount of data in the master data sets, only data subsets were used for this test.

A) Phase 3 Data Subset

The scatterplot matrix graphical results included the following:

- All parameters (conventionals, metals, organics, and physical, Figure E-1),
- Metals plus bioassays (Figure E-2), and
- Organics (TPAH) plus bioassays (Figure E-3).

B) Phase 2 + 3 Data Subset

The same suite of parameters were used for the combined data analysis. The scatterplot matrix graphical results included the following:

- All parameters (conventionals, metals, organics, and physical, Figure E-4),
- Metals plus bioassays (Figure E-5), and
- Organics (TPAH) plus bioassays (Figure E-6).

C) Conclusions

Scatterplots and scatterplot matrices proved to be a helpful graphical tool to indicate outliers. The graphs are limited in that the sample code colors were often hard to discern. For the most part, the plots agreed with the whole data set histograms. Outliers found in the Phase 3 data set were often observed again in the Phase 2 + 3 combined data sets.

Table E-1. GWSA Histograms with Normality Curve and Outliers for Phase 3 Dataset

Whole Dataset

Parameters included:

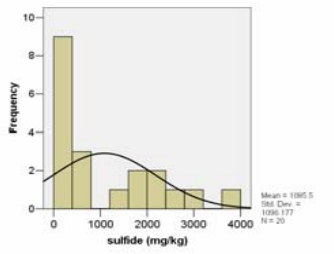
Conventionals: sulfide, ammonia, TOC, cyanide

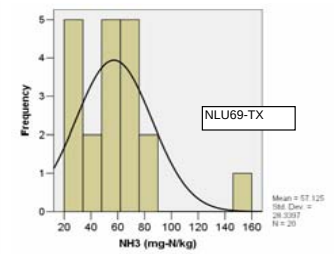
Metals: arsenic, cadmium, chromium, copper, iron, lead, mercury, silver, zinc, TBT

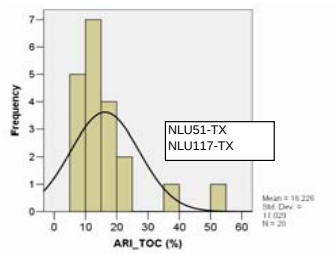
Organics: TPAH, TPAH-oc, phenol, 2,4-Dimethylphenol, carbazole, dibenzofuran, PCBs

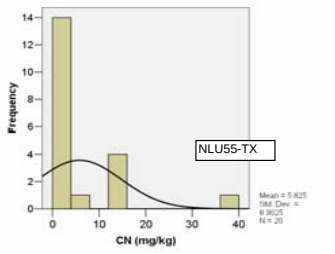
Physical: total solids, percent fines

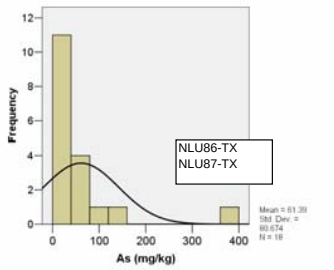
Bioassays: *Hyalella azteca* 10-day survival, Microtox® luminescence porewater test, *Choronomid. tentans S* , and *Chronomid. tentans G.*

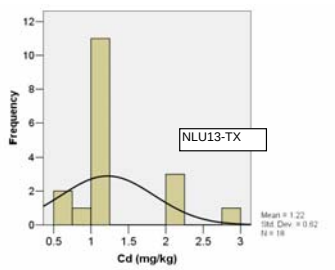


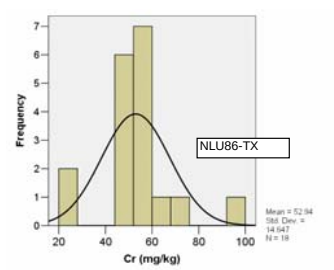


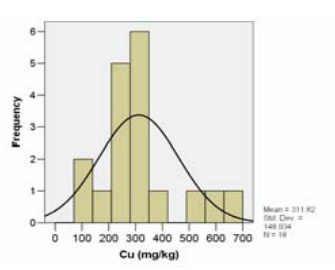


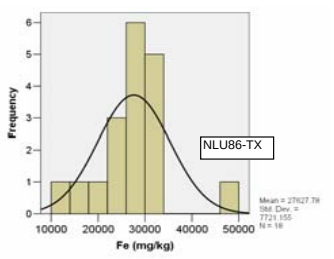


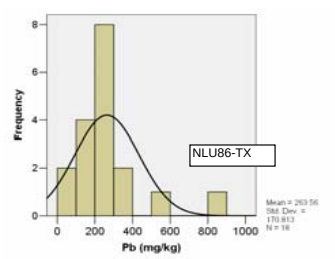


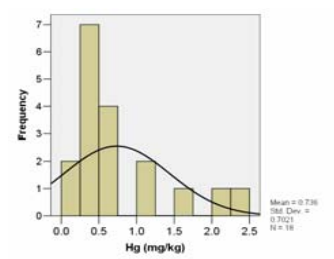


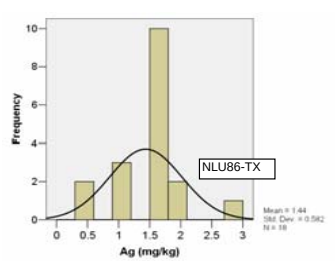


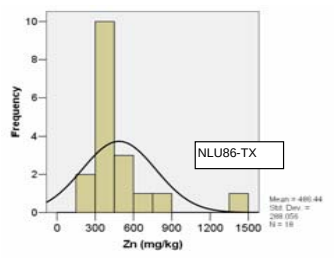


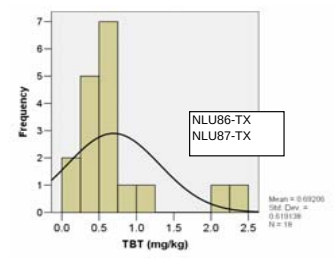


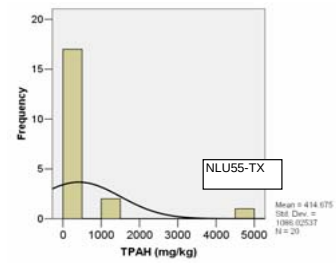












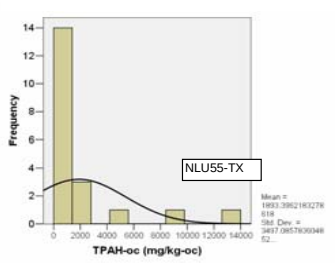
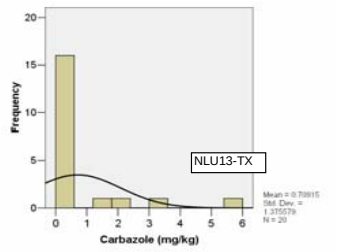
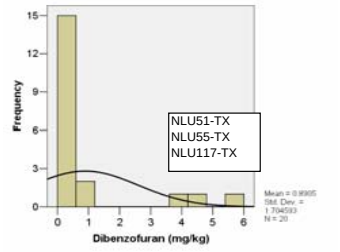
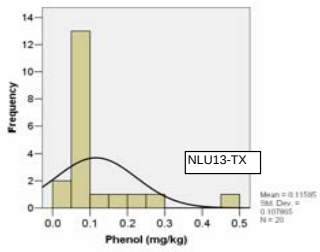
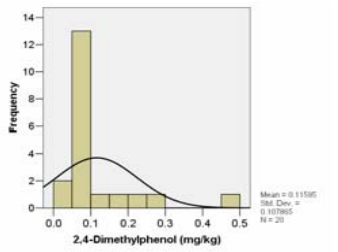


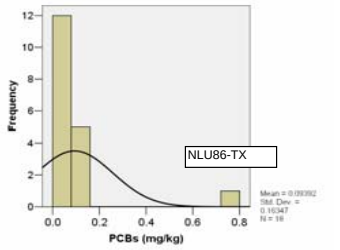
Table E-1. GWSA Histograms with Normality Curve and Outliers for Phase 3 Dataset – Continued

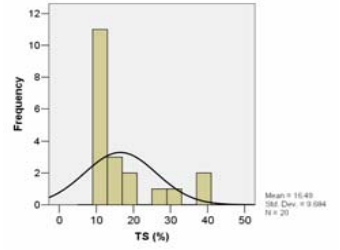


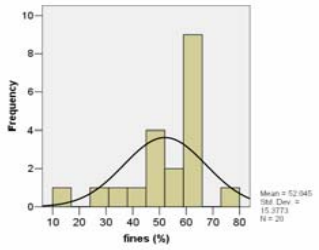


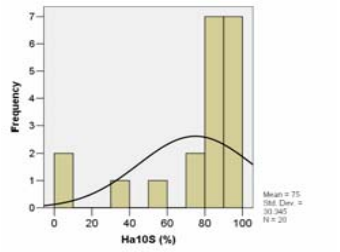


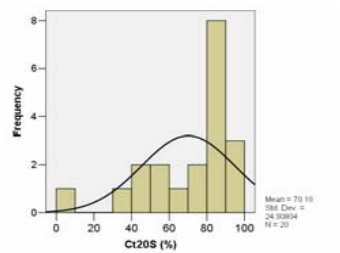


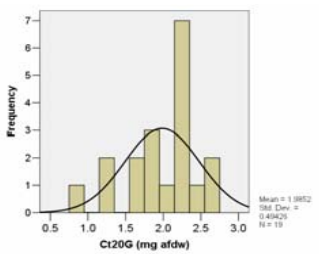












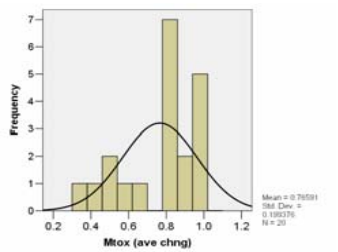


Table E-2. GWSA Histograms with Normality Curve and Outliers for Phase 2 + 3 Combined Dataset

Whole Dataset.

Parameters included:

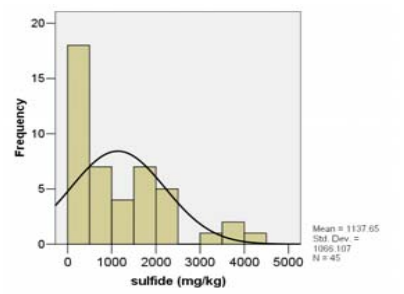
Conventionals: sulfide, ammonia, TOC

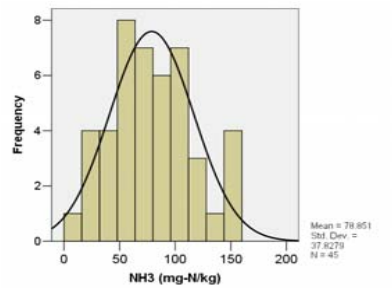
Metals: arsenic, cadmium, chromium, copper, lead, mercury, zinc

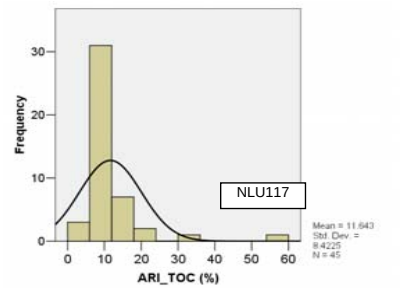
Organics: TPAH, TPAH-oc, dibenzofuran

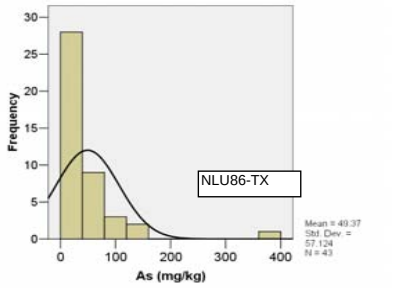
Physical: total solids, percent fines

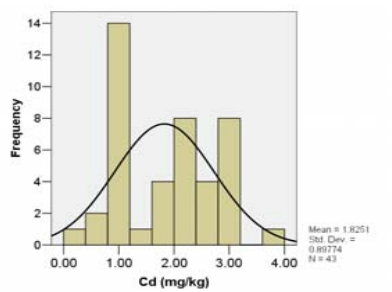
Bioassays: *Hyalella azteca* 10-day survival, Microtox® luminescence porewater test, *Choronomid. tentans S* , and *Chronomid. tentans G.*

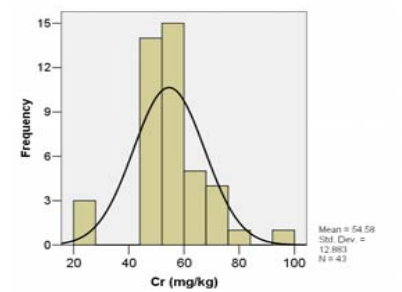


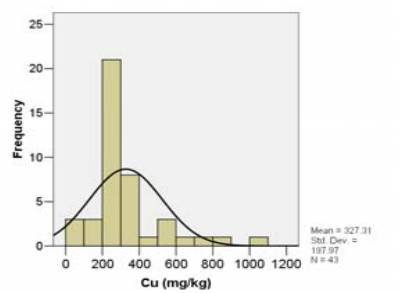


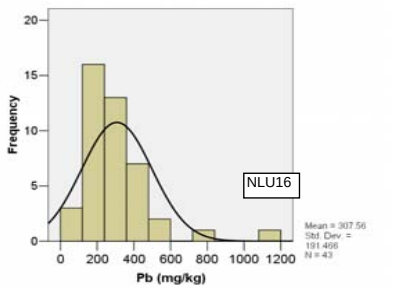


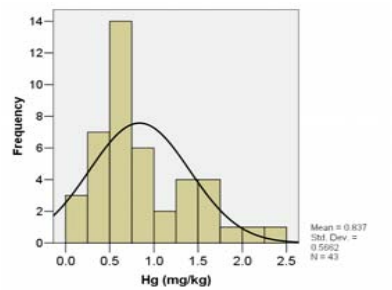












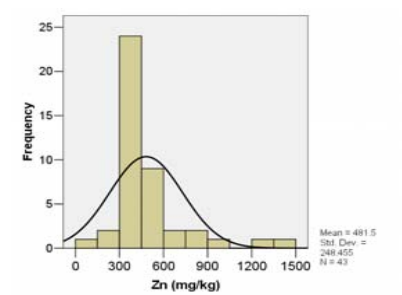
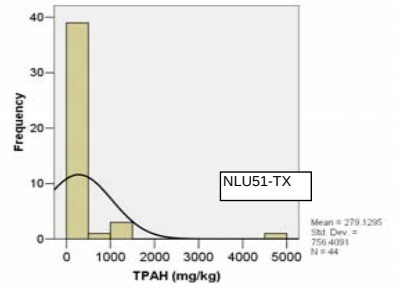
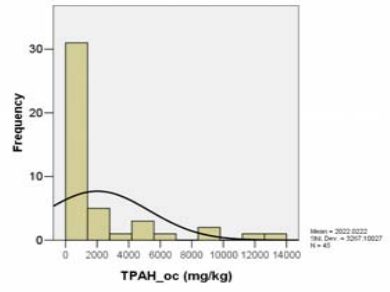
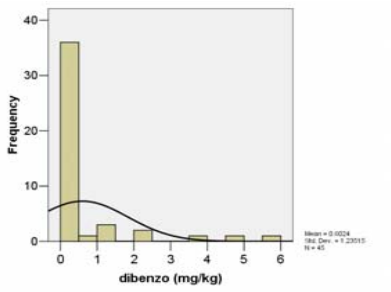
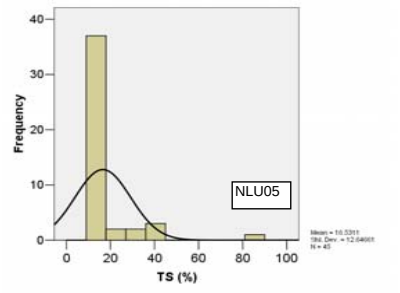


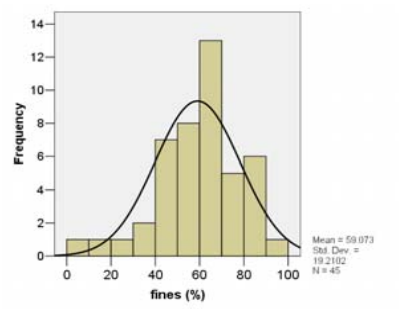
Table E-2. GWSA Histograms with Normality Curve and Outliers for Phase 2 + 3 Combined Dataset – Continued

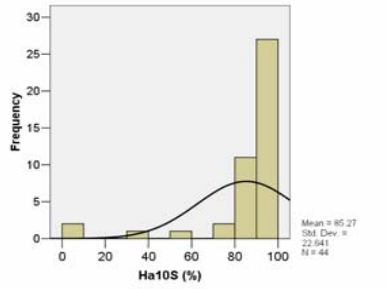


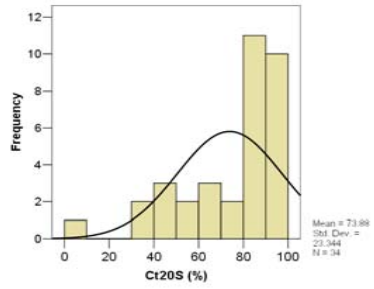


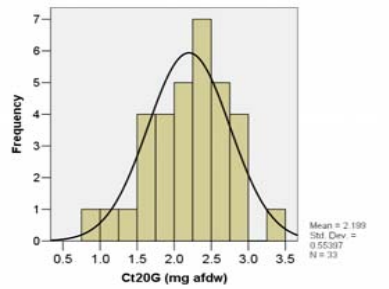












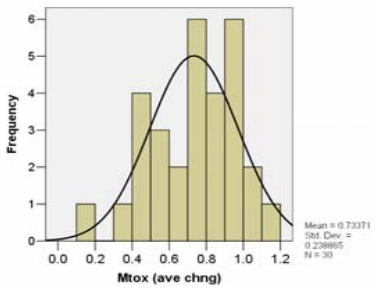
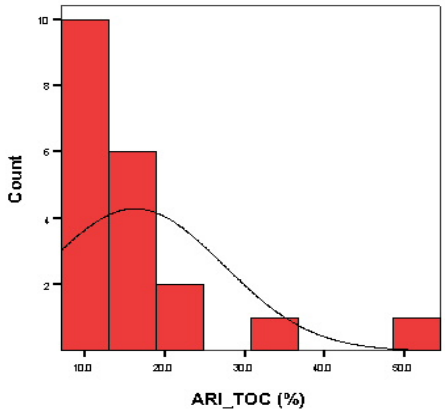


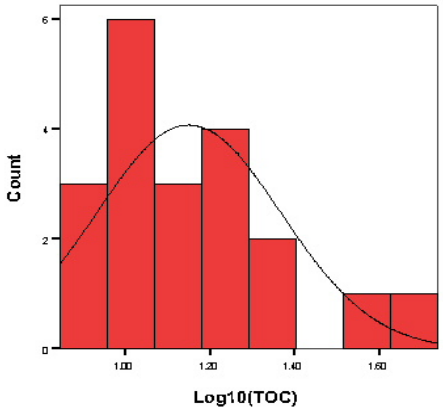
Table E-3. Comparision of Transformed vs Untransformed Distributions

Phase 3 Only, Initial Dataset

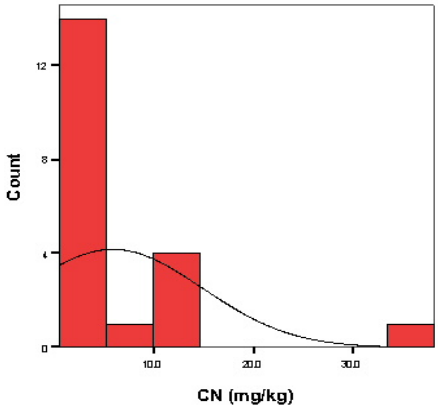
TOC, Phase 3 Only Initial



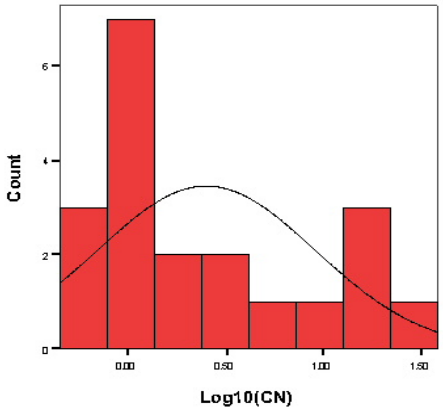
Log(TOC), Phase 3 Only Initial



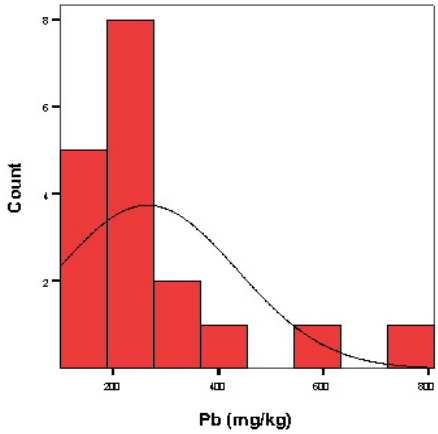
Cyanide, Phase 3 Only Initial



Log(Cyanide), Phase 3 Only Initial



Lead, Phase 3 Only Initial



Log(Lead), Phase 3 Only Initial

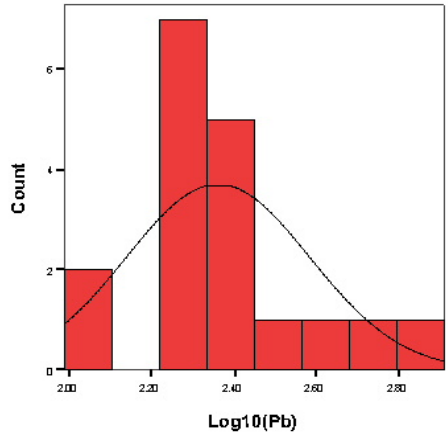
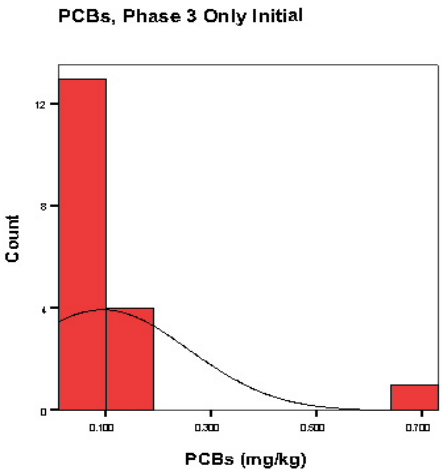
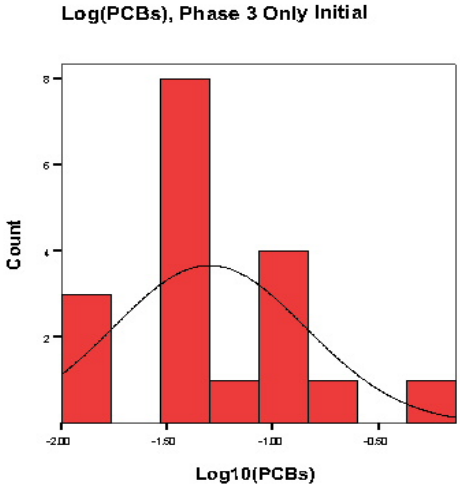
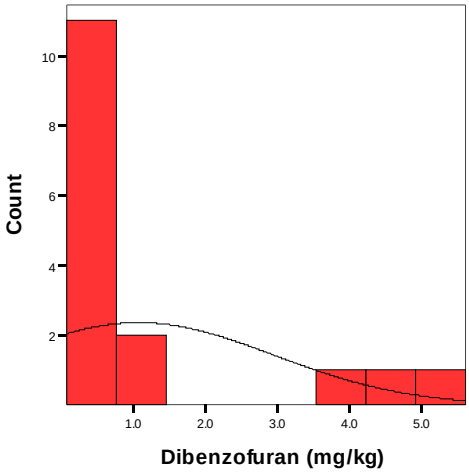


Table E-3. Comparision of Transformed vs Untransformed Distributions

Phase 3 Only, Initial Dataset







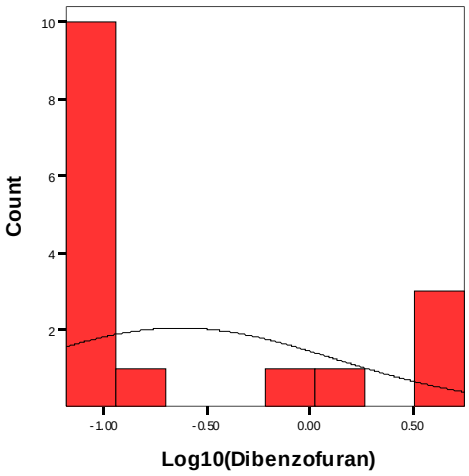
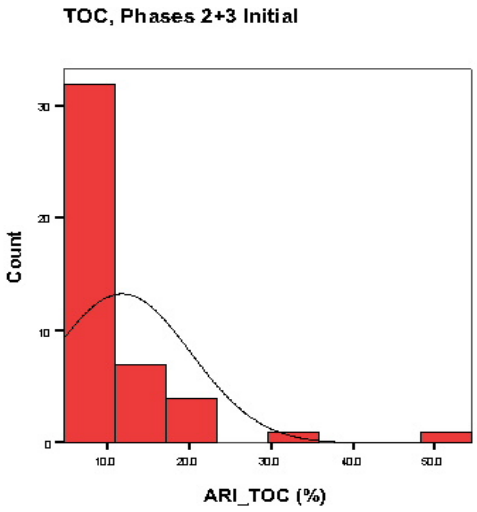
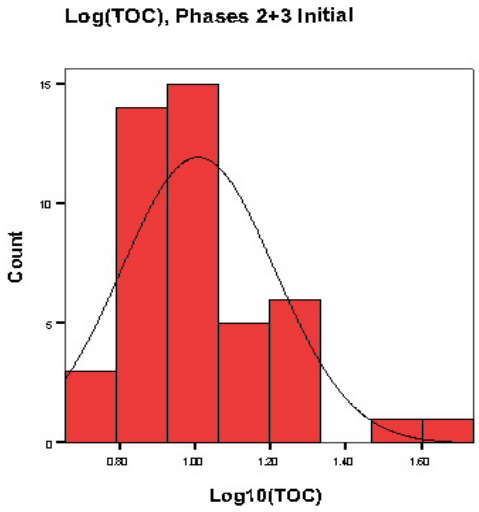
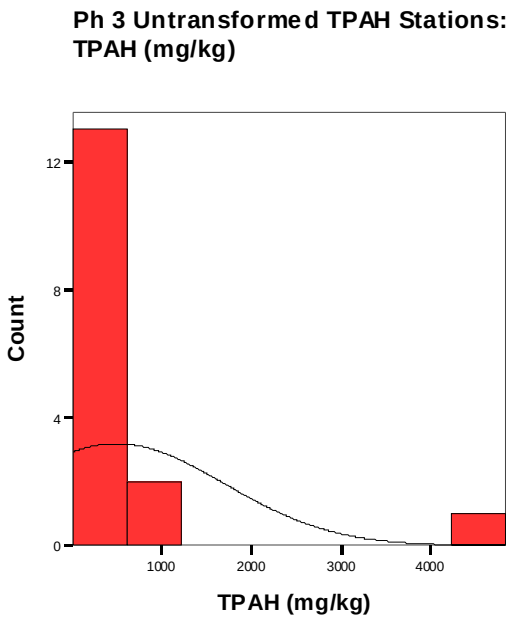


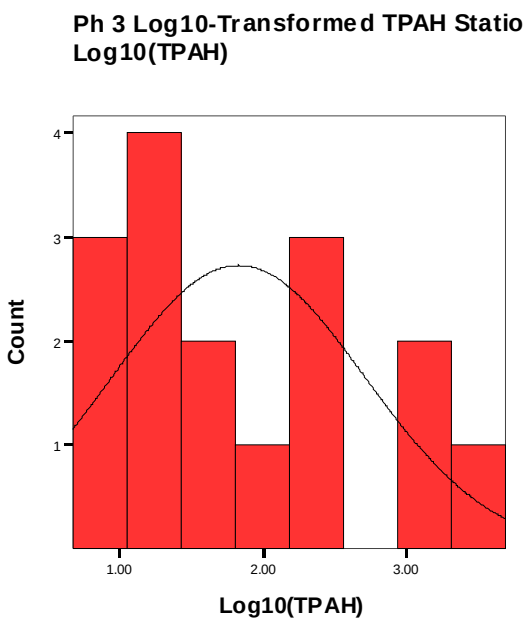
Table E-4. Comparison of Transformed vs. Untransformed Distributions

Phases 2 + 3, Initial Dataset









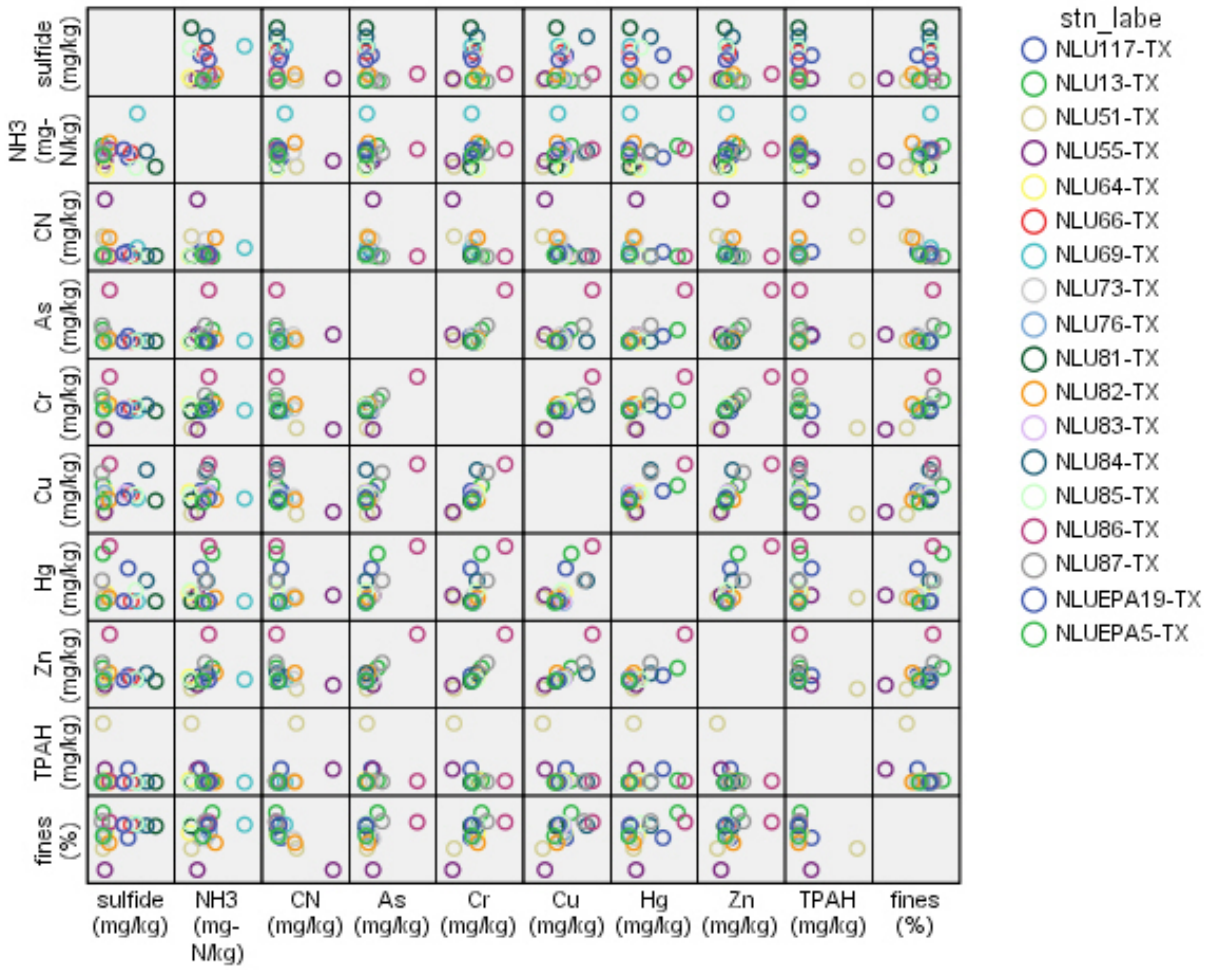


Figure E-1. GWSA Phase 3 data subset scatterplot matrix of all parameters. Parameters include conventionals: sulfide, ammonia, and cyanide; metals: arsenic, chromium, copper, mercury, and zinc; organics: total polycyclic aromatic hydrocarbons (TPAH); and physical: percent fines.

Outliers include samples NLU69-TX (sulfide, Cr, Cu, Zn, As, Hg, ammonia), NLU55-TX (sulfide, cyanide, fines), NLU86-TX (sulfide, Cr, Cu, Zn, As, Hg), and NLU51-TX (TPAH).

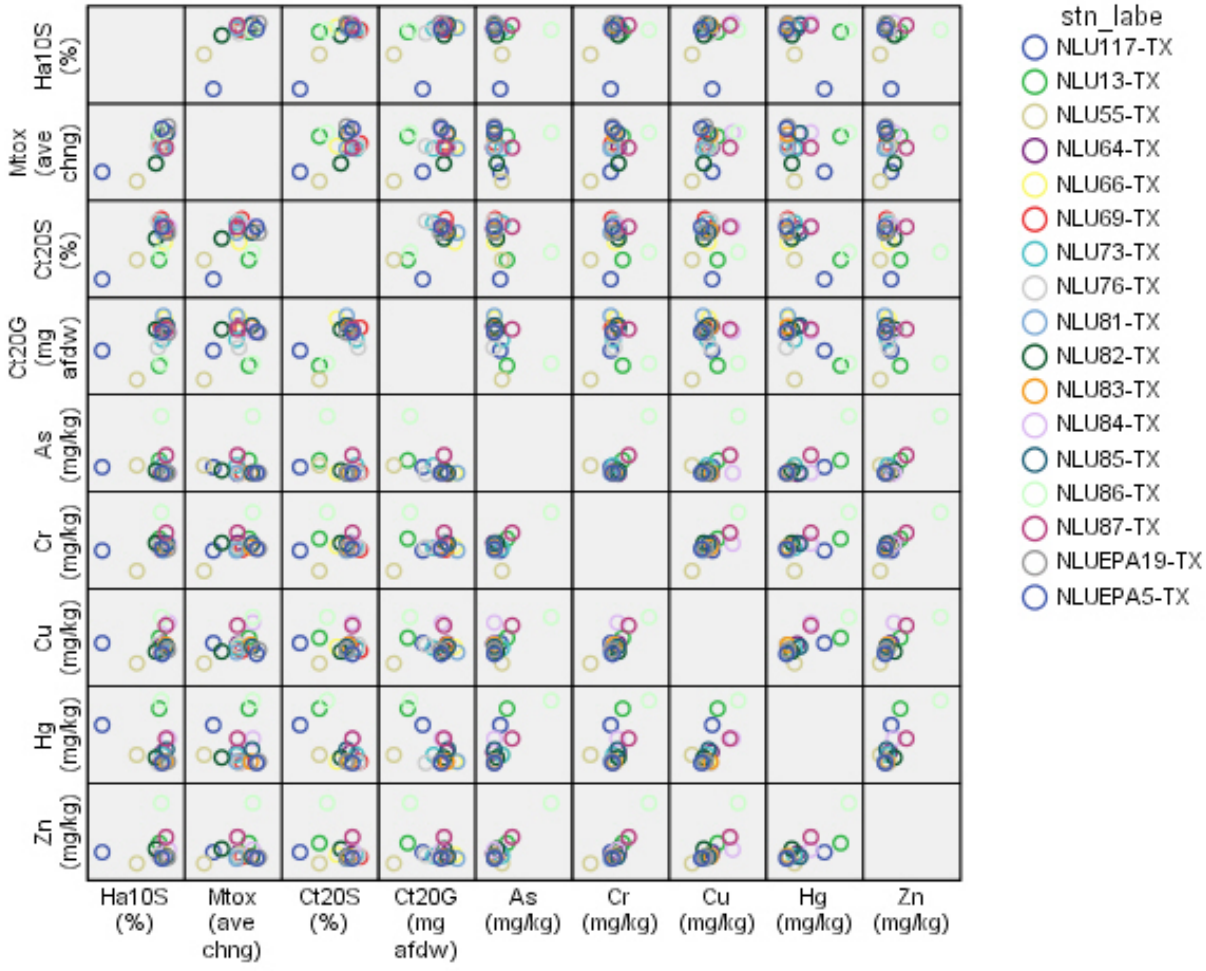


Figure E-2. GWSA Phase 3 data subset scatterplot matrix of metals plus bioassays. Parameters included metals: arsenic, chromium, copper, mercury, and zinc; and bioassays: *Hyalella azteca*, Microtox®, *Choronomid tentans G, and Chronomid tentans S.*

Outliers for bioassays include samples NLU117-TX and NLU55-TX, and sample NLU86-TX for metals.

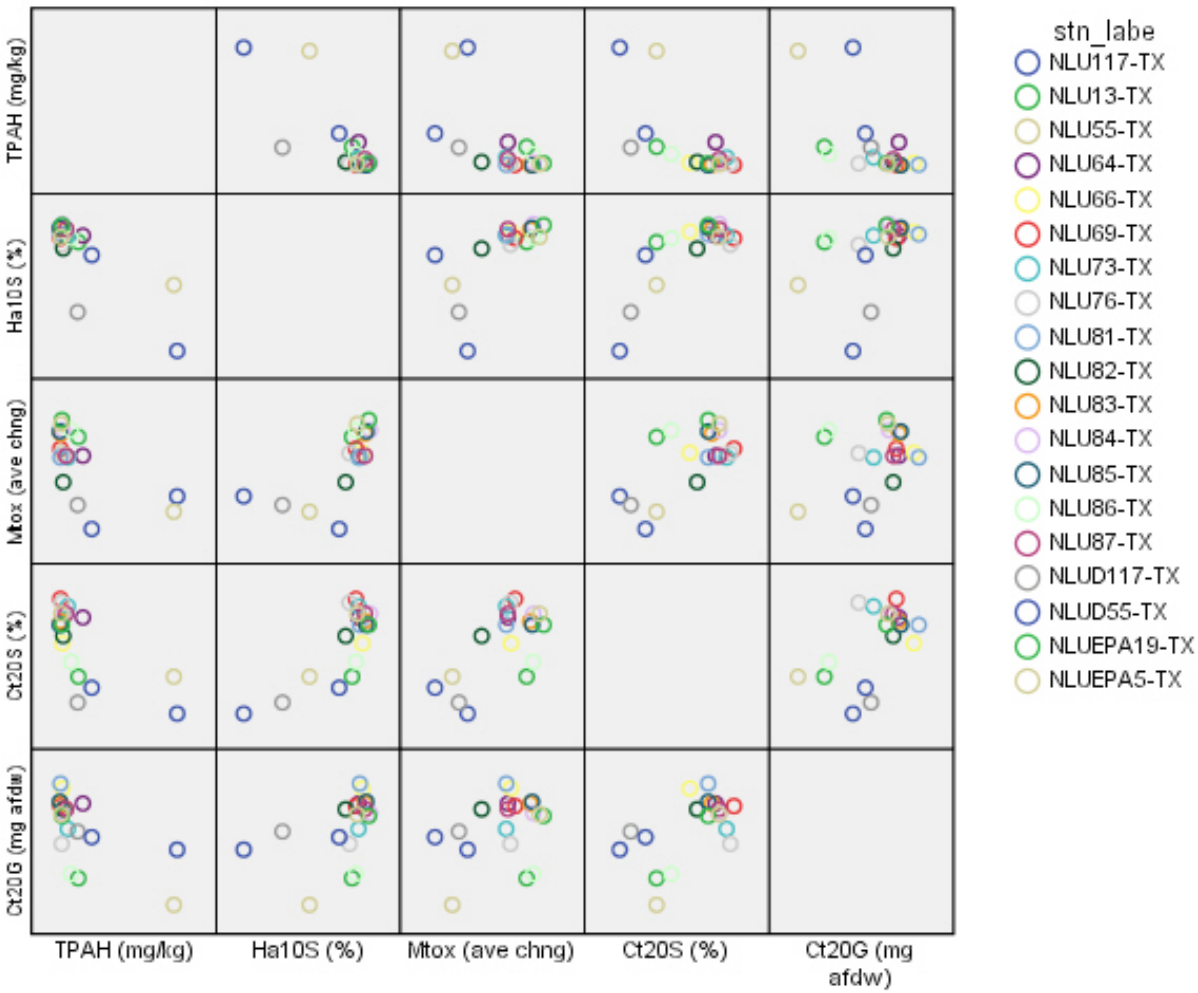


Figure E-3. GWSA Phase 3 data subset scatterplot matrix of organics (TPAH) and bioassays. Parameters included organics: total polycyclic aromatic hydrocarbons (TPAH); and bioassays: *Hyalella azteca*, Microtox®, *Choronomid tentans G, and Chronomid tentans S.*

The outliers include samples NLU55-TX and NLU117-TX.

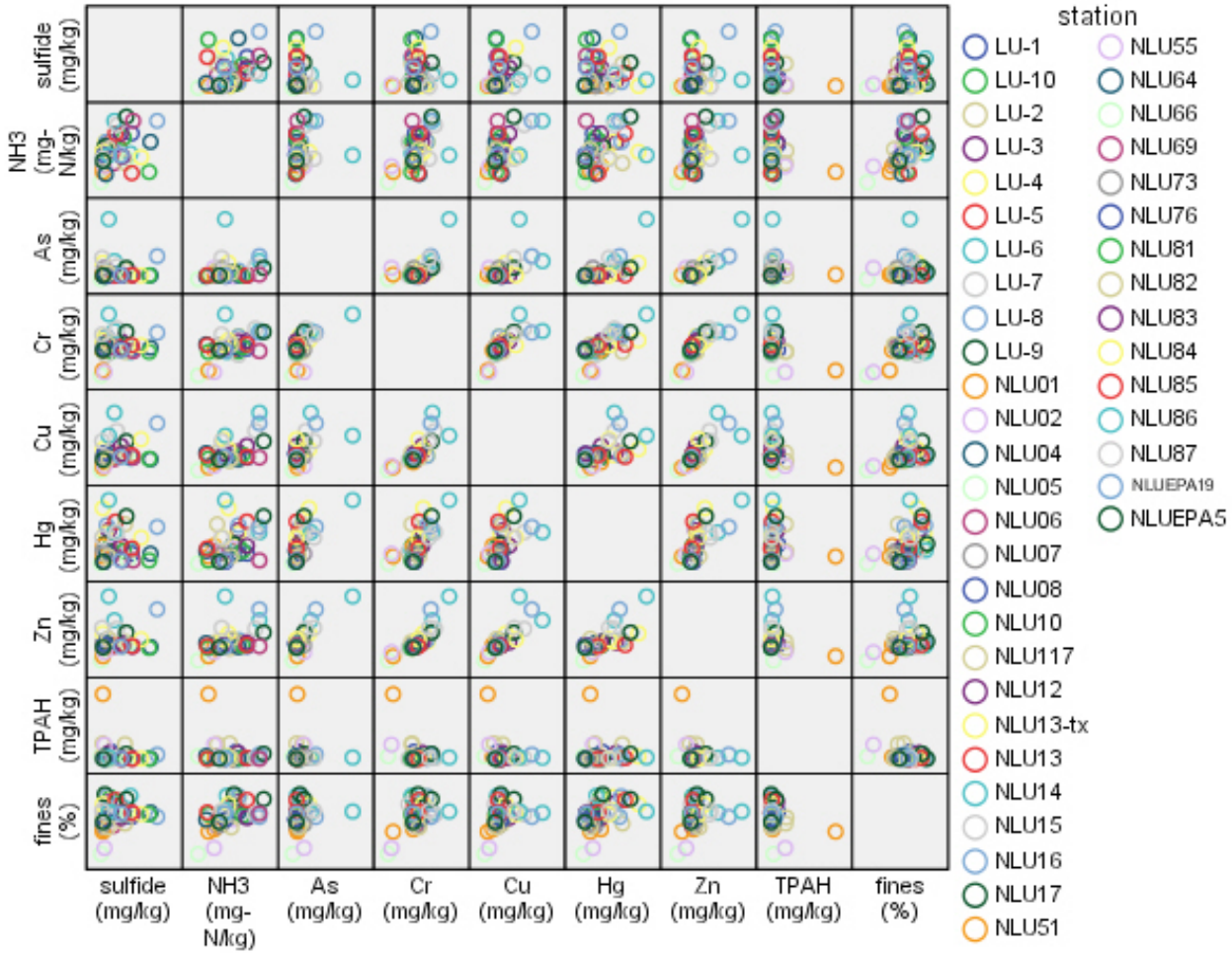


Figure E-4. GWSA Phase 2 + 3 data subset scatterplot matrix of all parameters. Parameters included conventionals: sulfide, ammonia; metals: arsenic, chromium, copper, mercury, zinc; organics: total polycyclic aromatic hydrocarbons (TPAH); and physical: percent fines.

Outliers include samples NLU16 (sulfide), NLU86-TX (ammonia, As, Cr, Cu, Hg, Zn, fines), and NLU51-TX (TPAH).

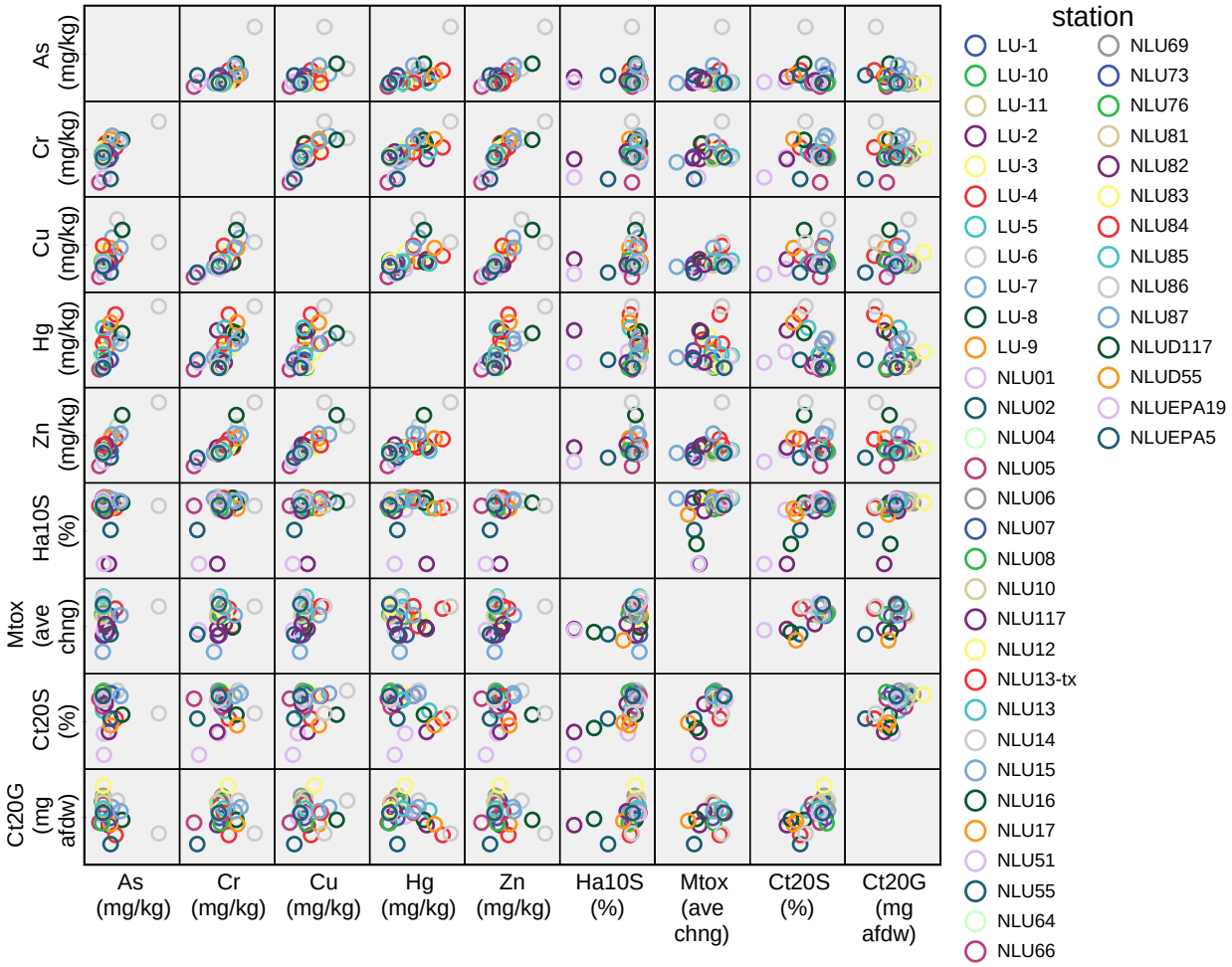


Figure E-5. GWSA Phase 2 + 3 data subset scatterplot matrix of metals plus bioassays. Parameters included metals: arsenic, chromium, copper, mercury, zinc; and bioassays: *Hyalella azteca*, *Chironomus tentans* (survival and growth), and Microtox®.

Outliers include sample NLU86-TX (metals).

Figure E-6. GWSA Phase 2 + 3 data subset scatterplot matrix of organics (TPAH) plus bioassays. Parameters included total polycyclic aromatic hydrocarbons (TPAH), *Hyalella azteca*, *Chironomus tentans* (survival and growth), and Microtox®.

Outliers include sample NLU51-TX (TPAH).

Appendix F

Initial Screening –
Correlations and Cluster Analysis (SPSS)

APPENDIX F
Initial Screening

Correlations and Cluster Analyses
Phase 3 and Phase 2/3 Datasets
H. azteca, C. tentans, and Microtox®

PSE10-18628-610
08-19-05

This document summarizes the preliminary examination and assessment of the Gas Works Sediment Area (GWSA) bioassay and synoptic parameters data for both Phase 2 (2002) and Phase 3 (2005) sampling events. This initial screening is conducted with the combined Phases 2 and 3 dataset, and then repeated with only the Phase 3 dataset to confirm the findings. Because the Phase 3 dataset has more chemical parameters (although it has fewer samples), it was used as a quality control check on the list of significant parameters derived using the combined dataset. The scope of this effort was to initially explore the relationships between variables and to identify those parameters that best account for the variance observed in bioassay test results. These parameters will, in turn, be carried forward into more focused secondary analyses (Appendix G).

SPSS version 10.0 was used for all analyses.

I) PHASES 2 and 3 COMBINED DATASET – Initial Screening (N = 45)

Only those parameters comprising a complete dataset once Phases 2 and 3 sampling events (March and October 2002; April 2005) were combined were retained for analysis. The preliminary dataset included the following parameters:

Conventionals: sulfide, ammonia, Log^{10} (total organic carbon [TOC])

Organics: total polycyclic aromatic hydrocarbons (TPAH)

Metals: arsenic, cadmium, chromium, copper, lead, mercury, zinc

Physical: percent fines

Bioassays: *Hyalella azteca* 10-day survival; *Chironomus tentans* 20-day survival and growth; Microtox® luminescence porewater test

A) Whole-Data Set – General Exploration

1) Correlation

Correlation measures the strength of the association between variables. The closer the correlation coefficient is to |1.0|, the stronger the association. Correlation is a good preliminary tool to use in data assessment.

A correlation matrix of all variables — chemical, physical, and biological — was generated using Pearson's bivariate correlation (Table F-1) with pairwise exclusion. (In pairwise exclusion, cases with missing values for one or both of a pair of variables for a correlation coefficient are excluded from the analysis. Since each coefficient is based on all cases that have valid codes on that

particular pair of variables, the maximum information available is used in every calculation.) The observed correlation results can be summarized as follows:

- ammonia is significantly correlated with sulfide, all metals except arsenic, percent fines, and *H. azteca*;
- TPAH is significantly correlated with Log10(TOC), chromium, percent fines, and all bioassays except Microtox®;
- all metals are significantly correlated with each other with the exception of arsenic and cadmium;
- *H. azteca* is significantly correlated (alpha = 0.01) with Log10(TOC), chromium, TPAH, percent fines, and *C. tentans* survival and growth;
- *C. tentans* survival is significantly correlated (alpha = 0.01) with TPAH and all other bioassays;
- *C. tentans* growth is significantly correlated (alpha = 0.01) with TPAH and all bioassays except Microtox®; and
- Microtox® is significantly correlated (alpha = 0.01) with *C. tentans* survival and moderately correlated (alpha = 0.05) with sulfide, copper, and *H. azteca*.

Findings: Because of the significant correlations between TPAH and TOC, TPAH will be used in future statistical analyses as representative of TOC. Most metals significantly correlated with each other; selection of a subset will be deferred to review of the Phase 3 Only dataset, which will help determine which subset of metals should be carried forward.

II) PHASE 3 ONLY – Initial Screening (N = 20)

The preliminary Phase 3 dataset (April 2005) included the following parameters:

Conventionals: sulfide, ammonia, Log10(TOC), Log10(cyanide)

Organics: TPAH, carbon-normalized TPAH (TPAH-oc), carbazole, dibenzofuran, and Log10(total polychlorinated biphyenyls [PCBs])

Metals: arsenic, cadmium, chromium, copper, iron, Log10(lead), mercury, silver, zinc, tributyl tin (TBT)

Physical: percent fines, total solids

Bioassays: *Hyalella azteca* 10-day survival; *Chironomus tentans* 20-day survival and growth; Microtox® luminescence porewater test

A) Whole-Dataset – General Exploration

1) Correlation (Pearson's Bivariate)

A correlation matrix of all variables — chemical, physical, and biological — was generated using Pearson's bivariate correlation (Table F-2) with pairwise exclusion. The observed correlation results can be summarized as follows:

- sulfide is only significantly correlated with total solids;
- ammonia is not significantly correlated with any parameters;
- TPAH dw is significantly correlated with Log10(TOC), TPAH-oc, carbazole, dibenzofuran, chromium and iron, total solids, and all bioassay tests;

- all metals are significantly correlated with each other;
- total solids and percent fines are significantly correlated with many of the same parameters;
- *H. azteca* survival is significantly correlated (alpha = 0.01) with all organics (except Log10[PCBs]), Log10(TOC), and *C. tentans* growth;
- Microtox® is significantly correlated (alpha = 0.01) with chromium, iron, TPAH-oc, carbazole, dibenzofuran, total solids, percent fines, *H. azteca*, and *C. tentans* survival;
- *C. tentans* survival is significantly correlated (alpha = 0.01) with all organics (except Log10[PCBs] and Log10[TOC]), total solids, H. azteca, and Microtox®; and
- *C. tentans* growth is significantly correlated (alpha = 0.01) with TPAH, TPAH-oc, carbazole, and total solids.

2) Exploratory Regression

Exploratory regressions were run of the largest number of predictor variables possible, which comprised the Phase 3 only dataset. Stepwise regression yields a model with a reduced set of variables that is often useful in prediction of the dependent variable (percent survival or growth). Stepwise selection begins by adding variables into the model one by one, starting with the variable with the strongest correlation to the dependent variable. In addition, stepwise regression also tests variables already in the model for removal at each step. This is a commonly used method, particularly when there are correlations among the independent variables (SPSS, 1998). Listwise exclusion was used to include only stations that had no missing values.

a) *Hyalella azteca*

Stepwise regression of *H. azteca* data using listwise exclusion resulted in four models (Table F-3). The final model, which accounted for 98% of the variance observed in the toxicity test, included dibenzofuran, TPAH, carbazole, and total solids. Other variables were excluded from the model.

b) *C. tentans* survival

Stepwise regression of *C. tentans* survival data using listwise exclusion produced three models (Table F-3). The final model, which included TPAH, mercury, and copper, accounted for 92% of the variance. TPAH alone accounted for 74% of the variance.

c) *C. tentans* growth

Stepwise regression of *C. tentans* growth data using listwise exclusion and all variables was overwhelmed by the influence of total solids. When total solids was removed, the regression resulted in two models, the last of which included TPAH-oc and mercury (Table F-3). This model accounted for 77% of the variance.

d) Microtox®

Stepwise regression of untransformed Microtox® data using listwise exclusion resulted in two models (Table F-3). The final model, which accounted for 75% of the variance in the toxicity test, included dibenzofuran and percent fines.

Findings: Although ammonia and sulfides are not correlated with the bioassay tests or any chemicals, these parameters are retained because of potential confounding influences on toxicity results that may not be apparent in linear relationships. Since percent fines and total solids are significantly correlated

with each other, only one parameter is needed to represent physical influences, therefore percent fines was selected because it has a spatial component, as well.

B) Organic Parameters Dataset – Question #1: Does TPAH account for other SVOCS? Can a smaller subset of organics, represented by TPAH, reliably be carried forward?

The initial dataset contains a high number of organic parameters which could potentially confound analyses such as stepwise regression. As shown in the whole dataset correlation, the relationships between many of these organics are strong enough to warrant a reduced parameter list in further statistical analyses; this should increase the power of those analyses. Can TPAH account for other organic parameters (e.g. can the parameter list be reduced)? Results of a statistical exploration are described below.

1) Correlation

Refer to the correlation matrix (Table F-2) generated previously for all data. To summarize:

- Log10(PCBs) does not significantly correlate with any other organics;
- TPAH and dibenzofuran are significantly correlated with all other organic parameters; and
- carbazole and TPAH-oc are significantly correlated with all other organic parameters except Log10(TOC).

Findings: Because of the significant correlations between TPAH and all other organic parameters except Log10(PCBs), TPAH will be used in future statistical analyses as representative of all organics except Log10(PCBs). TPAH was selected over TPAH-oc in part because of the high TOC values encountered in the GWSA. Since Log10(PCBs) was not correlated to any bioassay test, and does not correlate with other organics, Log10(PCBs) was not carried forward.

C) Metals Dataset – Question #2: Which metals should be carried forward? Can a smaller subset of metals reliably represent the metals group?

All bioassay sediment samples were analyzed for the Sediment Management Standard (Ecology, 2003a) metals suite, along with iron and TBT, bringing the total number of analyzed metals to ten. As with the organics, this large number of metals variables may confound future statistical analyses. Can a selected list of metals be used to represent a larger suite of metals? Correlation and other lines of evidence were used to identify a more focused subset of metals to be used in future analyses.

1) Correlation

Refer to the correlation matrix (Table F-2) generated previously for all data. To summarize:

- all metals are significantly correlated with each other;
- chromium and iron are significantly correlated with TPAH;
- *H. azteca* significantly (alpha = 0.05) correlates to chromium and iron;
- *C. tentans* survival correlates with no metals, while growth correlates with mercury;
- Microtox® significantly correlates to chromium, copper, iron, Log10(lead), and silver;
- cadmium lacks significant relationships with non-metals; and
- TBT has no significant relationships with most other non-metals.

2) Other Lines of Evidence

a) GWSA-area History

Shipyards have historically been located adjacent to the GWSA; some of these remain in operation today. Metals and TBT are often chemicals of concern associated with shipyard activities. Historical studies in Lake Union (Tomlinson et al. 1977; Cubbage 1992, as reported in the NLU Sediment Investigation Report 2002) found extensive similarities among copper, lead, and zinc, likely contributed by the same sources. Statistical comparisons by Cubbage (1992) also showed co-occurrence of arsenic, mercury, nickel, and zinc, with similar distribution patterns in north Lake Union.

b) GWSA Phase 3 Dataset

Silver did have three exceedances of Washington Department of Ecology (Ecology) screening criteria within the GWSA Phase 3 dataset. However, the concentrations in these samples were similar to the silver concentrations in the reference sample. Chromium had no exceedances of screening criteria (Ecology, 2003b), although values were detected in all synoptic chemistry samples.

Findings: Because iron is not a chemical of concern for the GWSA and Ecology has not established screening levels for it, iron will be excluded from future statistical analyses. Lead, cadmium, and TBT will also be excluded due to the lack of significant correlation with non-metals. Lead may also have lake-wide influences. Nickel was not reported, and was not carried forward as a COPC. Silver, which was never detected above the apparent lake-wide background level, will also be removed from future analyses. The final list of metals includes arsenic, copper, chromium, mercury, and zinc. These metals are significantly correlated to other SMS metals and will be carried forward as indicator metals in subsequent statistical analyses.

III) CLUSTER ANALYSIS

Cluster analysis is a multivariate tool for detecting groupings in data. The objects in these groups may be cases (e.g., station ID) or variables (e.g., TPAH). In the hierarchical clustering method, clustering begins by finding the closes pair of objects (cases or variables) according to a distance measure and combines them to form a cluster. The algorithm continues stepwise, joining pairs of objects, pairs of clusters, or an object with a cluster, until all data are in a cluster.

The predominant statistical method used for clustering was square Euclidean distance, between groups linkage, and z-scores to equalize variance. This method was recommended by a statistician for detecting groups of stations. Several other exploratory methods were also used for clustering, but the data clusters were usually similar.

Cluster analysis of the Phase 2 + 3 combined data subset found several distinct clusters within the GWSA, as well as identified two chemical outliers (Figure F-1). The following clusters emerged: the "shipyard" cluster (offshore stations in the Western Study Area in the vicinity of current and historic shipyard operations), and the "extended shipyard" cluster, which includes Western Study Area stations that are to the south and west of the Area of Investigation. NLU51 and NLU86 were identified as chemical outliers, but will be folded into one cluster group or another for TPAH standard derivations. Stations NLU01, NLU02, and NLU82, which are all northeast of the study area near marinas, did not cluster out in the hierarchical cluster analysis. These three stations are nevertheless spatially removed from the other stations by virtue of bioassay pass/fail results. Ecology agreed that these stations could be considered alongside the shipyard clusters, with the combined stations forming a Shipyard/Marina cluster. The Shipyard/Marina cluster seems to be affected by commingled metals and organics. All remaining stations appear to be predominantly affected by TPAH; these are hereafter referred to as the "GWSA Cluster." The associated data, used for later statistical analyses, are presented in Table F-4.

Findings:

These clusters are consistent with historic uses in and around the GWSA. Additionally, the outliers match those identified most routinely by the histogram and scatterplot analysis. The graphical correlations provided an additional tool to determine outliers and assess the relationship between TPAH and bioassays.

IV) CONCLUSIONS

Based upon the statistical analyses described above, the following subset is proposed for Secondary statistical analyses (Appendix G):

Conventionals: sulfide, ammonia

Organics: TPAH dry weight (dw)

Metals: arsenic, chromium, copper, mercury, zinc

Physical: percent fines

Bioassays: *Hyalella azteca* 10-day survival; *Chironomus tentans* 20-day survival and growth; Microtox® luminescence porewater test

The Phase 3 only dataset, which has a larger analyte list, supports the analyte list described above. The same parameters were considered significant in the correlations except with the addition of Log10(cyanide). The Phase 3 data analysis findings were used as a quality control check for the subset of parameters selected in the combined Phase 2 and 3 dataset.

The two data subsets (combined Phases 2 and 3 and Phase 3 only) agree except for cyanide, which is not available for the combined Phases 2 and 3 data subset. The combined dataset is more robust than the Phase 3 Only dataset for observing trends in the data because the sample set increases from about 20 samples to 45. In addition, the Phases 2 and 3 combined dataset incorporates more samples spatially throughout the GWSA, providing better spatial coverage than Phase 3 data alone. Therefore only the combined dataset will be carried forward in the Secondary statistical analyses (Appendix G) to better assess the GWSA chemical and bioassay inter-relationships.

Cluster analysis has identified stations affected by commingled chemicals ("Shipyard/Marina Cluster"). Later analyses designed to explore the TPAH-toxicity interaction will therefore focus on those stations identified primarily by TPAH (the "GWSA Cluster").

V) REFERENCES

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Table F-1 Pearson's Bivariate Correlations: GWSA Phases 2 & 3 Bioassay and Synoptic Parameters (Pairwise Exclusion)

		Sulfide (mg/kg)	Ammonia (mg-N/kg)	Log(TOC)	Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Mercury (mg/kg)	Zinc (mg/kg)	TPAH (mg/kg)	Log(TPAH)	Dibenzofuran (mg/kg)	Log (Dibenzofuran)	Fines (%)	*H. azteca* 10-day Mortality (%)	*C. tentans* 20-day Mortality (%)	*C. tentans* 20-day Growth (mg afdw)	Microtox (ave chng)
Sulfide (mg/kg)	Pearson Correlation	1	.319(*)	0.147	-0.047	0.073	0.127	0.273	0.219	-0.027	0.151	-0.185	-.306(*)	-0.029	-0.005	0.214	-0.155	-0.213	0.313	.417(*)
	Sig. (2-tailed)	.	0.033	0.337	0.766	0.643	0.417	0.076	0.158	0.862	0.335	0.229	0.044	0.851	0.976	0.157	0.315	0.226	0.076	0.022
	N	45	45	45	43	43	43	43	43	43	43	44	44	45	45	45	44	34	33	30
Ammonia (mg-N/kg)	Pearson Correlation	.319(*)	1	-0.255	0.15	.583(**)	.517(**)	.547(**)	.487(**)	.381(*)	.415(**)	-0.232	-0.134	-0.189	-0.109	.541(**)	-.366(*)	-0.258	0.239	-0.008
	Sig. (2-tailed)	0.033	.	0.09	0.337	0	0	0	0.001	0.012	0.006	0.13	0.387	0.214	0.477	0	0.015	0.14	0.181	0.965
	N	45	45	45	43	43	43	43	43	43	43	44	44	45	45	45	44	34	33	30
log(TOC)	Pearson Correlation	0.147	-0.255	1	-0.016	-.349(*)	-0.211	-0.105	-0.181	-0.162	-0.119	.449(**)	0.12	.507(**)	0.243	-0.15	.581(**)	0.24	-0.139	0.088
	Sig. (2-tailed)	0.337	0.09	.	0.921	0.022	0.174	0.502	0.247	0.298	0.448	0.002	0.438	0	0.108	0.325	0	0.172	0.442	0.646
	N	45	45	45	43	43	43	43	43	43	43	44	44	45	45	45	44	34	33	30
Arsenic (mg/kg)	Pearson Correlation	-0.047	0.15	-0.016	1	0.284	.636(**)	.572(**)	.717(**)	.673(**)	.877(**)	-0.025	0.181	0.076	0.141	0.09	0.034	0.176	-.445(*)	0.123
	Sig. (2-tailed)	0.766	0.337	0.921	.	0.065	0	0	0	0	0	0.874	0.251	0.628	0.369	0.566	0.829	0.335	0.012	0.532
	N	43	43	43	43	43	43	43	43	43	43	42	42	43	43	43	42	32	31	28
Cadmium (mg/kg)	Pearson Correlation	0.073	.583(**)	-.349(*)	0.284	1	.607(**)	.552(**)	.683(**)	.664(**)	.528(**)	-0.14	0.141	-0.059	0.027	.481(**)	-0.187	0.073	0.156	-0.109
	Sig. (2-tailed)	0.643	0	0.022	0.065	.	0	0	0	0	0	0.375	0.374	0.706	0.861	0.001	0.236	0.691	0.403	0.581
	N	43	43	43	43	43	43	43	43	43	43	42	42	43	43	43	42	32	31	28
Chromium (mg/kg)	Pearson Correlation	0.127	.517(**)	-0.211	.636(**)	.607(**)	1	.770(**)	.745(**)	.690(**)	.853(**)	-.415(**)	-0.183	-.371(*)	-0.199	.529(**)	-.401(**)	-0.209	0.109	0.322
	Sig. (2-tailed)	0.417	0	0.174	0	0	.	0	0	0	0	0.006	0.246	0.014	0.201	0	0.009	0.25	0.558	0.095
	N	43	43	43	43	43	43	43	43	43	43	42	42	43	43	43	42	32	31	28
Copper (mg/kg)	Pearson Correlation	0.273	.547(**)	-0.105	.572(**)	.552(**)	.770(**)	1	.776(**)	.575(**)	.840(**)	-0.227	-0.002	-0.105	0.044	0.271	-0.214	-0.156	0.035	.422(*)
	Sig. (2-tailed)	0.076	0	0.502	0	0	0	.	0	0	0	0.149	0.988	0.503	0.777	0.079	0.174	0.394	0.852	0.025
	N	43	43	43	43	43	43	43	43	43	43	42	42	43	43	43	42	32	31	28
Lead (mg/kg)	Pearson Correlation	0.219	.487(**)	-0.181	.717(**)	.683(**)	.745(**)	.776(**)	1	.701(**)	.896(**)	-0.169	0.076	-0.029	0.027	.381(*)	-0.188	0.094	-0.165	0.181
	Sig. (2-tailed)	0.158	0.001	0.247	0	0	0	0	.	0	0	0.286	0.633	0.856	0.862	0.012	0.233	0.609	0.376	0.356
	N	43	43	43	43	43	43	43	43	43	43	42	42	43	43	43	42	32	31	28
Mercury (mg/kg)	Pearson Correlation	-0.027	.381(*)	-0.162	.673(**)	.664(**)	.690(**)	.575(**)	.701(**)	1	.717(**)	-0.05	0.279	0.1	0.155	.429(**)	0.046	0.347	-.391(*)	-0.002
	Sig. (2-tailed)	0.862	0.012	0.298	0	0	0	0	0	.	0	0.754	0.073	0.524	0.321	0.004	0.773	0.052	0.03	0.993
	N	43	43	43	43	43	43	43	43	43	43	42	42	43	43	43	42	32	31	28
Zinc (mg/kg)	Pearson Correlation	0.151	.415(**)	-0.119	.877(**)	.528(**)	.853(**)	.840(**)	.896(**)	.717(**)	1	-0.217	0.047	-0.086	0.041	0.271	-0.166	0.02	-0.215	0.251
	Sig. (2-tailed)	0.335	0.006	0.448	0	0	0	0	0	0	.	0.168	0.768	0.582	0.793	0.079	0.292	0.914	0.246	0.198
	N	43	43	43	43	43	43	43	43	43	43	42	42	43	43	43	42	32	31	28
TPAH (mg/kg)	Pearson Correlation	-0.185	-0.232	.449(**)	-0.025	-0.14	-.415(**)	-0.227	-0.169	-0.05	-0.217	1	.673(**)	.679(**)	.560(**)	-.300(*)	.711(**)	.685(**)	-.582(**)	-0.335
	Sig. (2-tailed)	0.229	0.13	0.002	0.874	0.375	0.006	0.149	0.286	0.754	0.168	.	0	0	0	0.048	0	0	0	0.071
	N	44	44	44	42	42	42	42	42	42	42	44	44	44	44	44	44	34	33	30
Log(TPAH)	Pearson Correlation	-.306(*)	-0.134	0.12	0.181	0.141	-0.183	-0.002	0.076	0.279	0.047	.673(**)	1	.724(**)	.837(**)	-.423(**)	.604(**)	.743(**)	-.538(**)	-.559(**)
	Sig. (2-tailed)	0.044	0.387	0.438	0.251	0.374	0.246	0.988	0.633	0.073	0.768	0	.	0	0	0.004	0	0	0.001	0.001
	N	44	44	44	42	42	42	42	42	42	42	44	44	44	44	44	44	34	33	30
Dibenzofuran (mg/kg)	Pearson Correlation	-0.029	-0.189	.507(**)	0.076	-0.059	-.371(*)	-0.105	-0.029	0.1	-0.086	.679(**)	.724(**)	1	.786(**)	-.435(**)	.805(**)	.671(**)	-.518(**)	-.450(*)
	Sig. (2-tailed)	0.851	0.214	0	0.628	0.706	0.014	0.503	0.856	0.524	0.582	0	0	.	0	0.003	0	0	0.002	0.013
	N	45	45	45	43	43	43	43	43	43	43	44	44	45	45	45	44	34	33	30
Log(Dibenzofuran)	Pearson Correlation	-0.005	-0.109	0.243	0.141	0.027	-0.199	0.044	0.027	0.155	0.041	.560(**)	.837(**)	.786(**)	1	-.604(**)	.666(**)	.749(**)	-.494(**)	-.473(**)
	Sig. (2-tailed)	0.976	0.477	0.108	0.369	0.861	0.201	0.777	0.862	0.321	0.793	0	0	0	.	0	0	0	0.003	0.008
	N	45	45	45	43	43	43	43	43	43	43	44	44	45	45	45	44	34	33	30
Fines (%)	Pearson Correlation	0.214	.541(**)	-0.15	0.09	.481(**)	.529(**)	0.271	.381(*)	.429(**)	0.271	-.300(*)	-.423(**)	-.435(**)	-.604(**)	1	-.445(**)	-0.206	0.246	0.328
	Sig. (2-tailed)	0.157	0	0.325	0.566	0.001	0	0.079	0.012	0.004	0.079	0.048	0.004	0.003	0	.	0.002	0.243	0.167	0.077
	N	45	45	45	43	43	43	43	43	43	43	44	44	45	45	45	44	34	33	30
H. azteca	Pearson Correlation	-0.155	-.366(*)	.581(**)	0.034	-0.187	-.401(**)	-0.214	-0.188	0.046	-0.166	.711(**)	.604(**)	.805(**)	.666(**)	-.445(**)	1	.786(**)	-.478(**)	-.372(*)
10-day Mortality (%)	Sig. (2-tailed)	0.315	0.015	0	0.829	0.236	0.009	0.174	0.233	0.773	0.292	0	0	0	0	0.002	.	0	0.005	0.043
	N	44	44	44	42	42	42	42	42	42	42	44	44	44	44	44	44	34	33	30
C. tentans	Pearson Correlation	-0.213	-0.258	0.24	0.176	0.073	-0.209	-0.156	0.094	0.347	0.02	.685(**)	.743(**)	.671(**)	.749(**)	-0.206	.786(**)	1	-.622(**)	-.661(**)
20-day Mortality (%)	Sig. (2-tailed)	0.226	0.14	0.172	0.335	0.691	0.25	0.394	0.609	0.052	0.914	0	0	0	0	0.243	0	.	0	0.001
	N	34	34	34	32	32	32	32	32	32	32	34	34	34	34	34	34	34	33	20
C. tentans	Pearson Correlation	0.313	0.239	-0.139	-.445(*)	0.156	0.109	0.035	-0.165	-.391(*)	-0.215	-.582(**)	-.538(**)	-.518(**)	-.494(**)	0.246	-.478(**)	-.622(**)	1	0.332
20-day Growth (mg afdw)	Sig. (2-tailed)	0.076	0.181	0.442	0.012	0.403	0.558	0.852	0.376	0.03	0.246	0	0.001	0.002	0.003	0.167	0.005	0	.	0.165
	N	33	33	33	31	31	31	31	31	31	31	33	33	33	33	33	33	33	33	19
Microtox (ave chng)	Pearson Correlation	.417(*)	-0.008	0.088	0.123	-0.109	0.322	.422(*)	0.181	-0.002	0.251	-0.335	-.559(**)	-.450(*)	-.473(**)	0.328	-.372(*)	-.661(**)	0.332	1
	Sig. (2-tailed)	0.022	0.965	0.646	0.532	0.581	0.095	0.025	0.356	0.993	0.198	0.071	0.001	0.013	0.008	0.077	0.043	0.001	0.165	.
	N	30	30	30	28	28	28	28	28	28	28	30	30	30	30	30	30	20	19	30

NOTES
* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
Log = Log10
TOC = Total Organic Carbon
TPAH = Total Polycyclic Aromatic Hydrocarbons
mg afdw = milligrams ash-free dry weight

Table F-2 Pearson's Bivariate Correlations: GWSA Phase 3 Only, Bioassay and Synoptic Parameters (Pairwise Exclusion)

		Sulfide (mg/kg)	Ammonia (mg-N/kg)	Log(TOC)	Log(Cyanide)	Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Iron (mg/kg)	Log(Lead)	Mercury (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)	TBT (mg/kg)	TPAH (mg/kg)	Log(TPAH)	TPAH-oc (mg/kg-oc)	Carbazole (mg/kg)	Dibenzofuran (mg/kg)	Log (Dibenzofuran)	Log(PCBs)	Total Solids (%)	Fines (%)	*H. azteca* 10-day Mortality (%)	*C. tentans* 20-day Mortality (%)	*C. tentans* 20-day Growth (mg afdw)	Microtox (ave chng)
Sulfide (mg/kg)	Pearson Correlation	1	0.122	0.156	-0.227	-0.286	-0.18	-0.031	0.082	0.105	-0.053	-0.161	0.202	-0.167	-0.138	-0.237	-.520(*)	-0.372	-0.267	-0.144	-0.298	-0.177	-.464(*)	0.388	-0.23	-0.285	.527(*)	0.32
	Sig. (2-tailed)	.	0.61	0.51	0.337	0.249	0.475	0.903	0.746	0.679	0.835	0.522	0.422	0.508	0.586	0.313	0.019	0.107	0.256	0.545	0.202	0.482	0.039	0.091	0.329	0.224	0.02	0.169
	N	20	20	20	20	18	18	18	18	18	18	18	18	18	18	20	20	20	20	20	20	18	20	20	20	20	19	20
Ammonia (mg-N/kg)	Pearson Correlation	0.122	1	-0.121	0.11	0.095	0.134	0.213	0.16	0.251	0.142	0.019	0.136	0.185	0.052	-0.3	-0.366	-0.349	-0.293	-0.286	-0.322	-0.065	-0.364	0.324	-0.302	-0.398	-0.001	0.322
	Sig. (2-tailed)	0.61	.	0.611	0.644	0.708	0.595	0.397	0.526	0.314	0.575	0.94	0.591	0.463	0.838	0.199	0.112	0.132	0.21	0.222	0.166	0.797	0.115	0.164	0.196	0.083	0.996	0.166
	N	20	20	20	20	18	18	18	18	18	18	18	18	18	18	20	20	20	20	20	20	18	20	20	20	20	19	20
Log(TOC)	Pearson Correlation	0.156	-0.121	1	0.195	-0.284	-0.096	-.480(*)	-0.44	-.484(*)	-0.344	-0.139	-0.083	-0.426	-.483(*)	.515(*)	0.304	0.254	0.249	.547(*)	0.335	0.014	-0.131	-0.067	.541(*)	0.307	0.065	-0.002
	Sig. (2-tailed)	0.51	0.611	.	0.411	0.254	0.704	0.044	0.068	0.042	0.162	0.583	0.743	0.078	0.042	0.02	0.193	0.281	0.29	0.013	0.148	0.955	0.583	0.779	0.014	0.188	0.792	0.995
	N	20	20	20	20	18	18	18	18	18	18	18	18	18	18	20	20	20	20	20	20	18	20	20	20	20	19	20
Log(Cyanide)	Pearson Correlation	-0.227	0.11	0.195	1	-0.213	-.516(*)	-.684(**)	-.688(**)	-.675(**)	-.686(**)	-0.363	-.654(**)	-0.459	-.534(*)	0.43	0.415	.572(**)	.660(**)	.520(*)	.518(*)	-0.098	.573(**)	-.801(**)	0.341	0.264	-0.311	-.551(*)
	Sig. (2-tailed)	0.337	0.644	0.411	.	0.397	0.028	0.002	0.002	0.002	0.002	0.138	0.003	0.056	0.022	0.058	0.069	0.008	0.002	0.019	0.019	0.7	0.008	0	0.141	0.26	0.195	0.012
	N	20	20	20	20	18	18	18	18	18	18	18	18	18	18	20	20	20	20	20	20	18	20	20	20	20	19	20
Arsenic (mg/kg)	Pearson Correlation	-0.286	0.095	-0.284	-0.213	1	.516(*)	.703(**)	.619(**)	.651(**)	.728(**)	.771(**)	.615(**)	.924(**)	.762(**)	-0.073	0.201	-0.002	-0.008	-0.021	0.088	.714(**)	0.082	0.178	-0.038	0.157	-.510(*)	0.117
	Sig. (2-tailed)	0.249	0.708	0.254	0.397	.	0.028	0.001	0.006	0.003	0.001	0	0.007	0	0	0.773	0.424	0.995	0.975	0.933	0.728	0.001	0.747	0.48	0.88	0.535	0.036	0.644
	N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	17	18
Cadmium (mg/kg)	Pearson Correlation	-0.18	0.134	-0.096	-.516(*)	.516(*)	1	.548(*)	.558(*)	.585(*)	.719(**)	.833(**)	0.419	.598(**)	.495(*)	-0.088	0.197	-0.131	-0.169	0.027	0.098	0.227	-0.116	.524(*)	0.082	0.261	-0.377	0.155
	Sig. (2-tailed)	0.475	0.595	0.704	0.028	0.028	.	0.019	0.016	0.011	0.001	0	0.084	0.009	0.037	0.728	0.433	0.603	0.503	0.914	0.7	0.364	0.647	0.026	0.745	0.295	0.135	0.539
	N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	17	18
Chromium (mg/kg)	Pearson Correlation	-0.031	0.213	-.480(*)	-.684(**)	.703(**)	.548(*)	1	.861(**)	.940(**)	.933(**)	.625(**)	.831(**)	.903(**)	.827(**)	-.556(*)	-0.349	-.624(**)	-.667(**)	-.577(*)	-.531(*)	0.369	-.585(*)	.694(**)	-.519(*)	-0.36	0.026	.592(**)
	Sig. (2-tailed)	0.903	0.397	0.044	0.002	0.001	0.019	.	0	0	0	0.006	0	0	0	0.017	0.155	0.006	0.002	0.012	0.023	0.132	0.011	0.001	0.027	0.142	0.922	0.01
	N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	17	18
Copper (mg/kg)	Pearson Correlation	0.082	0.16	-0.44	-.688(**)	.619(**)	.558(*)	.861(**)	1	.872(**)	.913(**)	.694(**)	.763(**)	.822(**)	.896(**)	-0.45	-0.191	-.493(*)	-.494(*)	-0.388	-0.379	0.416	-.474(*)	.631(**)	-0.401	-0.284	-0.073	.498(*)
	Sig. (2-tailed)	0.746	0.526	0.068	0.002	0.006	0.016	0	.	0	0	0.001	0	0	0	0.061	0.448	0.038	0.037	0.111	0.121	0.086	0.047	0.005	0.099	0.253	0.779	0.035
	N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	17	18
Iron (mg/kg)	Pearson Correlation	0.105	0.251	-.484(*)	-.675(**)	.651(**)	.585(*)	.940(**)	.872(**)	1	.899(**)	.665(**)	.816(**)	.867(**)	.770(**)	-.596(**)	-0.389	-.640(**)	-.596(**)	-.479(*)	-0.453	0.247	-.550(*)	.672(**)	-.473(*)	-0.326	-0.085	.597(**)
	Sig. (2-tailed)	0.679	0.314	0.042	0.002	0.003	0.011	0	0	.	0	0.003	0	0	0	0.009	0.11	0.004	0.009	0.044	0.059	0.323	0.018	0.002	0.047	0.187	0.746	0.009
	N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	17	18
Log(Lead)	Pearson Correlation	-0.053	0.142	-0.344	-.686(**)	.728(**)	.719(**)	.933(**)	.913(**)	.899(**)	1	.771(**)	.822(**)	.895(**)	.878(**)	-0.45	-0.147	-.512(*)	-.514(*)	-0.355	-0.323	.476(*)	-.469(*)	.666(**)	-0.338	-0.19	-0.113	.476(*)
	Sig. (2-tailed)	0.835	0.575	0.162	0.002	0.001	0.001	0	0	0	.	0	0	0	0	0.061	0.562	0.03	0.029	0.148	0.19	0.046	0.05	0.003	0.17	0.451	0.665	0.046
	N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	17	18
Mercury (mg/kg)	Pearson Correlation	-0.161	0.019	-0.139	-0.363	.771(**)	.833(**)	.625(**)	.694(**)	.665(**)	.771(**)	1	.493(*)	.785(**)	.648(**)	-0.041	0.331	-0.024	-0.013	0.131	0.235	.504(*)	0.044	0.331	0.122	0.316	-.571(*)	0.1
	Sig. (2-tailed)	0.522	0.94	0.583	0.138	0	0	0.006	0.001	0.003	0	.	0.038	0	0.004	0.871	0.179	0.925	0.96	0.606	0.348	0.033	0.862	0.18	0.631	0.201	0.017	0.694
	N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	17	18
Silver (mg/kg)	Pearson Correlation	0.202	0.136	-0.083	-.654(**)	.615(**)	0.419	.831(**)	.763(**)	.816(**)	.822(**)	.493(*)	1	.769(**)	.737(**)	-0.437	-0.307	-.567(*)	-.532(*)	-0.308	-0.369	0.418	-.587(*)	.598(**)	-0.276	-0.267	0.118	.494(*)
	Sig. (2-tailed)	0.422	0.591	0.743	0.003	0.007	0.084	0	0	0	0	0.038	.	0	0	0.07	0.215	0.014	0.023	0.213	0.131	0.084	0.01	0.009	0.267	0.284	0.652	0.037
	N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	17	18
Zinc (mg/kg)	Pearson Correlation	-0.167	0.185	-0.426	-0.459	.924(**)	.598(**)	.903(**)	.822(**)	.867(**)	.895(**)	.785(**)	.769(**)	1	.882(**)	-0.311	-0.022	-0.297	-0.311	-0.265	-0.185	.580(*)	-0.217	0.429	-0.25	-0.063	-0.321	0.322
	Sig. (2-tailed)	0.508	0.463	0.078	0.056	0	0.009	0	0	0	0	0	0	.	0	0.209	0.931	0.231	0.21	0.287	0.461	0.012	0.387	0.076	0.316	0.804	0.209	0.192
	N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	17	18
TBT (mg/kg)	Pearson Correlation	-0.138	0.052	-.483(*)	-.534(*)	.762(**)	.495(*)	.827(**)	.896(**)	.770(**)	.878(**)	.648(**)	.737(**)	.882(**)	1	-0.302	-0.026	-0.281	-0.294	-0.276	-0.266	.536(*)	-0.235	0.407	-0.305	-0.171	-0.139	0.298
	Sig. (2-tailed)	0.586	0.838	0.042	0.022	0	0.037	0	0	0	0	0.004	0	0	.	0.224	0.918	0.258	0.237	0.267	0.286	0.022	0.347	0.093	0.219	0.496	0.595	0.23
	N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	17	18
TPAH (mg/kg)	Pearson Correlation	-0.237	-0.3	.515(*)	0.43	-0.073	-0.088	-.556(*)	-0.45	-.596(**)	-0.45	-0.041	-0.437	-0.311	-0.302	1	.723(**)	.896(**)	.625(**)	.659(**)	.654(**)	0.015	.497(*)	-0.435	.745(**)	.782(**)	-.632(**)	-.447(*)
	Sig. (2-tailed)	0.313	0.199	0.02	0.058	0.773	0.728	0.017	0.061	0.009	0.061	0.871	0.07	0.209	0.224	.	0	0	0.003	0.002	0.002	0.951	0.026	0.055	0	0	0.004	0.048
	N	20	20	20	20	18	18	18	18	18	18	18	18	18	18	20	20	20	20	20	20	18	20	20	20	20	19	20
Log(TPAH)	Pearson Correlation	-.520(*)	-0.366	0.304	0.415	0.201	0.197	-0.349	-0.191	-0.389	-0.147	0.331	-0.307	-0.022	-0.026	.723(**)	1	.810(**)	.742(**)	.788(**)	.869(**)	0.373	.734(**)	-.597(**)	.790(**)	.834(**)	-.706(**)	-.699(**)
	Sig. (2-tailed)	0.019	0.112	0.193	0.069	0.424	0.433	0.155	0.448	0.11	0.562	0.179	0.215	0.931	0.918	0	.	0	0	0	0	0.127	0	0.005	0	0	0.001	0.001
	N	20	20	20	20	18	18	18	18	18	18	18	18	18	18	20	20	20	20	20	20	18	20	20	20	20	19	20
TPAH-oc (mg/kg-oc)	Pearson Correlation	-0.372	-0.349	0.254	.572(**)	-0.002	-0.131	-.624(**)	-.493(*)	-.640(**)	-.512(*)	-0.024	-.567(*)	-0.297	-0.281	.896(**)	.810(**)	1	.850(**)	.720(**)	.776(**)	0.107	.770(**)	-.680(**)	.691(**)	.787(**)	-.713(**)	-.630(**)
	Sig. (2-tailed)	0.107	0.132	0.281	0.008	0.995	0.603	0.006	0.038	0.004	0.03	0.925	0.014	0.231	0.258	0	0	.	0	0	0	0.672	0	0.001	0.001	0	0.001	0.003
	N	20	20	20	20	18	18	18	18	18	18	18	18	18	18	20	20	20	20	20	20	18	20	20	20	20	19	20
Carbazole (mg/kg)	Pearson Correlation	-0.267	-0.293	0.249	.660(**)	-0.008	-0.169	-.667(**)	-.494(*)	-.596(**)	-.514(*)	-0.013	-.532(*)	-0.311	-0.294	.625(**)	.742(**)	.850(**)	1	.865(**)	.828(**)	0.161	.755(**)	-.796(**)	.637(**)	.614(**)	-.667(**)	-.654(**)
	Sig. (2-tailed)	0.256	0.21	0.29	0.002	0.975	0.503	0.002	0.037	0.009	0.029	0.96	0.023	0.21	0.237	0.003	0	0	.	0	0	0.523	0	0	0.003	0.004	0.002	0.002
	N	20	20	20	20	18	18	18	18	18	18	18	18	18	18	20	20	20	20	20	20	18	20	20	20	20	19	20
Dibenzofuran (mg/kg)	Pearson Correlation	-0.144	-0.286	.547(*)	.520(*)	-0.021	0.027	-.577(*)	-0.388	-.479(*)	-0.355	0.131	-0.308	-0.265	-0.276	.659(**)	.788(**)	.720(**)	.865(**)	1	.918(**)	0.135	.616(**)	-.639(**)	.866(**)	.737(**)	-.571(*)	-.657(**)
	Sig. (2-tailed)	0.545	0.222	0.013	0.019	0.933	0.914	0.012	0.111	0.044	0.148	0.606	0.213	0.287	0.267	0.002	0	0	0	.	0	0.593	0.004	0.002	0	0	0.011	0.002
	N	20	20	20	20	18	18	18	18	18	18	18	18	18	18	20	20	20	20	20	20	18	20	20	20	20	19	20
Log(Dibenzofuran)	Pearson Correlation	-0.298	-0.322	0.335	.518(*)	0.088	0.098	-.531(*)	-0.379	-0.453	-0.323	0.235	-0.369	-0.185	-0.266	.654(**)	.869(**)	.776(**)	.828(**)	.918(**)	1	0.194	.823(**)	-.697(**)	.892(**)	.874(**)	-.680(**)	-.801(**)
	Sig. (2-tailed)	0.202	0.166	0.148	0.019	0.728	0.7	0.023	0.121	0.059	0.19	0.348	0.131	0.461	0.286	0.002	0	0	0	0	.	0.441	0	0.001	0	0	0.001	0
	N	20	20	20	20	18	18	18	18	18	18	18	18	18	18	20	20	20	20	20	20	18	20	20	20	20	19	20
Log(PCBs)	Pearson Correlation	-0.177	-0.065	0.014	-0.098	.714(**)	0.227	0.369	0.416	0.247	.476(*)	.504(*)	0.418	.580(*)	.536(*)	0.015	0.373	0.107	0.161	0.135	0.194	1	0.121	0.001	0.036	0.16	-0.337	-0.026
	Sig. (2-tailed)	0.482	0.797	0.955	0.7	0.001	0.364	0.132	0.086	0.323	0.046	0.033	0.084	0.012	0.022	0.951	0.127	0.672	0.523	0.593	0.441	.	0.633	0.996	0.886	0.527	0.186	0.919
	N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	17	18
Total Solids (%)	Pearson Correlation	-.464(*)	-0.364	-0.131	.573(**)	0.082	-0.116	-.585(*)	-.474(*)	-.550(*)	-.469(*)	0.044	-.587(*)	-0.217	-0.235	.497(*)	.734(**)	.770(**)	.755(**)	.616(**)	.823(**)	0.121	1	-.836(**)	.605(**)	.715(**)	-.579(**)	-.878(**)
	Sig. (2-tailed)	0.039	0.115	0.583	0.008	0.747	0.647	0.011	0.047	0.018	0.05	0.862	0.01	0.387	0.347	0.026	0	0	0	0.004	0	0.633	.	0	0.005	0	0.009	0
	N	20	20	20	20	18	18	18	18	18	18	18	18	18	18	20	20	20	20	20	20	18	20	20	20	20	19	20
Fines (%)	Pearson Correlation	0.388	0.324	-0.067	-.801(**)	0.178	.524(*)	.694(**)	.631(**)	.672(**)	.666(**)	0.331	.598(**)	0.429	0.407	-0.435	-.597(**)	-.680(**)	-.796(**)	-.639(**)	-.697(**)	0.001	-.836(**)	1	-.522(*)	-.445(*)	0.406	.800(**)
	Sig. (2-tailed)	0.091	0.164	0.779	0	0.48	0.026	0.001	0.005	0.002	0.003	0.18	0.009	0.076	0.093	0.055	0.005	0.001	0	0.002	0.001	0.996	0	.	0.018	0.05	0.084	0
	N	20	20	20	20	18	18	18	18	18	18	18	18	18	18	20	20	20	20	20	20	18	20	20	20	20	19	20
H. azteca	Pearson Correlation	-0.23	-0.302	.541(*)	0.341	-0.038	0.082	-.519(*)	-0.401	-.473(*)	-0.338	0.122	-0.276	-0.25	-0.305	.745(**)	.790(**)	.691(**)	.637(**)	.866(**)	.892(**)	0.036	.605(**)	-.522(*)	1	.869(**)	-0.446	-.705(**)
10-day Mortality (%)	Sig. (2-tailed)	0.329	0.196	0.014	0.141	0.88	0.745	0.027	0.099	0.047	0.17	0.631	0.267	0.316	0.219	0	0	0.001	0.003	0	0	0.886	0.005	0.018	.	0	0.056	0.001
	N	20	20	20	20	18	18	18	18	18	18	18	18	18	18	20	20	20	20	20	20	18	20	20	20	20	19	20
C. tentans	Pearson Correlation	-0.285	-0.398	0.307	0.264	0.157	0.261	-0.36	-0.284	-0.326	-0.19	0.316	-0.267	-0.063	-0.171	.782(**)	.834(**)	.787(**)	.614(**)	.737(**)	.874(**)	0.16	.715(**)	-.445(*)	.869(**)	1	-.569(*)	-.661(**)
20-day Mortality (%)	Sig. (2-tailed)	0.224	0.083	0.188	0.26	0.535	0.295	0.142	0.253	0.187	0.451	0.201	0.284	0.804	0.496	0	0	0	0.004	0	0	0.527	0	0.05	0	.	0.011	0.001
	N	20	20	20	20	18	18	18	18	18	18	18	18	18	18	20	20	20	20	20	20	18	20	20	20	20	19	20
C. tentans	Pearson Correlation	.527(*)	-0.001	0.065	-0.311	-.510(*)	-0.377	0.026	-0.073	-0.085	-0.113	-.571(*)	0.118	-0.321	-0.139	-.632(**)	-.706(**)	-.713(**)	-.667(**)	-.571(*)	-.680(**)	-0.337	-.579(**)	0.406	-0.446	-.569(*)	1	0.332
20-day Growth (mg afdw)	Sig. (2-tailed)	0.02	0.996	0.792	0.195	0.036	0.135	0.922	0.779	0.746	0.665	0.017	0.652	0.209	0.595	0.004	0.001	0.001	0.002	0.011	0.001	0.186	0.009	0.084	0.056	0.011	.	0.165
	N	19	19	19	19	17	17	17	17	17	17	17	17	17	17	19	19	19	19	19	19	17	19	19	19	19	19	19
Microtox (ave chng)	Pearson Correlation	0.32	0.322	-0.002	-.551(*)	0.117	0.155	.592(**)	.498(*)	.597(**)	.476(*)	0.1	.494(*)	0.322	0.298	-.447(*)	-.699(**)	-.630(**)	-.654(**)	-.657(**)	-.801(**)	-0.026	-.878(**)	.800(**)	-.705(**)	-.661(**)	0.332	1
	Sig. (2-tailed)	0.169	0.166	0.995	0.012	0.644	0.539	0.01	0.035	0.009	0.046	0.694	0.037	0.192	0.23	0.048	0.001	0.003	0.002	0.002	0	0.919	0	0	0.001	0.001	0.165	.
	N	20	20	20	20	18	18	18	18	18	18	18	18	18	18	20	20	20	20	20	20	18	20	20	20	20	19	20

NOTES
* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
Log = Log10
TOC = Total Organic Carbon
TBT = Tributyl tin
TPAH = Total Polycyclic Aromatic Hydrocarbons
TPAH-oc = Carbon-normalized TPAH
PCBs = Polychlorinated biphenyls
mg afdw = milligrams ash-free dry weight

Table F-3 Exploratory Regression Summary: GWSA Phase 3 Only, All Parameters

Parameters included:

Conventionals: sulfide, ammonia, Log(TOC), Log(cyanide)
Organics: TPAH, carbon-normalized TPAH (TPAH-oc), carbazole, dibenzofuran, and Log(PCBs)
Metals: arsenic, cadmium, chromium, copper, iron, Log(lead), mercury, silver, zinc, tributyl tin (TBT)
Physical: percent fines, total solids

Stepwise Regression	*H. azteca* 10-day Survival	*C. tentans* 20-day Survival	*C. tentans* 20-day Growth	Microtox® Luminescence
Model	dibenzofuran (84%) TPAH (8%) carbazole (6%) total solids (0.4%)	TPAH (74%) mercury (13%) copper (5%)	TPAH-oc (53%) mercury (24%)	dibenzofuran (65%) fines (10%)
Total Variance Explained	98.4%	92%	77%	75%
Strength of Relationship	0.992	0.960	0.875	0.868

NOTES

Only the final model produced by the stepwise regression analysis is summarized.
Listwise exclusion was used for all regression analyses.
Additional variance explained (R-squared) given in ( ) after each model parameter.
Strength of relationship = regression coefficient (R); the closer the value is to 1, the stronger the relationship.

Table F-4 GWSA Cluster Dataset

STATION	SULFIDE	AMMONIA	ARSENIC	CHROMIUM	COPPER	MERCURY	ZINC	TPAH	DIBENZOFURAN	H. azteca 10-d Survival (%)	Microtox (ave.	C. tentans 20-d Survival (%)	C. tentans 20-d Growth (mg afdw)
LU-1	800	94	38.6	50.7	251	0.85	413	528.8	0.52	99	0.44		
LU-2	130	79	24.1	48.8	182	0.578	326	1149.9	2.4	92	0.42		
LU-5	1400	85	28	51.2	310	0.656	412	14.971	0.016	98	1.13		
LU-6	2200	72	26.6	48.1	238	0.629	399	22.361	0.0155	100	1.10		
LU-7	380	100	23.4	44.2	198	0.588	349	34.196	0.0155	98	0.14		
LU-9	290	89	45.5	55.8	304	0.869	484	9.635	0.0145	99	0.81		
LU-10	700	100	32.9	48.4	246	0.781	383	23.286	0.0185	100	0.76		
LU-11	1500	83	36.7	47.4	233	0.76	399		0.036	98			
NLU04	3700	100	25	53	215	0.5	359	32.75	0.195	96		96	2.79
NLU05	4.1	3.8	3	20.1	15.8	0.14	56.7	195	0.45	87		84	1.74
NLU06	970	49	25	54	215	0.5	372	47.65	0.195	91		90	2.94
NLU07	120	52	25	56	266	0.6	438	198.39	0.195	94		88	2.78
NLU08	2300	120	25	52	243	0.5	377	45.92	0.195	95		94	2.68
NLU10	1700	110	25	54	298	0.6	388	30.1	0.195	96		92	2.84
NLU12	1500	120	25	61	456	0.8	460	48.4	0.195	92		90	3.40
NLU51-TX	150	28.2	30	26	70.7	0.4	153	4826	3.9	0	0.53	0	
NLU55-TX	270	41.7	70	24	95	0.5	245	1064.4	4.7	51	0.45	54	0.77
NLUD55-TX	250	37.8						301.2	1.1	74	0.34	48	1.82
NLU64-TX	370	22.9	20	57	324	0.6	445	218.8	0.07	89	0.80	86	2.34
NLU66-TX	2000	59.3	25	53	291	0.25	423	28.26	0.075	92	0.81	72	2.57
NLU69-TX	2400	150	30	49	246	0.25	377	9.202	0.08	87	0.84	96	2.30
NLU73-TX	220	60.7	70	51	273	0.5	399	77.52	0.16	89	0.78	92	1.94
NLU76-TX	240	69.3	20	52	314	0.2	412	21.57	0.065	82	0.81	94	1.71
NLU81-TX	3600	28.1	25	48	223	0.25	338	10.09	0.075	90	0.79	82	2.64
NLU83-TX	1600	64.9	25	52	313	0.25	389	12.12	0.075	94	0.93	84	2.33
NLU84-TX	3000	63.2	25	56	574	1.1	528	30.26	0.075	98	0.95	88	2.18
NLU85-TX	2300	25.5	25	56	290	0.7	378	4.71	0.075	95	0.95	82	2.36
NLU117-TX	1800	49	60	48	333	1.6	474	1095.6	5.6	0	0.55	34	1.62
NLUD117-TX	470	33.1						170.2	1	30	0.49	40	1.90
NLUEPA5-TX	160	54.4	25	50	204	0.2	348	15.68	0.07	88	0.99	88	2.17
NLUEPA19-TX	1500	67.8	25	50	253	0.25	366	24.018	0.075	97	1.02	82	2.14

Figure F-1 – Cluster Analysis

Cluster #1 - Phase 2 and 3 Combined Subset, Square Euclidean Measure, Between groups linkage, Z-score, Parameters: ammonia, sulfides, arsenic, copper, chromium mercury, zinc, TPAH (6-30-05, agf)

Case Processing Summary[a]

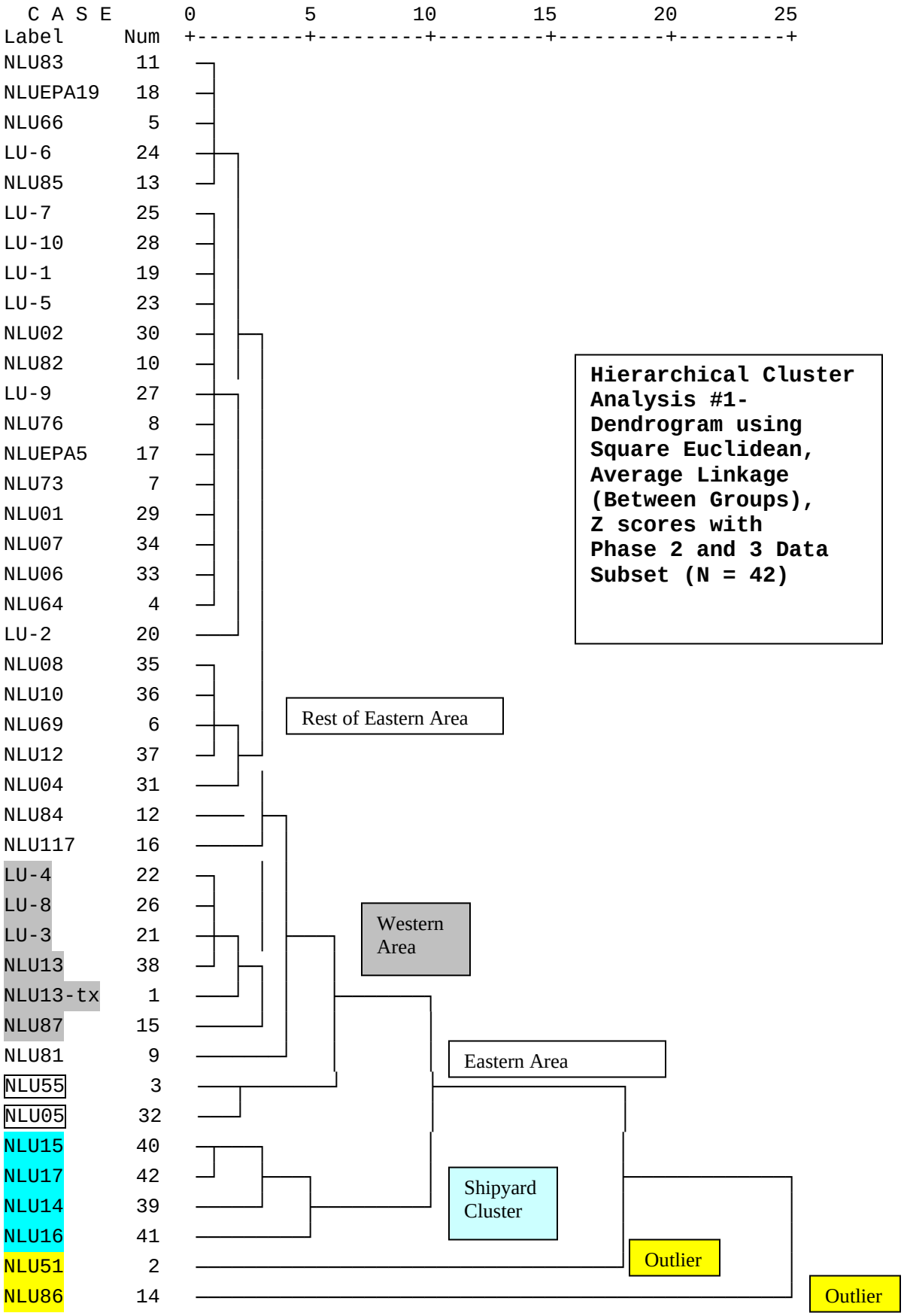
Cases					
Valid		Missing		Total	
N	Percent	N	Percent	N	Percent
42	93.3%	3	6.7%	45	100.0%

a. Squared Euclidean Distance used

Agglomeration Schedule

	Cluster Combined			Stage Cluster First Appears		
Stage	Cluster 1	Cluster 2	Coefficients	Cluster 1	Cluster 2	Next Stage
1	11	18	.137	0	0	2
2	5	11	.298	0	1	11
3	22	26	.353	0	0	9
4	25	28	.408	0	0	10
5	23	30	.454	0	0	14
6	35	36	.505	0	0	19
7	8	17	.559	0	0	15
8	29	34	.725	0	0	13
9	21	22	.783	0	3	20
10	19	25	.888	0	4	17
11	5	24	.908	2	0	21
12	10	27	.956	0	0	14
13	29	33	.957	8	0	16
14	10	23	1.053	12	5	17
15	7	8	1.107	0	7	18
16	4	29	1.164	0	13	18
17	10	19	1.303	14	10	22
18	4	7	1.486	16	15	22
19	6	35	1.506	0	6	23
20	21	38	1.790	9	0	28
21	5	13	2.104	11	0	26
22	4	10	2.494	18	17	25
23	6	37	2.690	19	0	27
24	40	42	3.044	0	0	32
25	4	20	3.262	22	0	26
26	4	5	3.450	25	21	30
27	6	31	3.936	23	0	30
28	1	21	4.805	0	20	33
29	3	32	4.867	0	0	38
30	4	6	6.098	26	27	34
31	12	16	6.256	0	0	34
32	39	40	6.952	0	24	37
33	1	15	7.757	28	0	35
34	4	12	8.466	30	31	35
35	1	4	8.847	33	34	36
36	1	9	11.358	35	0	38
37	39	41	12.296	32	0	39
38	1	3	16.967	36	29	39
39	1	39	27.509	38	37	40
40	1	2	53.071	39	0	41
41	1	14	74.408	40	0	0

Figure F-1. Dendogram Rescaled Distance Cluster Combined Bioassay Datasets



Appendix G

Secondary Screening – Stepwise Regression (SPSS)

Table G-1. Station Description for Secondary and GWSA Cluster Statistical Analyses

Area	Phases 2 & 3 Combined	GWSA Cluster Phase 3	GWSA Cluster Phases 2 & 3	Shipyard/Marina Cluster Phases 2 & 3
East of IAOI	NLU01			NLU01
	NLU02			NLU02
	NLU81	NLU81	NLU81	
	NLU82			NLU82
Eastern Study Area	LU-2		LU-2	
	LU-5		LU-5	
	LU-6		LU-6	
	LU-7		LU-7	
	LU-11		LU-11	
	NLU04		NLU04	
	NLU05		NLU05	
	NLU06		NLU06	
	NLU07		NLU07	
	NLU08		NLU08	
	NLU10		NLU10	
	NLU51	NLU51	NLU51	
	NLU55	NLU55	NLU55	
	NLUD55	NLUD55	NLUD55	
	NLU64	NLU64	NLU64	
	NLU66	NLU66	NLU66	
	NLU69	NLU69	NLU69	
	NLU73	NLU73	NLU73	
	NLU76	NLU76	NLU76	
	NLUEPA5	NLUEPA5	NLUEPA5	
	NLUEPA19	NLUEPA19	NLUEPA19	
Western Study Area	LU-1		LU-1	
	LU-3			LU-3
	LU-4			LU-4
	NLU12		NLU12	
	NLU14			NLU14
	NLU16			NLU16
	NLU17			NLU17
	NLU83	NLU83	NLU83	
	NLU84	NLU84	NLU84	
	NLU85	NLU85	NLU85	
	NLU86			NLU86
	NLU87			NLU87
	NLU117	NLU117	NLU117	
	NLUD117	NLUD117	NLUD117	
South/West of IAOI	LU-8			LU-8
	LU-9		LU-9	
	LU-10		LU-10	
	NLU13			NLU13
	NLU13-TX			NLU13-TX
	NLU15			NLU15
Total Stations:	**45**	**16**	**31**	**14**

Table G-2. Stepwise Regression Summary: Phases 2 & 3, Subset Parameters, All Stations

Parameters included:

Conventionals: sulfide, ammonia
Organics: TPAH
Metals: arsenic, chromium, copper, mercury, zinc
Physical: percent fines

Log Transforms	Regression Results	*H. azteca* 10-day Survival		*C. tentans* 20-day		Microtox® Luminescence
		with physical parameters	without physical parameters	Survival	Growth	
None	Model	TPAH (61%) % Fines (4%) Mercury (4%)	TPAH (61%)	TPAH (54%) Mercury (14%) Copper (7%)	TPAH (33%) Arsenic (15%) Chromium (10%)	Copper (18%) Mercury (12%)
	Total Variance Explained	69%	61%	75%	58%	30%
	Strength of Relationship	0.831	0.781	0.867	0.764	0.550
TPAH	Model	Log(TPAH) (38%) Chromium (8%)	—	Log(TPAH) (54%)	Log(TPAH) (27%)	Log(TPAH) (29%) Copper (11%)
	Total Variance Explained	46%	—	54%	27%	40%
	Strength of Relationship	0.678	—	0.738	0.521	0.629

NOTES

— = not applicable; test not analyzed
Only the final model produced by the stepwise regression analysis is summarized.
Listwise exclusion was used for all regression analyses.
Additional variance explained (R-squared) given in ( ) after each model parameter.
Strength of relationship = regression coefficient (R); the closer the value is to 1, the stronger the relationship.

Table G-3. Summary of Stepwise Regression Results for Clustered GWSA Dataset

Parameters included:

Conventionals: sulfide, ammonia
Organics: TPAH, dibenzofuran, carbazole (TPAH only for Run 3)
Metals: arsenic, chromium, copper, mercury, zinc

Cluster Data Set	Log Transforms	Regression Results	*H. azteca* 10-day Survival	*C. tentans* 20-day Survival	*C. tentans* 20-day Growth	Microtox® Luminescence
Run 1: GWSA Cluster (Phase 3)	None	Model	dibenzofuran (85%) TPAH (8%) carbazole (6%)	TPAH (84%) dibenzofuran (10%)	carbazole (76%) sulfide (9%)	dibenzofuran (77%)
		Total Variance Explained	99%	94%	85%	77%
		Strength of Relationship	0.992	0.969	0.921	0.876
	TPAH	Model	dibenzofuran (85%)	log(TPAH) (71%)	chromium (63%) log(TPAH) (13%)	dibenzofuran (77%)
		Total Variance Explained	85%	71%	76%	77%
		Strength of Relationship	0.921	0.840	0.870	0.876
Run 2: GWSA Cluster (Phase 2 and 3)	None	Model	dibenzofuran (79%) TPAH (6%)	TPAH (82%) dibenzofuran (11%) ammonia (1%)	chromium (50%) zinc (23%)	dibenzofuran (26%)
		Total Variance Explained	85%	94%	73%	26%
		Strength of Relationship	0.923	0.972	0.856	0.511
	TPAH, Dibenzofuran	Model	log(dibenzofuran) (52%)	log(dibenzofuran) (63%)	chromium (50%) zinc (23%)	log(TPAH) (41%)
		Total Variance Explained	52%	63%	73%	41%
		Strength of Relationship	0.722	0.794	0.856	0.642
Run 3: GWSA Cluster (Phase 2 and 3, TPAH only)	None	Model	TPAH (63%) arsenic (8%)	TPAH (82%) mercury (4%)	chromium (50%) zinc (23%)	chromium (24%)
		Total Variance Explained	71%	86%	73%	24%
		Strength of Relationship	0.841	0.929	0.856	0.490
	TPAH	TPAH	Log(TPAH) (46%)	Log(TPAH) (59%)	chromium (50%) zinc (23%)	Log(TPAH) (41%)
		Total Variance Explained	46%	59%	73%	41%
		Strength of Relationship	0.676	0.769	0.856	0.642

NOTES

Only the final model produced by the stepwise regression analysis is summarized.
Additional variance explained (R-squared) given in ( ) after each model parameter.
Strength of relationship = regression coefficient (R); the closer the value is to 1, the stronger the relationship.

Table G-4. Stepwise Regression Results with Ecology-Modified GWSA Data Subsets (TPAH as Organics Indicator) — Phases 2 & 3 Shipyard/Marina Station Cluster

Parameters included:

Conventionals: sulfide, ammonia
Organics: TPAH
Metals: arsenic, chromium, copper, mercury, zinc

Log Transforms	Shipyard/Marina Cluster Regression Results	*H. azteca* 10-day Survival	*C. tentans* 20-day Survival	*C. tentans* 20-day Growth	Microtox® Luminescence
Run 1: None	Model	NR	TPAH (37%) copper (37%)	mercury (55%)	copper (69%)
	Total Variance Explained	NA	74%	55%	69%
	Strength of Relationship	NA	0.857	0.743	0.833
Run 2: TPAH	Model	NR	Log(TPAH) (46%) copper (43%)	mercury (55%)	copper (69%)
	Total Variance Explained	NA	89%	55%	69%
	Strength of Relationship	NA	0.943	0.743	0.833

NOTES

NR = no model produced; NA = not applicable.
Only the final model produced by the stepwise regression analysis is summarized.
Additional variance explained (R-squared) given in ( ) after each model parameter.
Strength of relationship = regression coefficient (R); the closer the value is to 1, the stronger the relationship.

Appendix H

Concentration-Response Curves

Table H-1. Effect Level Concentrations Based on Concentration-Response Curves
GWSA Cluster Dataset

Bioassay Organism	Bioassay Endpoint	Effect Level	Effect Level Unit	GWSA Cluster Dataset (by SPSS) Approx. TPAH (mg/kg dw)	GWSA Cluster Dataset (by CETIS) TPAH (mg/kg dw)
H. azteca 10-day Mortality	Percent Mortality	LC25	25% mortality	380	365
		LC20	20% mortality	240	285
		LC15	15% mortality	160	213
	Percent Mortality Normalized to Control *	LC25	25% mortality	440	
		LC20	20% mortality	310	
		LC15	15% mortality	220	
C. tentans 20-day Mortality	Percent Mortality	LC25	25% mortality	190	338
		LC20	20% mortality	120	275
		LC15	15% mortality	75	217
	Percent Mortality Normalized to Control *	LC25	25% mortality	500	
		LC20	20% mortality	395	
		LC15	15% mortality	270	

Notes:

Concentration-Response Curves derived in SPSS version 10.0 scatterplots using cubic regression and log transformed TPAH concentrations. R-squared values ranged from 0.57 to 0.80 (a value of 1 is perfect curve fit).

LC20 values for GWSA Cluster derived by Nautilus bioassay testing lab as a QC check. Method used CETIS software version 1.1.1 scatterplots using linear regression, log transformed TPAH concentrations, probit transformation of bioassays, and 95% confidence intervals.

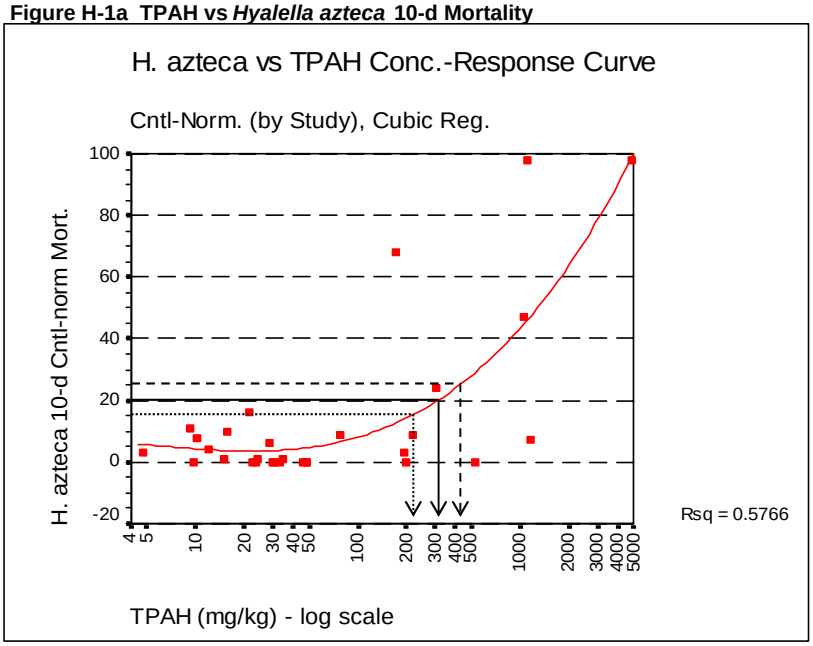
LC20 = lethal concentration where up to 20% of the population is expected to have biological mortality.

mg/kg dw = milligrams per kilogram dry weight

* Results normalized to control by substracting the avg percent mortality of control from the avg percent mortality of the test sample.

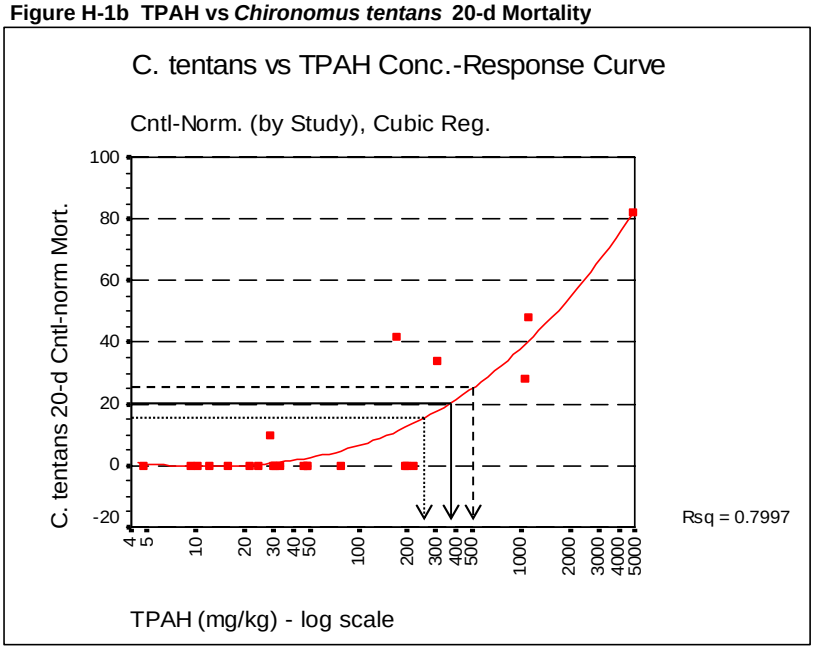
Figure H-1 GWSA Cluster Dataset TPAH Concentration-Bioassay Response Curves: Normalized to Control

Figure H-1a TPAH vs *Hyalella azteca* 10-d Mortality



Lethal Conc. (% mortality)	Approx. TPAH
LC25	440
LC20	310
LC15	220

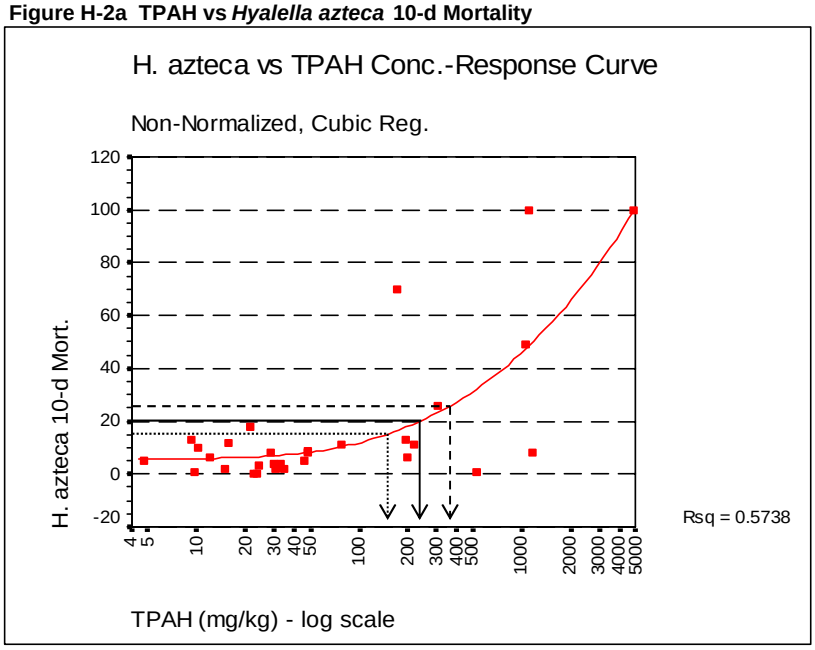
Figure H-1b TPAH vs *Chironomus tentans* 20-d Mortality



Lethal Conc. (% mortality)	Approx. TPAH
LC25	500
LC20	395
LC15	270

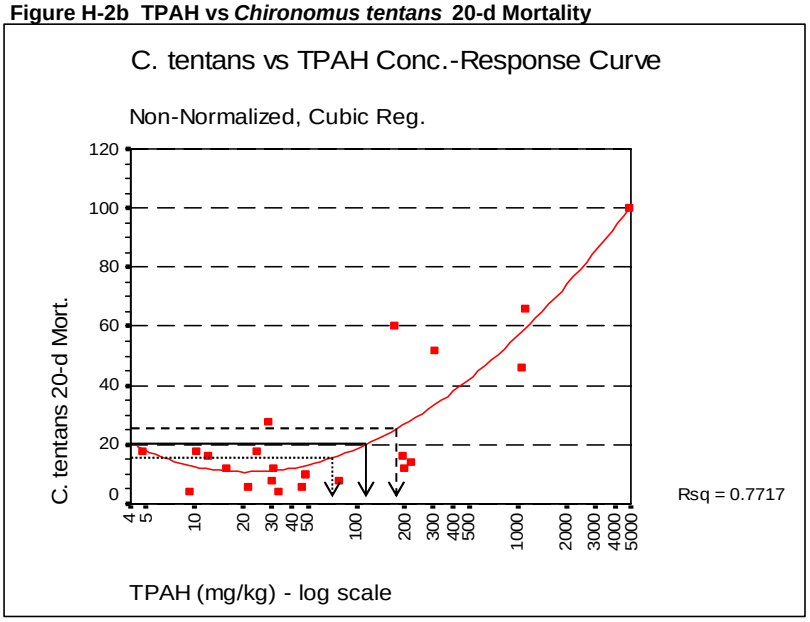
Figure H-2 GWSA Cluster Dataset TPAH Concentration-Bioassay Response Curves: Non-Normalized

Figure H-2a TPAH vs *Hyalella azteca* 10-d Mortality



Lethal Conc. (% mortality)	Approx. TPAH
LC25	380
LC20	240
LC15	160

Figure H-2b TPAH vs *Chironomus tentans* 20-d Mortality



Lethal Conc. (% mortality)	Approx. TPAH
LC25	190
LC20	120
LC15	75

Nautilus Environmental, LLC

August 10, 2005

Memo:	**Additional statistical evaluation of Gas Works Park toxicity and TPAH data**		
To	Anne Fitzpatrick	*From*	Karen Bergmann
Company	RETEC	*Tel*	253-922-4296
Phone	206-624-9349	*Fax*	253-922-5814
e-mail	Afitzpatrick@retec.com	*e-mail*	karen@nautilusenvironmental.com

As requested, we have evaluated the dataset of *Hyalella azteca* survival and *Chironomus tentans* survival and growth on the basis of TPAH data provided by you for pooled data for the Gas Works Park Project for samples collected in April 2002 (*Hyalella* only), November 2002, and April 2005. The statistical analyses were conducted using the CETIS software package.

The table below provides a summary of LC15, LC20 LC25 (and, in the case of *C. tentans* dry weight, IC15, IC20 and IC25) values and associated 95% confidence intervals for the tests.

End-point	Statistical method	Transformation	LC15/IC15	LC20/IC20	LC25/IC25
H. azteca survival	Linear regression (LC values)	Probit	213 (115 – 314)	285 (169 – 404)	365 (233 – 506)
C. tentans survival	Linear regression (LC values)	Probit	217 (102 – 338)	275 (143 – 414)	338 (189 – 497)
C. tentans growth	Linear interpolation (IC values)	None	>1096	>1096	>1096

It should be noted that the survival datasets for both *H. azteca* and *C. tentans* both failed to meet the assumptions of the Linear Regression analysis, as evaluated with a Chi-square test, indicating that this statistical tool may not be appropriate. The Linear Regression estimates have been presented regardless, because alternative methods such as Trimmed Spearman-Karber are not able to calculate LC15, LC20 and LC25 values. Caution should be used in interpreting the results of the regression analyses because of the failure to meet the assumptions.

Washington Laboratory
5009 Pacific Hwy. E., Suite 2
Tacoma, WA 98424
Tel 253-922-4296
Fax 253-922-5814

In order to further evaluate the appropriateness of the Linear Regression method, LC50 values have been presented in the following table calculated on the basis of both the Linear Regression and Trimmed Spearman-Karber methods for comparative purposes. Trimmed Spearman-Karber is a non-parametric test, and is more appropriate when the assumptions of the Linear Regression test are not met. The LC50 estimates associated with the Linear Regression and Trimmed Spearman-Karber methods were similar (± approximately 10%) for both tests. Thus, although the assumptions of the Linear Regression test were not met, the test did appear to provide a reasonable estimate of the 50% effect level and, therefore, the values presented for the LC15, LC20 and LC25 values presented above may also be reasonable estimates.

End-point	Statistical method	Transformation	LC50
H. azteca survival	Linear regression	Probit	994 (725 – 1466)
	Trimmed Spearman Karber	None	877 (780 – 987)
C. tentans survival	Linear regression	Probit	769 (525 – 1165)
	Trimmed Spearman Karber	None	707 (589 – 850)

Please feel free to contact me should you have any questions regarding these analyses.

Sincerely,

Karen Bergmann
Northwest Operations Manager

CETIS Test Summary

Report Date: 10 Aug-05 2:00 PM
Link: 01-9370-5039/TPAHHA3

Hyallela 10-d Survival and Growth Sediment Test — **Nautilus Environmental WA**

Test No:	08-9451-2089	**Test Type:**	Survival-Growth	**Duration:**	N/A
Start Date:	29 Jul-05 12:04 PM	**Protocol:**	EPA/600/R-99/064 (2000)	**Species:**	Hyalella azteca
Ending Date:		**Dil Water:**	Mod-Hard Synthetic Water	**Source:**	Aquatic Biosystems, CO
Setup Date:	29 Jul-05	**Brine:**			

Sample No:	01-4238-4191	**Material:**	sediment	**Client:**	The Retec Group
Sample Date:	29 Jul-05 12:04 PM	**Code:**	142384191	**Project:**	
Receive Date:		**Source:**	Gas Works Park		
Sample Age:	1m	**Station:**			

Point Estimate Summary

Analysis	Endpoint	% Effect	Conc-mg/kg	95% LCL	95% UCL	Method
14-9940-8264	Proportion Survived	15	212.97060	115.19840	314.47960	Linear Regression
		20	284.51030	169.16910	404.18470	
		25	364.75780	233.05920	505.94060	
		50	994.21810	725.15810	1466.35100	
10-3766-7732	Proportion Survived	50	877.81380	780.40780	987.37760	Trimmed Spearman-Karber

Test Acceptability

Analysis	Endpoint	Attribute	Statistic	Acceptable Range	Decision
14-9940-8264	Proportion Survived	Control Response	0.95667	0.8 - N/A	Passes acceptability criteria

Proportion Survived Summary

Conc-mg/kg	Control Type	Reps	Mean	Minimum	Maximum	SE	SD	CV
0	Control Sed	5	0.98000	0.95000	1.00000	0.01225	0.02739	2.79%
0	Dilution Water	5	0.99000	0.95000	1.00000	0.01000	0.02236	2.26%
0	Lab Control	5	0.90000	0.85000	0.95000	0.02236	0.05000	5.56%
5		5	0.95000	0.90000	1.00000	0.01581	0.03536	3.72%
9		5	0.87000	0.80000	1.00000	0.03742	0.08367	9.62%
10		10	0.95000	0.85000	1.00000	0.02236	0.07071	7.44%
12		5	0.94000	0.80000	1.00000	0.04000	0.08944	9.52%
15		5	1.00000	1.00000	1.00000	0.00000	0.00000	0.00%
16		5	0.88000	0.80000	0.95000	0.03391	0.07583	8.62%
22		10	0.90000	0.75000	1.00000	0.02887	0.09129	10.14%
23		5	0.98000	0.95000	1.00000	0.01225	0.02739	2.79%
24		5	0.97000	0.90000	1.00000	0.02000	0.04472	4.61%
28		5	0.92000	0.75000	1.00000	0.04637	0.10368	11.27%
30		10	0.97000	0.90000	1.00000	0.01106	0.03496	3.60%
33		5	0.96000	0.90000	1.00000	0.01871	0.04183	4.36%
34		5	0.99000	0.95000	1.00000	0.01000	0.02236	2.26%
46		5	0.95000	0.90000	1.00000	0.02236	0.05000	5.26%
48		10	0.91500	0.85000	1.00000	0.01500	0.04743	5.18%
78		5	0.89000	0.80000	1.00000	0.03674	0.08216	9.23%
170		5	0.30000	0.20000	0.45000	0.04472	0.10000	33.33%
195		5	0.84000	0.70000	0.95000	0.04301	0.09618	11.45%
198		5	0.94000	0.90000	1.00000	0.01871	0.04183	4.45%
219		5	0.89000	0.80000	0.95000	0.02915	0.06519	7.32%
301		5	0.74000	0.60000	0.90000	0.05339	0.11937	16.13%
529		5	0.92000	0.85000	1.00000	0.02550	0.05701	6.20%
1064		5	0.51000	0.40000	0.55000	0.02915	0.06519	12.78%
1096		5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00%
1150		5	0.94000	0.85000	1.00000	0.02915	0.06519	6.94%
4826		5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00%

CETIS Test Summary

Report Date: 10 Aug-05 2:00 PM
Link: 01-9370-5039/TPAHHA3

Proportion Survived Detail

Conc-mg/kg	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5					
0	Control Sed	1.00000	0.95000	1.00000	0.95000	1.00000					
0	Dilution Water	1.00000	1.00000	0.95000	1.00000	1.00000					
0	Lab Control	0.95000	0.95000	0.90000	0.85000	0.85000					
5		1.00000	0.95000	0.95000	0.90000	0.95000					
9		0.85000	0.80000	0.90000	1.00000	0.80000					
10		1.00000	1.00000	1.00000	0.85000	1.00000	1.00000	1.00000	0.85000	0.85000	0.95000
12		0.80000	1.00000	0.90000	1.00000	1.00000					
15		1.00000	1.00000	1.00000	1.00000	1.00000					
16		0.90000	0.80000	0.95000	0.95000	0.80000					
22		0.85000	0.85000	0.80000	1.00000	0.95000	0.85000	0.75000	1.00000	0.95000	1.00000
23		0.95000	1.00000	1.00000	0.95000	1.00000					
24		1.00000	0.95000	1.00000	1.00000	0.90000					
28		0.90000	1.00000	1.00000	0.95000	0.75000					
30		0.95000	1.00000	0.95000	0.95000	1.00000	1.00000	0.90000	1.00000	0.95000	1.00000
33		1.00000	0.95000	1.00000	0.90000	0.95000					
34		1.00000	0.95000	1.00000	1.00000	1.00000					
46		0.95000	0.90000	0.90000	1.00000	1.00000					
48		0.90000	0.90000	0.95000	1.00000	0.95000	0.90000	0.95000	0.90000	0.85000	0.85000
78		0.80000	1.00000	0.85000	0.95000	0.85000					
170		0.20000	0.25000	0.35000	0.45000	0.25000					
195		0.85000	0.80000	0.90000	0.70000	0.95000					
198		0.90000	1.00000	0.95000	0.95000	0.90000					
219		0.85000	0.95000	0.90000	0.80000	0.95000					
301		0.90000	0.60000	0.80000	0.65000	0.75000					
529		0.90000	0.90000	0.95000	1.00000	0.85000					
1064		0.55000	0.40000	0.55000	0.55000	0.50000					
1096		0.00000	0.00000	0.00000	0.00000	0.00000					
1150		1.00000	0.85000	0.95000	0.90000	1.00000					
4826		0.00000	0.00000	0.00000	0.00000	0.00000					

CETIS Analysis Detail

Hyallela 10-d Survival and Growth Sediment Test — **Nautilus Environmental WA**

Endpoint	Analysis Type	Sample Link	Control Link	Date Analyzed	Version
Proportion Survived	Linear Regression	01-9370-5039	01-9370-5039	29 Jul-05 12:31 PM	CETISv1.025

Linear Regression Options

Model	Threshold Option	Lower Threshold	Threshold Optimized	Reweighted	Pooled Groups	Heterogeneity Corr.
Log-Normal	Control Threshold	0.04333333	Yes	Yes	No	Yes

Regression Parameters

Parameter	Estimate	Std Error	95% LCL	95% UCL	t Statistic	P Level	Decision(0.05)
Threshold	0.05489	0.01248	0.03022	0.07956	4.397	0.00019	Significant
Slope	1.54685	0.23265	1.08911	2.00859	6.657	0.00000	Significant
Intercept	0.35734	0.64690	-0.92101	1.63569	0.552	0.58579	Not Significant

Regression Summary

Iters	Log Likelihood	Mu	Sigma	G Stat	Chi-Sq	Critical	P Level	Decision(0.05)
6	-400.26950	0.23071	0.64564	0.08811	647.21040	177.10410	0.00000	Significant Heterogeneity

Residual Analysis

Attribute	Method	Statistic	Critical	P Level	Decision(0.05)
Variances	Modified Levene	7.87900	1.58588	0.00000	Unequal Variances
Distribution	Shapiro-Wilk W	0.79324	0.96976	0.00000	Non-normal Distribution

Point Estimates

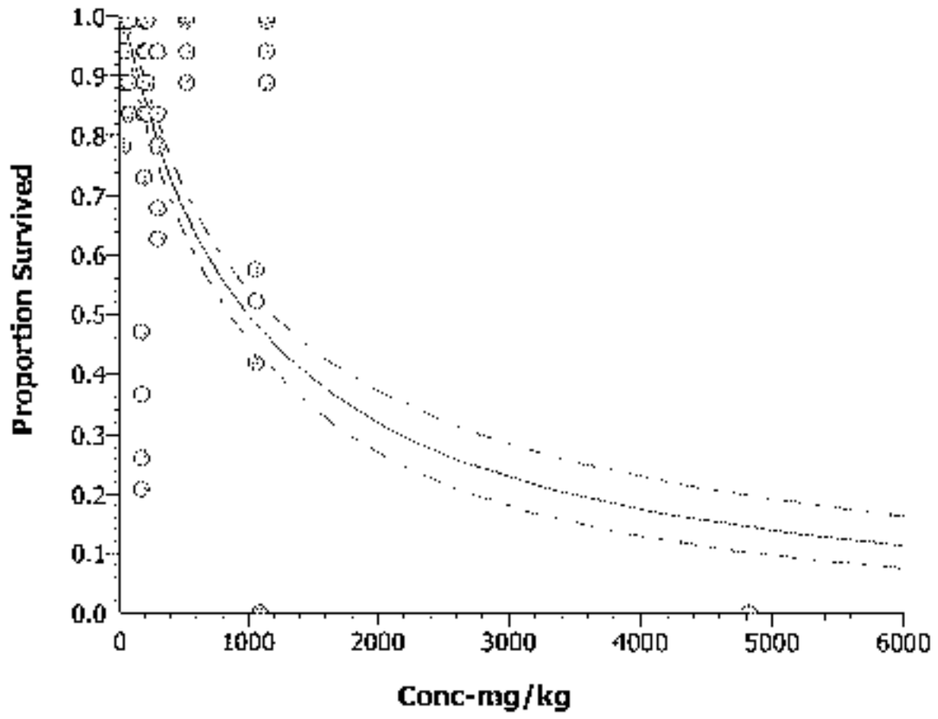
% Effect	Conc-mg/kg	95% LCL	95% UCL
15	212.97060	115.19840	314.47960
20	284.51030	169.16910	404.18470
25	364.75780	233.05920	505.94060
50	994.21810	725.15810	1466.35100

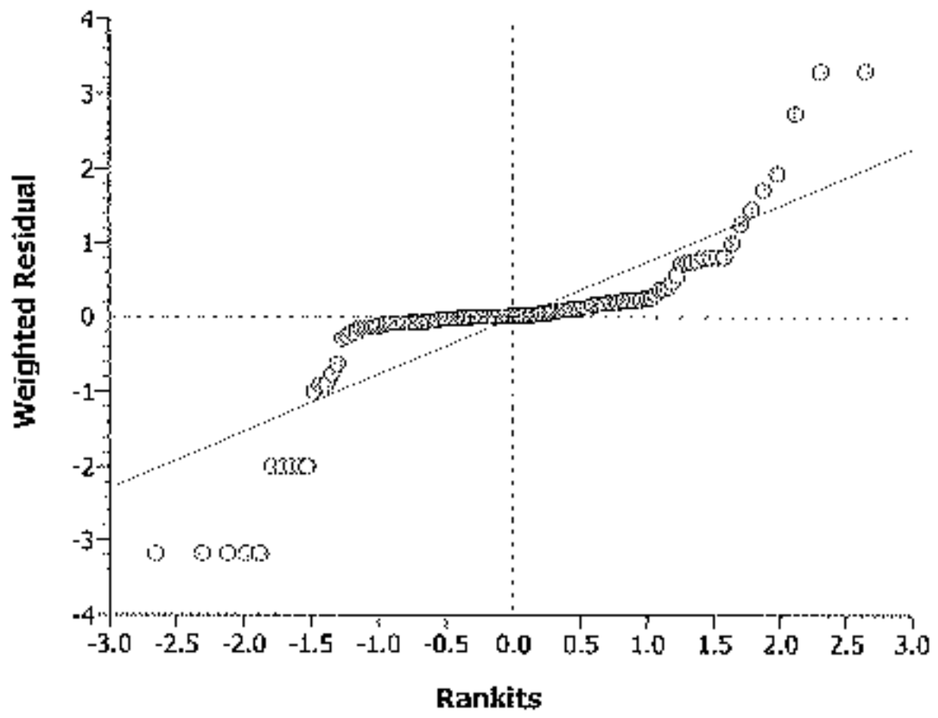
CETIS Analysis Detail

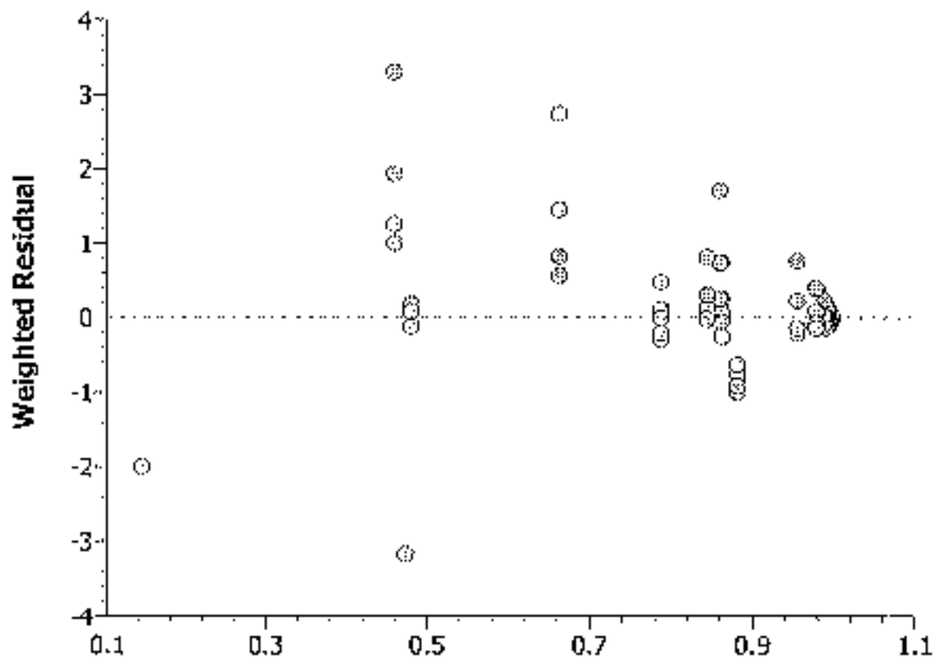
Data Summary			Calculated Variate(A/B)						
Conc-mg/	Control Type	Count	Mean	Minimum	Maximum	SE	SD	A	B
5		5	0.95000	0.90000	1.00000	0.00722	0.03536	95	100
9		5	0.87000	0.80000	1.00000	0.01708	0.08367	87	100
10		10	0.95000	0.85000	1.00000	0.01443	0.07071	190	200
12		5	0.94000	0.80000	1.00000	0.01826	0.08944	94	100
15		5	1.00000	1.00000	1.00000	0.00000	0.00000	100	100
16		5	0.88000	0.80000	0.95000	0.01548	0.07583	88	100
22		10	0.90000	0.75000	1.00000	0.01863	0.09129	180	200
23		5	0.98000	0.95000	1.00000	0.00559	0.02739	98	100
24		5	0.97000	0.90000	1.00000	0.00913	0.04472	97	100
28		5	0.92000	0.75000	1.00000	0.02116	0.10368	92	100
30		10	0.97000	0.90000	1.00000	0.00714	0.03496	194	200
33		5	0.96000	0.90000	1.00000	0.00854	0.04183	96	100
34		5	0.99000	0.95000	1.00000	0.00456	0.02236	99	100
46		5	0.95000	0.90000	1.00000	0.01021	0.05000	95	100
48		10	0.91500	0.85000	1.00000	0.00968	0.04743	183	200
78		5	0.89000	0.80000	1.00000	0.01677	0.08216	89	100
170		5	0.30000	0.20000	0.45000	0.02041	0.10000	30	100
195		5	0.84000	0.70000	0.95000	0.01963	0.09618	84	100
198		5	0.94000	0.90000	1.00000	0.00854	0.04183	94	100
219		5	0.89000	0.80000	0.95000	0.01331	0.06519	89	100
301		5	0.74000	0.60000	0.90000	0.02437	0.11937	74	100
529		5	0.92000	0.85000	1.00000	0.01164	0.05701	92	100
1064		5	0.51000	0.40000	0.55000	0.01331	0.06519	51	100
1096		5	0.00000	0.00000	0.00000	0.00000	0.00000	0	100
1150		5	0.94000	0.85000	1.00000	0.01331	0.06519	94	100
4826		5	0.00000	0.00000	0.00000	0.00000	0.00000	0	100
0		15	0.95667	0.85000	1.00000	0.01082	0.05300	287	300

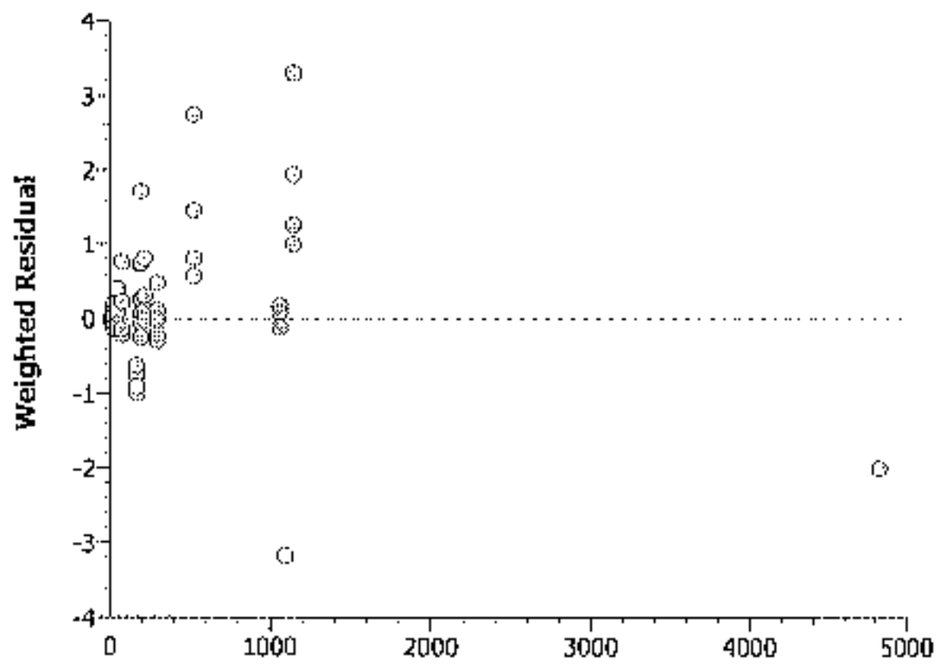
CETIS Analysis Detail

Graphics









CETIS Analysis Detail

Report Date: 10 Aug-05 2:00 PM
Analysis: 10-3766-7732/TPAHHA3

Hyallela 10-d Survival and Growth Sediment Test — **Nautilus Environmental WA**

Endpoint	Analysis Type	Sample Link	Control Link	Date Analyzed	Version
Proportion Survived	Trimmed Spearman-Karber	01-9370-5039	01-9370-5039	10 Aug-05 1:42 PM	CETISv1.025

Spearman-Karber Options

Threshold Option	Lower Threshold	Trim Level	Mu	Sigma
Control Threshold	0.04333333	0.70%	2.943403	0.02554042

Point Estimates

EC50/LC50	95% LCL	95% UCL
877.81380	780.40780	987.37760

CETIS Test Summary

Report Date: 10 Aug-05 1:57 PM
Link: 06-8408-2221/TPAHCT2

Chironomus 20-d Survival and Growth Sediment Test — **Nautilus Environmental WA**

Test No:	09-9622-5155	**Test Type:**	Survival-AF Growth	**Duration:**	N/A
Start Date:	29 Jul-05 12:35 PM	**Protocol:**	EPA/600/R-99/064 (2000)	**Species:**	Chironomus tentans
Ending Date:		**Dil Water:**	Mod-Hard Synthetic Water	**Source:**	Aquatic Biosystems, CO
Setup Date:	29 Jul-05	**Brine:**			

Sample No:	01-4238-4191	**Material:**	sediment	**Client:**	The Retec Group
Sample Date:	29 Jul-05 12:04 PM	**Code:**	142384191	**Project:**	
Receive Date:		**Source:**	Gas Works Park		
Sample Age:	32m	**Station:**			

Point Estimate Summary

Analysis	Endpoint	% Effect	Conc-mg/kg	95% LCL	95% UCL	Method
14-8808-2547	Proportion Survived	15	217.00670	102.02690	337.97270	Linear Regression
		20	275.24690	142.90120	414.25590	
		25	337.52120	189.42480	496.85170	
		50	768.73450	524.76740	1164.97800	
20-1509-6621	Proportion Survived	50	707.31960	588.56410	850.03670	Trimmed Spearman-Karber

Test Acceptability

Analysis	Endpoint	Attribute	Statistic	Acceptable Range	Decision
14-8808-2547	Proportion Survived	Control Response	0.82	0.7 - N/A	Passes acceptability criteria

Proportion Survived Summary

Conc-mg/kg	Control Type	Reps	Mean	Minimum	Maximum	SE	SD	CV
0	Control Sed	5	0.82000	0.50000	1.00000	0.08602	0.19235	23.46%
0	Dilution Water	5	0.82000	0.70000	0.90000	0.03742	0.08367	10.20%
5		5	0.82000	0.50000	1.00000	0.09165	0.20494	24.99%
9		5	0.96000	0.90000	1.00000	0.02449	0.05477	5.71%
10		5	0.82000	0.40000	1.00000	0.10677	0.23875	29.12%
12		5	0.84000	0.70000	0.90000	0.04000	0.08944	10.65%
16		5	0.88000	0.70000	1.00000	0.05831	0.13038	14.82%
22		5	0.94000	0.80000	1.00000	0.04000	0.08944	9.52%
24		5	0.82000	0.60000	1.00000	0.08000	0.17889	21.82%
28		5	0.72000	0.60000	0.90000	0.05831	0.13038	18.11%
30		10	0.90000	0.70000	1.00000	0.03333	0.10541	11.71%
33		5	0.96000	0.80000	1.00000	0.04000	0.08944	9.32%
46		5	0.94000	0.80000	1.00000	0.04000	0.08944	9.52%
48		10	0.90000	0.70000	1.00000	0.02981	0.09428	10.48%
78		5	0.92000	0.70000	1.00000	0.05831	0.13038	14.17%
170		5	0.40000	0.10000	0.80000	0.13038	0.29155	72.89%
195		5	0.84000	0.70000	1.00000	0.05099	0.11402	13.57%
198		5	0.88000	0.80000	1.00000	0.03742	0.08367	9.51%
219		5	0.86000	0.50000	1.00000	0.09798	0.21909	25.48%
301		5	0.48000	0.10000	0.80000	0.11576	0.25884	53.93%
1064		5	0.54000	0.00000	0.80000	0.14697	0.32863	60.86%
1096		5	0.34000	0.00000	0.60000	0.10296	0.23022	67.71%
4826		5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00%

CETIS Test Summary

Report Date: 10 Aug-05 1:57 PM
Link: 06-8408-2221/TPAHCT2

Proportion Survived Detail

Conc-mg/kg	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5					
0	Control Sed	0.90000	0.50000	1.00000	0.80000	0.90000					
0	Dilution Water	0.80000	0.80000	0.90000	0.70000	0.90000					
5		1.00000	1.00000	0.50000	0.80000	0.80000					
9		0.90000	1.00000	1.00000	1.00000	0.90000					
10		0.90000	1.00000	0.90000	0.90000	0.40000					
12		0.80000	0.70000	0.90000	0.90000	0.90000					
16		1.00000	0.90000	1.00000	0.70000	0.80000					
22		1.00000	0.90000	0.80000	1.00000	1.00000					
24		0.80000	1.00000	1.00000	0.70000	0.60000					
28		0.90000	0.80000	0.60000	0.60000	0.70000					
30		0.80000	0.90000	0.90000	1.00000	0.90000	1.00000	1.00000	0.80000	0.70000	1.00000
33		1.00000	1.00000	0.80000	1.00000	1.00000					
46		0.90000	1.00000	0.80000	1.00000	1.00000					
48		0.90000	1.00000	0.80000	1.00000	0.90000	0.90000	0.90000	0.90000	1.00000	0.70000
78		1.00000	0.70000	1.00000	0.90000	1.00000					
170		0.80000	0.60000	0.10000	0.30000	0.20000					
195		0.80000	0.80000	0.70000	0.90000	1.00000					
198		1.00000	0.90000	0.80000	0.90000	0.80000					
219		1.00000	0.50000	0.80000	1.00000	1.00000					
301		0.60000	0.50000	0.10000	0.40000	0.80000					
1064		0.00000	0.80000	0.60000	0.50000	0.80000					
1096		0.30000	0.30000	0.50000	0.00000	0.60000					
4826		0.00000	0.00000	0.00000	0.00000	0.00000					

CETIS Analysis Detail

Chironomus 20-d Survival and Growth Sediment Test — **Nautilus Environmental WA**

Endpoint	Analysis Type	Sample Link	Control Link	Date Analyzed	Version
Proportion Survived	Linear Regression	06-8408-2221	06-8408-2221	29 Jul-05 12:46 PM	CETISv1.025

Linear Regression Options

Model	Threshold Option	Lower Threshold	Threshold Optimized	Reweighted	Pooled Groups	Heterogeneity Corr.
Log-Normal	Control Threshold	0.18	Yes	Yes	No	Yes

Regression Parameters

Parameter	Estimate	Std Error	95% LCL	95% UCL	t Statistic	P Level	Decision(0.05)
Threshold	0.12868	0.01956	0.08993	0.16743	6.580	0.00000	Significant
Slope	1.88681	0.33017	1.23268	2.54095	5.715	0.00002	Significant
Intercept	-0.44493	0.92511	-2.27774	1.38789	-0.481	0.63605	Not Significant

Regression Summary

Iters	Log Likelihood	Mu	Sigma	G Stat	Chi-Sq	Critical	P Level	Decision(0.05)
10	-103.56060	-0.23581	0.52999	0.12019	267.54800	138.52560	0.00000	Significant Heterogeneity

Residual Analysis

Attribute	Method	Statistic	Critical	P Level	Decision(0.05)
Variances	Modified Levene	3.86301	1.67065	0.00000	Unequal Variances
Distribution	Shapiro-Wilk W	0.68500	0.96629	0.00000	Non-normal Distribution

Point Estimates

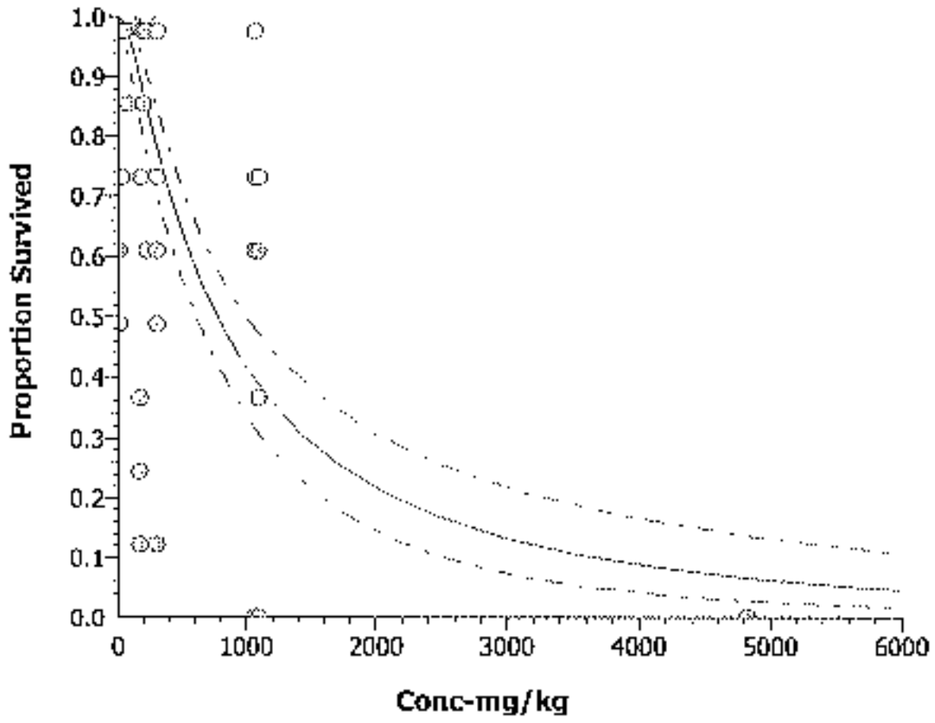
% Effect	Conc-mg/kg	95% LCL	95% UCL
15	217.00670	102.02690	337.97270
20	275.24690	142.90120	414.25590
25	337.52120	189.42480	496.85170
50	768.73450	524.76740	1164.97800

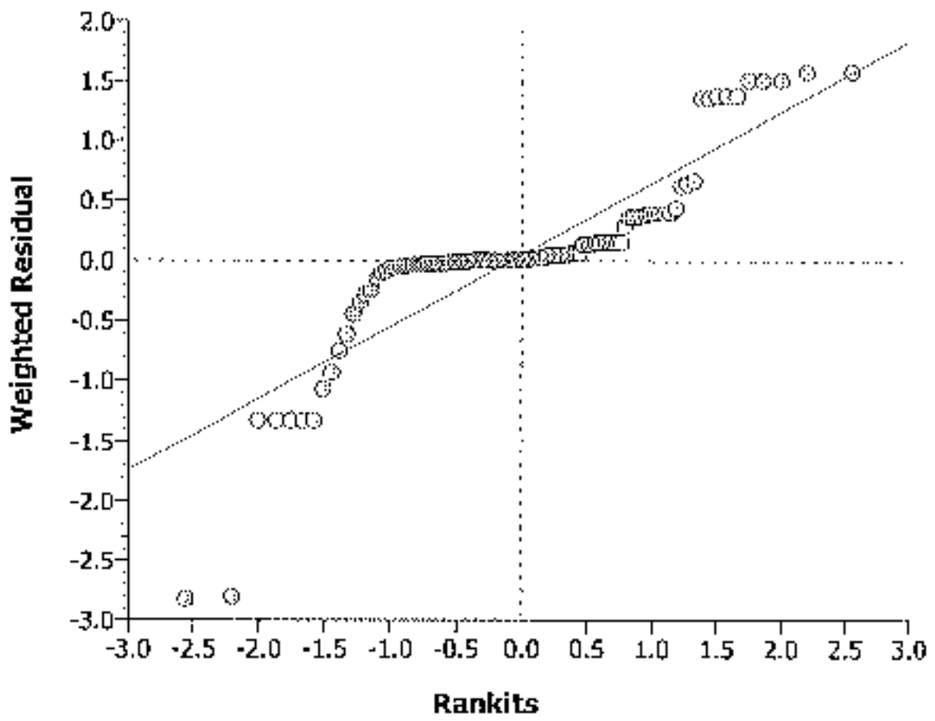
Data Summary — Calculated Variate(A/B)

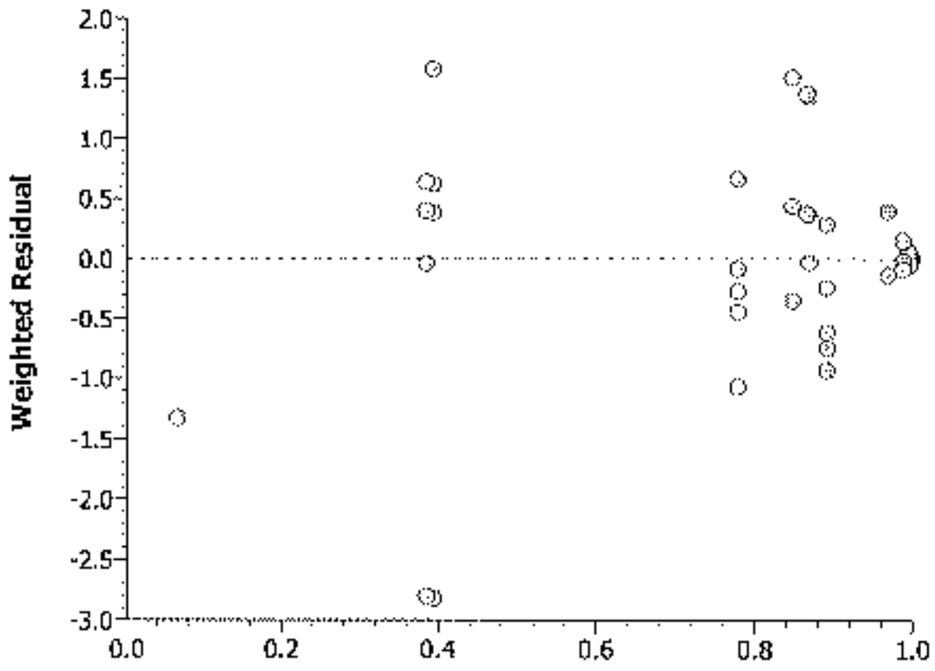
Conc-mg/	Control Type	Count	Mean	Minimum	Maximum	SE	SD	A	B
5		5	0.82000	0.50000	1.00000	0.04183	0.20494	41	50
9		5	0.96000	0.90000	1.00000	0.01118	0.05477	48	50
10		5	0.82000	0.40000	1.00000	0.04873	0.23875	41	50
12		5	0.84000	0.70000	0.90000	0.01826	0.08944	42	50
16		5	0.88000	0.70000	1.00000	0.02661	0.13038	44	50
22		5	0.94000	0.80000	1.00000	0.01826	0.08944	47	50
24		5	0.82000	0.60000	1.00000	0.03651	0.17889	41	50
28		5	0.72000	0.60000	0.90000	0.02661	0.13038	36	50
30		10	0.90000	0.70000	1.00000	0.02152	0.10541	90	100
33		5	0.96000	0.80000	1.00000	0.01826	0.08944	48	50
46		5	0.94000	0.80000	1.00000	0.01826	0.08944	47	50
48		10	0.90000	0.70000	1.00000	0.01925	0.09428	90	100
78		5	0.92000	0.70000	1.00000	0.02661	0.13038	46	50
170		5	0.40000	0.10000	0.80000	0.05951	0.29155	20	50
195		5	0.84000	0.70000	1.00000	0.02327	0.11402	42	50
198		5	0.88000	0.80000	1.00000	0.01708	0.08367	44	50
219		5	0.86000	0.50000	1.00000	0.04472	0.21909	43	50
301		5	0.48000	0.10000	0.80000	0.05284	0.25884	24	50
1064		5	0.54000	0.00000	0.80000	0.06708	0.32863	27	50
1096		5	0.34000	0.00000	0.60000	0.04699	0.23022	17	50
4826		5	0.00000	0.00000	0.00000	0.00000	0.00000	0	50
0		10	0.82000	0.50000	1.00000	0.02854	0.13984	82	100

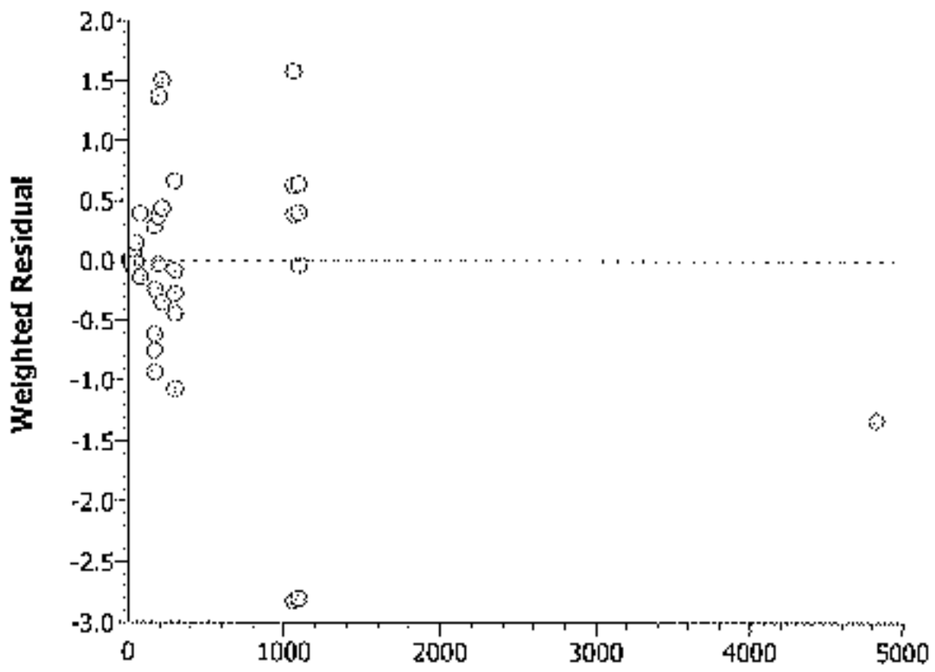
CETIS Analysis Detail

Graphics









CETIS Analysis Detail

Report Date: 10 Aug-05 1:57 PM
Analysis: 20-1509-6621/TPAHCT2

Chironomus 20-d Survival and Growth Sediment Test — **Nautilus Environmental WA**

Endpoint	Analysis Type	Sample Link	Control Link	Date Analyzed	Version
Proportion Survived	Trimmed Spearman-Karber	06-8408-2221	06-8408-2221	10 Aug-05 1:47 PM	CETISv1.025

Spearman-Karber Options

Threshold Option	Lower Threshold	Trim Level	Mu	Sigma
Control Threshold	0.18	0.00%	2.849616	0.03991097

Point Estimates

EC50/LC50	95% LCL	95% UCL
707.31960	588.56410	850.03670

Analyst: _____ Approval: _____

Appendix I

Confidence Analysis

APPENDIX I
Confidence Analysis

TPAH Cleanup Standard Determination
Gas Works Sediment Area
PSE10-18628-610
08-16-05

This appendix presents a confidence analysis used to qualitatively evaluate the overall reliability of a site-specific TPAH cleanup level(s) and the area boundary (AB) in which the level is applied. There are three basic categories of uncertainty that apply to the evaluation of sediment quality (USEPA, 1997):

1) Natural variation, site conditions, and parameter error – pertaining to the reliability of bioassay tests
2) Conceptual model uncertainties – pertaining to the chemicals of potential concern (COPC)
3) Model error – pertaining to the predictability of regression models to correlate chemical concentrations with bioassay response.

Uncertainty should be distinguished from variability, which arises from true heterogeneity or variation in the characteristics of the environment and receptors. Uncertainty, on the other hand, represents a lack of knowledge about certain factors, which can sometimes be reduced by additional study (USEPA, 1997). To address these areas of uncertainty, this analysis specifically looks at the confidence around the data assumptions and interpretations related to four factors: (1) the bioassay results, (2) the COPCs, (3) spatial boundary and clusters, and (4) the stepwise regression models. In the end, the confidence in determination of a site-specific TPAH cleanup level(s) and a GSWA area boundary to which the cleanup level will be applied is evaluated.

An overview of the statistical process, tools, and outcomes used in this document is presented in Table I-1, along with the confidence analysis used for each step.

I. Bioassay Results

There are no formal guidelines for verifying and validating sediment toxicity bioassays. However, since bioassays are simplistic ecological models, verification of model behavior can be conducted. Verification of the ecological model occurs when the sediment bioassay test behaves as expected.

Verification can be achieved by two methods. One is to conduct bioassay tests with samples representing a range of concentrations. If higher failure rates occur as

concentrations increase, the model is verified. This result has been shown to occur at the GWSA in association with TPAH concentrations, except in the case where metals occurrence complicates the response (section 1.2). A second approach to verification is to use diluted samples to observe a corresponding response gradient in bioassay results. This was accomplished in the GWSA by retrieving a range of sediment TPAH concentrations and supplementing the range with two diluted samples. The concentration response is shown clearly in the LOEC/NOEC tables, again with the exception of spatial outliers associated with other sources, predominantly metals. Both methods were used for verification in the GWSA and in both cases, the bioassay static variables (test endpoints) responded to increasing forcing functions (sediment-associated contaminants).

In contrast, few sediment bioassays datasets are validated (an independent objective evaluation of the model's predictive capacity). In order to do the latter, co-varying parameters and historical events must be excluded to determine precision and accuracy. Comparisons to chemical-specific species sensitivity predicted using laboratory studies is the best approach, which is achieved, to some extent, in the laboratory using references and controls. To address site-specific concerns, a sensitivity and efficiency analysis using site-specific bioassay data and the predictive ability of the proposed TPAH cleanup level was conducted in Section 4.4.

II. Chemicals of Potential Concern

The methodology used to increase confidence and reduce uncertainty in the COPC cleanup level is a percent overlap analysis, or measure of co-occurrence. Parameter uncertainty (e.g., sediment concentrations) can be characterized in two ways: (1) as a distribution of values described by ranges, averages, and clustering and (2) the ability of one parameter to represent another, as a surrogate of co-occurrence. The methodologies and observations used to increase confidence in measured parameters are discussed below.

Spatial Overlap Analysis. The validity of using TPAH as representative of other organic parameters and COPCs was checked by using a percent overlap analysis. First, the concentrations of other COPCs for the GWSA were placed on an overlay of the determined TPAH cleanup levels. The other COPCs were contoured using Ecology's Draft screening criteria for freshwater sediment. COPCs such as carbazole and dibenzofuran were then visually checked to see if there were any areas of occurrence that were not synoptic with the boundary defined by the TPAH cleanup levels. For most of the COPCs, about 90% or more of the areas were synoptic for the GWSA (excluding the shipyard area). For dibenzofuran, carbazole, and cyanide specifically, there is a 100% overlap in occurrence (Figures I-1, I-2, and I-3 respectively). Elevated arsenic concentrations (Figure I-4) occur mostly in the shipyard area. Elevated arsenic concentrations are also found in the eastern portion of the Eastern Study Area; the AB was extended offshore to account for this area of chemical exceedances.

Steep Concentration Gradients. TPAH concentrations greater than 100 mg/kg are found within 400 feet of the eastern GWP Site shoreline, and within 500 feet of the southern GWP shoreline. There is a steep concentration gradient separating elevated PAHs in a narrow band near GWP from PAHs less than 100 mg/kg range associated with ambient Lake Union conditions. TPAH concentrations greater than 100 mg/kg are found within 800 feet of the western GWP/western shipyard shoreline. Several lines of evidence including physical conditions, substrate type, bathymetry elevations, and steep chemical concentrations gradients support the development of an AB boundary with confidence.

III. Spatial Boundary and Clusters

Hierarchical cluster analysis was used previously (Appendix F) to identify groups of stations that are statistically similar. The combined Phases 2 and 3 dataset was used for this analysis. To reduce the uncertainty surrounding these clusters, the hierarchical cluster analysis was re-run using all available surface sediment chemistry. The datasets spanned 1999 through 2005, and included approximately 114 samples (versus the combined Phases 2 and 3 sample size of approximately 45).

Hierarchical cluster analysis (SPSS 10.0) uses listwise exclusion, which ignores any case (station) which has missing values for any variable. To increase the number of stations included in the analysis, the clustering was run with those analytes with the most complete dataset (Table I-2, Figure I-5). The clusters generated using the larger dataset generally agreed with the clusters generated using only the combined Phases 2 and 3 dataset, indicating that the station clusters determined in the previous cluster analysis are appropriate.

IV. Statistical Model Validation

Finally, there is uncertainty associated with how well a model approximates true relationships between site-specific environmental conditions (e.g., confounding influences on toxicity). To ensure that the stepwise regression model used to determine the significance of individual parameters was adequate, four quality control model runs were conducted to address two questions:

a) Is the model missing any important variables from the initial list of parameters?
b) Would the model change if significant outliers were removed?

Results of the four quality control model runs are included in this appendix as SPSS output tables. Attachment 1 summarizes the model validation results and how the questions stated above were answered.

The model can confidently state that the selected subset of parameters (five metals, TPAH, percent fines) has the most predictive ability related to biological effects. Whether these parameters were log-transformed, or not, did not change the parameters included in the model. The predictive ability of the model may have changed a little but the trends did not. When the two major outliers from the cluster

analyses (NLU86 and NLU51) were removed from the regression, then TBT and PCBs occasionally become significant in the model. But the predictive ability of TPAH did not change. The outcome of the outlier test shows that the outliers can influence results and that areas with co-mingling of chemicals, especially metals, should not be used for TPAH cleanup level derivation unless the contribution of metals and organics to observed toxicity is identified.

V. References

USEPA, 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. Interim final. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. EPA 540-R-97-006. OSWER 9285.7.25. June.

Table I-1. Process for GWSA Bioassay Cleanup-Level Statistical Strategy

Statistical Methodology Step / Question	Goal	Action / Tool	Parameters Included in Analysis	Outcome	Quality Assurance
Step 1- Visual Exploration					
Exploratory statistics: How are the parameters distributed (e.g., are they normal)?	Determine if any transformations are required. Determine if there are any outliers to consider.	Scatterplots; Histograms	All parameters	Necessary log10 transformations: *Phase 3* : TOC, cyanide, lead, PCBs, possibly TPAH and dibenzofuran *Phases 2+3* : TOC, possibly TPAH Chemical outliers: NLU51, NLU86 (3 times higher than next closest value)	Re-run regressions with outliers removed. Re-run regression with log and unlog transformed variables.
Step 2 - Initial Screening [1]					
How are the parameters related? Which parameters correlate with bioassay test results? Can the parameter list be reduced to a managable size but still be representative?	Determine which parameters correlate with bioassay test results and/or each other.	Pearsons bivariate correlation; Initial stepwise regressions (per Ecology request)	All parameters; organics only; metals only	*Phase 3 reduced to* : sulfide, ammonia, log(cyanide), TPAH, arsenic, chromium, copper, mercury, zinc, percent fines, all bioassays; *Phases 2+3 reduced to* : sulfide, ammonia, TPAH, arsenic, chromium, copper, mercury, zinc, percent fines, all bioassays as appropriate	Re-run regressions with subset variables and see if others are added to the model.
Step 3 - Spatial Cluster Analysis					
Does the dataset fall into groups, especially for Shipyard/Marina areas with commingled metals?	Determine if spatial clusters exist among chemical parameters.	Cluster analysis	TPAH, dibenzofuran, arsenic, copper, lead, mercury, zinc, ammonia, sulfides, (percent fines)	The Shipyard Cluster included: NLU13 through NLU17, NLU86, LU-3, LU-4, LU-8, and NLU87. The marina stations were added to the cluster: NLU01, NLU02, and NLU82.	Re-run regressions for the Shipyard/Marina Cluster and see if relationship improves. Cluster analysis re-ran using all grab samples to see if shipyard cluster still groups together.
Step 4 - Secondary Screening [2]					
Which parameters account for most of the variance in the bioassay tests?	Identify the parameter(s) that explain most of the variance seen in the observed toxicity results.	Stepwise regression	Parameter subset identified in Initial Screening	Carry forward with only the Phase 2 and 3 combined dataset. TPAH accounted for 50 to 60% percent of bioassay variability and the models usually included one or two metals.	Re-run regressions excluding the Shipyard/Marina Cluster and see if TPAH relationship improves.
Which bioassay tests best relate to TPAH?	Determine which toxicity tests can be used to derive a site-specific TPAH cleanup level.	Stepwise regression	Parameter subset identified in Initial Screening	TPAH was included in regression models for all bioassays except Microtox®	
Step 5 - Derivation of TPAH Effects Levels					
What concentration of TPAH corresponds to acceptable bioassay response?	Derive a site-specific TPAH cleanup value.	Ranking tables; Concentration-response curves	TPAH	Derived SSQS and SCSL values	Used the concentration-response curves to improve confidence in the threshold values (LOEC/NOEC). Confidence intervals included.
Step 6 - Confidence Analysis					
See quality assurance column to the right					

NOTES

TOC = total organic carbon, PCBs = polychlorinated biphenyls, TPAH = total polycyclic aromatic hydrocarbons

LOEC = lowest observed effect concentration, NOEC = no observed effect concentration

[1] This initial screening was conducted with the Phase 3 (2005) data set only, and then repeated as a combined data set (2002 and 2005).

[2] The secondary screening was conducted with the combined data subset (2002 and 2005), which had more stations to include in analysis.

Table I-2. Summary of Station Clusters: GWSA 1999 - 2005, All Surface Grab Stations

Dataset	Parameters	Clusters*	Stations	Comments
Ph 2&3 subset (Appendix F)	NH3, S2, As, Cu, Cr, Hg, Zn, TPAH	Shipyard	NLU14, 15, 16, 17	
		Extended Shipyard	LU-3, 4, 8; NLU13, 86, 87	
		Marina **	NLU01, NLU02, NLU82	
'99-'05 Dataset	TOC, As, Cd, Cr, Cu, Pb, Hg, Zn, DBF, TPAH	WSA	LU-3, 4, 8; NLU13, 17, 87; ST-05, 07	St ('99) stations included
		Shipyard boundary	NLU14, 15; ST-03, 04	
		Shipyard	NLU16, 86; ST-02, 35, 43	
99-'05 subset (same variables as Ph 2&3 subset)	NH3, S2, As, Cu, Cr, Hg, Zn, TPAH	WSA	LU-3, 4, 8; NLU12, 13, 84, 87, 117	no ST ('99) stations (no NH3)
		Shipyard	NLU14, 15, 16, 17, 86	

Notes:

* Clustering methods uses listwise exclusion, any stations for which there is not a complete dataset for listed parameters is excluded from the analysis.

** Marina cluster is assumed based on concentrations and spatial proximity to each other and potential sources; not clustered by SPSS.

WSA = Western Study Area

If stations are not listed, then they are included in the GWSA

CONCLUSION

The overall clusters agree with the original clusters developed using just the Ph 2&3 data subset. Of particular note is that when the 1999 "ST" stations were included (and the analyte list slightly modified from that of the 2&3 subset), the main clusters didn't change that much except to add geographically relevant ST stations.

0 150 300 Feet

N

SURFACE SEDIMENT SAMPLING STATIONS

PHASE 3 SAMPLING

- Grab Samples Collected in December 2002-April 2005 (RETEC)

PHASE 2 SAMPLING

- Grab Samples Collected in Fall 2002 (RETEC)
- Grab Samples Collected in March 2002 (TAMU)

PHASE 1 SAMPLING

- Grab Samples Collected in September 1999 (RETEC)

HISTORIC SAMPLING

- Grab Samples Collected in 1995 (EPA)
- Grab Samples Collected from 1995-2000 (SEDQUAL)

- Initial Area of Investigation
- Uplands Boundary As Defined By The Consent Decree (December 1999)
- Division Between Eastern And Western Study Areas
- Shipyard Consent Decree Boundary
- Harbor Patrol Boundary
- Gas Works Park Boundary

Interpolated Dibenzofuran Concentrations (mg/kg dry wt.)

- 0.39 - 0.44
- 0.44 - 15
- 15 - 34

Interpolated TPAH Concentrations (mg/kg dry wt.) *

- 170 - 290
- > 290
- No data available, or, if data exists, interpolation not shown

* Western Study Area values are preliminary and not validated

NOTES:

1. Basemap generated in ArcGIS version 8.1 from Seattle Public Utilities Geographic Systems data, 9/28/99. Overwater structure data updated, 12/18/03. Projection in Washington State Plane Coordinates, North Zone, HARN 1983/1991.
2. Concentration contour map generated through interpolation using an Inverse Distance Weighted (IDW) scheme (power = 6). Maximum reach from each sampling location is equal to 500 feet. Contoured interval may differ from actual data shown due to influence by neighboring data values.
3. RETEC March 2002 samples reported for LU-1 through LU-11.
4. All surface samples were collected by grab sampler except NLU81 which was collected using 18" diver push cores, only top 4" sampled.
5. Draft Ecology chemical screening values for dibenzofuran are 0.39 mg/kg (LAET) and 0.44 mg/kg (2LAET).

GAS WORKS PARK

Harbor Patrol

WESTERN STUDY AREA

EASTERN STUDY AREA

NLU129 0.67
NLU127 0.24
ST-34 0.28
NLU15 <0.39U
NLU126 0.9
ST-01 4.8
NLU124 0.49
NLU122 14
NLU16 2.1
NLU116 0.58
ST-02 2.4
NLU88-TX <0.34
ST-35 0.72
NLU107 0.19
ST-43 0.56
NLU17 1.1
ST-03 4.6
NLU13 <0.38U
NLU87-TX <0.12
NLU13-TX <0.53
ST-04 2.7
NLU114 0.18J
NLU12 <0.39U
NLU14 <0.39U
NLU135 <0.2U
LU-3 0.23
ST-05 0.5
NLU136 <0.19U
LU-1 0.52
LU-4 0.062
ST-06 0.1
NLU83-TX <0.15
NLU41-TX <0.16
NLU41 <0.086
NLU40 <0.082
NLU112 0.24
NLU64 0.21
NLU64-TX <0.14
NLU66 <0.087
NLU66-TX <0.15
NLU85-TX <0.15
LU-2 2.4
NLU70 <0.092UJ
NLU45 <0.09
NLU10 <0.39U
LU-5 <0.032U
ST-08 0.16
LU-8 <0.027U
NLU106 <0.06U
ST-07 0.11
NLU42 <0.027
NLU43 <0.029
NLU44 <0.089
NLU61 <0.027
LU-9 <0.029U
ST-10 0.1
LU-10 <0.037U
ST-13 0.044J
ST-16 0.058J
ST-20 0.077
ST-21 0.088
ST-11 0.086
NLU47 <0.086
LU-11 0.036
ST-18 0.11
ST-19 0.076
ST-15 0.12
NLU84-TX <0.15
NLU134 0.064
NLU120 0.033
NLU121 0.39
NLU117-TX 6.1
NLU123 0.3
NLU65 4.4
NLU74 1.6
NLU56 1.5
NLU131 1.6
NLU130 6.1
NLU51 3.6
NLU51-TX 3.9
NLU67 0.33
NLU06 <0.39U
NLU07 <0.39U
NLU72 <0.05U
NLU50 <0.084
NLU71 0.56
NLU46 0.03
NLU08 <0.39U
NLU48 <0.087
LU-7 <0.031U
LU-6 <0.031U
NLUEPA19-TX <0.15
NLU49 <0.079
NLU77 1.0
NLU58 <0.37
NLU76 0.17
NLU76-TX <0.13
NLU78 2.0
NLU58 1.5
NLU73-TX 0.19
NLU79 0.36
NLU55 1.6
NLU55-TX 4.7
NLU62 <0.24
NLU57 0.094
NLU04 0.39U
NLU63 1.8
NLU52 <0.087
NLU69-TX <0.16
NLU68 6.5
NLU69 0.65
NLU54 <0.085
NLU53 0.36
NLUEPA5-TX <0.14
NLU75 <0.088
NLU60 <0.25
NLU05 0.9U
NLU01 0.28J
NLU02 <0.38U
NLU82-TX 0.12
NLU81-TX <0.15
NLU81 <0.031
ST-31 0.23
ST-42 5.7
ST-28 0.65
ST-29 0.11
ST-26 0.085
ST-24 0.099
ST-22 0.069
NLU50 <0.084
NLU06 <0.39U
NLU67 0.33
NLU51-TX 3.9
NLU51 3.6
NLU131 1.6
NLU130 6.1
NLU123 0.3
NLU65 4.4
NLU74 1.6
NLU56 1.5
NLU64 0.21
NLU64-TX <0.14
NLU112 0.24
NLU40 <0.082
NLU83-TX <0.15
NLU41-TX <0.16
NLU41 <0.086
NLU66 <0.087
NLU66-TX <0.15
NLU71 0.56
NLU46 0.03
NLU08 <0.39U
NLU48 <0.087
LU-7 <0.031U
LU-6 <0.031U
NLUEPA19-TX <0.15
NLU49 <0.079
NLU10 <0.39U
LU-5 <0.032U
ST-08 0.16
NLU42 <0.027
NLU43 <0.029
NLU44 <0.089
NLU61 <0.027
NLU47 <0.086
LU-11 0.036
ST-18 0.11
ST-19 0.076
ST-15 0.12
LU-10 <0.037U
ST-13 0.044J
ST-16 0.058J
ST-20 0.077
ST-21 0.088
ST-11 0.086
ST-22 0.069
NLU48 <0.087
NLU49 <0.079
NLU10 <0.39U
LU-5 <0.032U
ST-08 0.16
LU-6 <0.031U
NLU42 <0.027
NLU43 <0.029
NLU44 <0.089
NLU61 <0.027
NLU47 <0.086
LU-11 0.036
ST-18 0.11
ST-19 0.076
ST-15 0.12
LU-10 <0.037U
ST-13 0.044J
ST-16 0.058J
ST-20 0.077
ST-21 0.088
ST-11 0.086
ST-22 0.069

CLEANUP STANDARD DETERMINATION GAS WORKS SEDIMENT AREA PSE10-18628-610			**SPATIAL OVERLAP WITH SURFACE SEDIMENT DIBENZOFURAN CONCENTRATIONS**
DATE: 7/21/05	DWN. BY: KBL/ftc		**FIGURE: I-1**

RETEC

FILE: T:/LakeUnion_N83/Projects/NLU/TPAHCleanUP_SD2005/PercOL_Dibenz_l1.mxd

0 150 300 Feet

N

SURFACE SEDIMENT SAMPLING STATIONS

PHASE 3 SAMPLING

- Grab Samples Collected in December 2004-April 2005 (RETEC)

HISTORIC SAMPLING

- Grab Samples Collected from 1995-2000 (SEDQUAL)
- Grab Samples Collected in 1995 (EPA)

- Initial Area of Investigation
- Uplands Boundary As Defined By The Consent Decree (December 1999)
- Division Between Eastern And Western Study Areas
- Shipyard Consent Decree Boundary
- Harbor Patrol Boundary
- Gas Works Park Boundary

Interpolated Carbozal Concentrations (mg/kg dry wt.)

- > 0.923

Interpolated TPAH Concentrations (mg/kg dry wt.)

- 170 - 290
- > 290

- No data available, or, if data exists, interpolation not shown

* Western Study Area values are preliminary or not validated

GAS WORKS PARK

Harbor Patrol

WESTERN STUDY AREA

EASTERN STUDY AREA

NOTES:

1. Basemap generated in ArcGIS version 8.1 from Seattle Public Utilities Geographic Systems data, 9/28/99. Overwater structure data updated, 12/18/03. Projection in Washington State Plane Coordinates, North Zone, HARN 1983/1991.
2. Concentration contour map generated through interpolation using an Inverse Distance Weighted (IDW) scheme (power = 6). Maximum reach from each sampling location is equal to 500 feet. Contoured interval may differ from actual data shown due to influence by neighboring data values.
3. RETEC March 2002 samples reported for LU-1 through LU-11.
4. All surface samples were collected by grab sampler except NLU81 which was collected using 18" diver push cores, only top 4" sampled.
5. Carbazole not reported in Phase 2 samples.
6. Draft Ecology chemical screening value for carbazole is 0.923 mg/kg (LAET)

RETEC

CLEANUP STANDARD DETERMINATION GAS WORKS SEDIMENT AREA PSE10-18628-610			**SPATIAL OVERLAP WITH SURFACE SEDIMENT CARBAZOLE CONCENTRATIONS**
DATE: 7/21/05	DWN. BY: KBL/ftc		**FIGURE: I-2**

FILE: T:/LakeUnion_N83/Projects/NLU/TPAHCleanUp_SD2005/PerOL_CarbozaL_int.mxd

0 150 300 Feet

N

SURFACE SEDIMENT SAMPLING STATIONS

PHASE 3 SAMPLING

- Grab Samples Collected in December 2004-April 2005 (RETEC)

HISTORIC SAMPLING

- Grab Samples Collected from 1995-2000 (SEDQUAL)
- Grab Samples Collected in 1995 (EPA)

- Initial Area of Investigation
- Uplands Boundary As Defined By The Consent Decree (December 1999)
- Division Between Eastern And Western Study Areas
- Shipyard Consent Decree Boundary
- Harbor Patrol Boundary
- Gas Works Park Boundary

Interpolated Total Cyanide Concentrations (mg/kg dry wt.)

- 5 - 25
- 25 - 50
- 50 - 100
- > 100

Interpolated TPAH Concentrations (mg/kg dry wt.) *

- 170 - 290
- > 290
- No data available, or, if data exists, interpolation not shown

* Western Study Area values are preliminary and not validated

GAS WORKS PARK

Harbor Patrol

WESTERN STUDY AREA

EASTERN STUDY AREA

NLU82-TX 0.15
NLU77 1.0
NLU58 0.44
NLU76 0.381
NLU76-TX <0.13
NLU78 1.5
NLU59 <0.37
NLU81-TX <0.15
NLU73-TX 0.23
NLU81 <0.031
NLU73 0.48
NLU62 0.28
NLU57 0.19
NLU55-TX 5.5
NLU55 1.7
NLU63 1.5
NLU52 <0.087
2 0.145J
1 1.03J
3 0.12J
4 <0.601U
NLU69-TX <0.16
NLU68 6.1
NLU69 0.79
NLU54 <0.085
NLU53 0.58
NLU75 <0.088
NLUEPA5-TX <0.14
5 0.813
7 0.061J
6 0.156J
8 0.069J
NLU60 <0.28
NLU51-TX 3.1
NLU51 4.8
NLU67 0.51
10 1.15J
11 0.477J
NLU50 <0.084
NLU72 <0.091
15 0.239J
12 <0.309J
527 <0.25UJ
NLU49 <0.079
527 <0.24UJ
19 0.234J
NLUEPA19-TX <0.15
16 <0.441U
NLU47 <0.086
NLU86-TX 0.193J
NLU84-TX 0.088J
NLU87-TX 0.12
NLU13-TX <0.53
NLU117-TX 2.00
25 1.25
26 0.674
NLU64-TX 0.3
NLU65 5.2
27 0.821
NLU64 0.3
20 2.69
NLU74 1.5
NLU56 0.69
NLU40 0.092
21 1.78J
NLU66 <0.087
NLU71 0.42
NLU83-TX <0.15
NLU66-TX <0.15
17 4.51
NLU41-TX <0.16
NLU46 0.003
NLU41 <0.086
NLU70 <0.092UJ
18 0.59J
NLU85-TX <0.15
22 <0.293U
NLU45 <0.09
NLU48 <0.087
23 0.219J
NLU42 0.034
24 <0.294U
NLU43 <0.029
NLU44 <0.089
NLU61 <0.027

NOTES:
1. Basemap generated in ArcGIS version 8.1 from Seattle Public Utilities Geographic Systems data, 9/28/99. Overwater structure data updated, 12/18/03. Projection in Washington State Plane Coordinates, North Zone, HARN 1983/1991.
2. Concentration contour map generated through interpolation using an Inverse Distance Weighted (IDW) scheme (power = 6). Maximum reach from each sampling location is equal to 500 feet. Contoured interval may differ from actual data shown due to influence by neighboring data values.
3. RETEC March 2002 samples reported for LU-1 through LU-11.
4. All surface samples were collected by grab sampler except NLU81 which was collected using 18" diver push cores, only top 4" sampled.
5. Cyanide not analyzed in Phase 2.

RETEC

CLEANUP STANDARD DETERMINATION GAS WORKS SEDIMENT AREA PSE10-18628-610			**SPATIAL OVERLAP WITH SURFACE SEDIMENT CYANIDE CONCENTRATIONS**
DATE: 7/20/05	DWN. BY: KBL/ftc		**FIGURE: I-3**

FILE: T:/LakeUnion_N83/Projects/NLU/TPAHCleanUp_SD2005/PerOL_Cyanide_int.mxd

0 150 300 Feet

N

SURFACE SEDIMENT SAMPLING STATIONS

PHASE 3 SAMPLING
- Grab Samples Collected in December 2004-April 2005 (RETEC)

PHASE 2 SAMPLING
- Grab Samples Collected in Fall 2002 (RETEC)

PHASE 1 SAMPLING
- Grab Samples Collected in September 1999 (RETEC)

HISTORIC SAMPLING
- Grab Samples Collected in 1995 (EPA)
- Grab Samples Collected from 1995-2000 (SEDQUAL)

- Initial Area of Investigation
- Uplands Boundary As Defined By The Consent Decree (December 1999)
- Division Between Eastern And Western Study Areas
- Shipyard Consent Decree Boundary
- Harbor Patrol Boundary
- Gas Works Park Boundary

Interpolated Arsenic Concentrations (mg/kg dry wt.)
- 31.4 - 50.9
- 50.9 - 100
- 100 - 500
- 500 - 1000
- >1,000
- No data available, or, if data exists, interpolation not shown

Interpolated TPAH Concentrations (mg/kg dry wt.) *
- 170 - 290
- > 290
- No data available, or, if data exists, interpolation not shown

* Western Study Area values are preliminary and not validated

NOTES:
1. Basemap generated in ArcGIS version 8.1 from Seattle Public Utilities Geographic Systems data, 9/28/99. Overwater structure data updated, 12/18/03. Projection in Washington State Plane Coordinates, North Zone, HARN 1983/1991.
2. Concentration contour map generated through interpolation using an Inverse Distance Weighted (IDW) scheme (power = 6). Maximum reach from each sampling location is equal to 500 feet. Contoured interval may differ from actual data shown due to influence by neighboring data values.
3. RETEC March 2002 samples reported for LU-1 through LU-11.
4. All surface samples were collected by grab sampler except NLU81 which was collected using 18" diver push cores, only top 4" sampled.
5. Draft Ecology chemical screening values for arsenic are 31.4 mg/kg (LAET) and 50.9 mg/kg (2LAET).

GAS WORKS PARK

Harbor Patrol

WESTERN STUDY AREA

EASTERN STUDY AREA

NLU129 300; NLU127 2920; ST-34 150; NLU15 80; NLU126 760; LU1-01 110; NLU124 51; NLU122 40; NLU16 140; NLU120 <6U; NLU116 110; ST-02 190; NLU121 70; NLU86-TX 360; NLU17 70; ST-03 100; ST-43 190; NLU84-TX <50; ST-35 270; NLU107 36; NLU13 50; NLU13-TX 100; NLU87-TX 130; ST-04 120; NLU12 <50U; NLU14 110; NLU117-TX 60; 25 36.5; 26 63.1; NLU64-TX <40; NLU65 <8; NLU64 30; 27 46.9; NLU74 20; 20 34.5; NLU40 50; 21 35; NLU56 6; NLU51-TX 30; NLU51 20; NLU67 20; ST-05 60; NLU83-TX <50; NLU66-TX <50; NLU71 <20; NLU66 30; ST-06 40; NLU41-TX <60; NLU41 <40; 17 10.8; NLU06 <50U; 11 56.5; NLU50 <30; NLU85-TX <50; 22 91.8; NLU70 <30; NLU46 <40; NLU45 <40; NLU07 <50U; 18 45.1; NLU72 <50; 15 28.2; 23 77.1; NLU10 <50U; NLU08 <50U; 527 35.2; NLU48 <30; 12 44.5; ST-22 <20U; ST-08 50; 19 55.4; 527 26.6; NLU49 <40; ST-07 50; 24 80.1; NLU42 50; NLUEPA19-TX <50; ST-18 <20U; 13 51.3; NLU106 21; NLU43 <40; NLU44 40; NLU61 30; ST-11 <30U; NLU47 <40; 16 74.6; ST-10 50; ST-15 <30U; ST-19 40; ST-13 30; ST-16 30; ST-20 40; ST-21 40

NLU82-TX 40; NLU01 30; NLU02 <40U; NLU77 10; NLU76 <30; NLU58 40; NLU76-TX <40; ST-31 <20U; NLU59 20; NLU78 17; ST-42 60; NLU73-TX 70; NLU81-TX <50; NLU81 <50; NLU73 60; NLU113-TX 70; ST-28 40; ST-29 <20U; NLU55-TX 70; NLU62 2,390; NLU57 <40; NLU55 19; NLU04 <50U; NLU52 <30; NLU63 100; 1 52.5; 2 35.3; 3 36.9; 4 27.2; ST-26 20; 32 22.4; NLU69 <40; NLU68 90; NLU69-TX <60; NLU54 <40; NLU60 7; NLU53 <6; NLUEPA5-TX <50; NLU75 <40; NLU05 <6U; 5 36; 7 32; 6 45.3; 8 47.7; ST-24 <20U; NLU50 <30; ST-22 <20U

RETEC

CLEANUP STANDARD DETERMINATION GAS WORKS SEDIMENT AREA PSE10-18628-610			SPATIAL OVERLAP WITH SURFACE SEDIMENT ARSENIC CONCENTRATIONS
DATE: 7/21/05	DWN. BY: KBL/ftc		FIGURE: I-4

Figure I-5. Hierarchical Clustering Dendrogram: GWSA 1999-2005 Stations (All Surface Sediment Grab Stations)

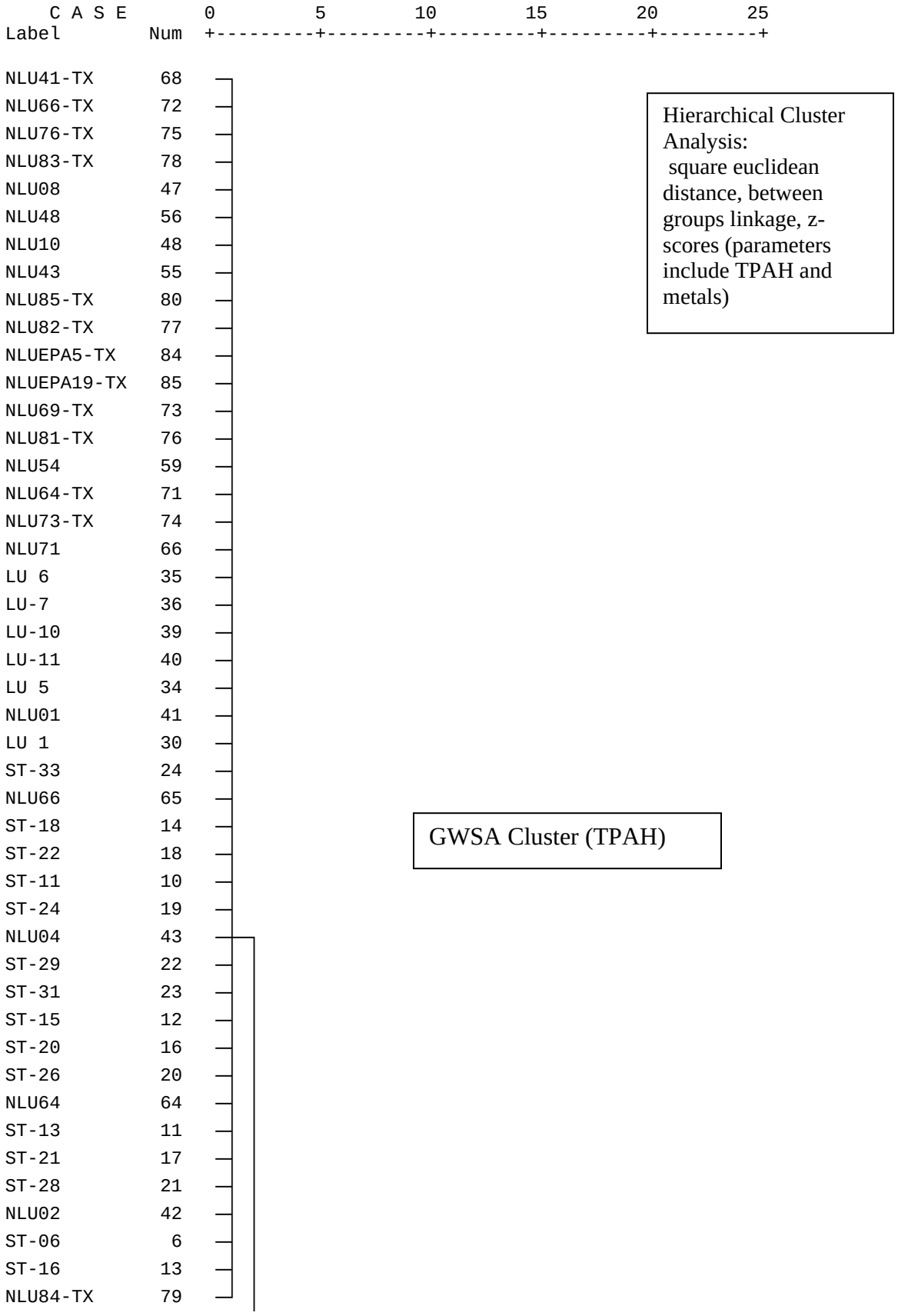
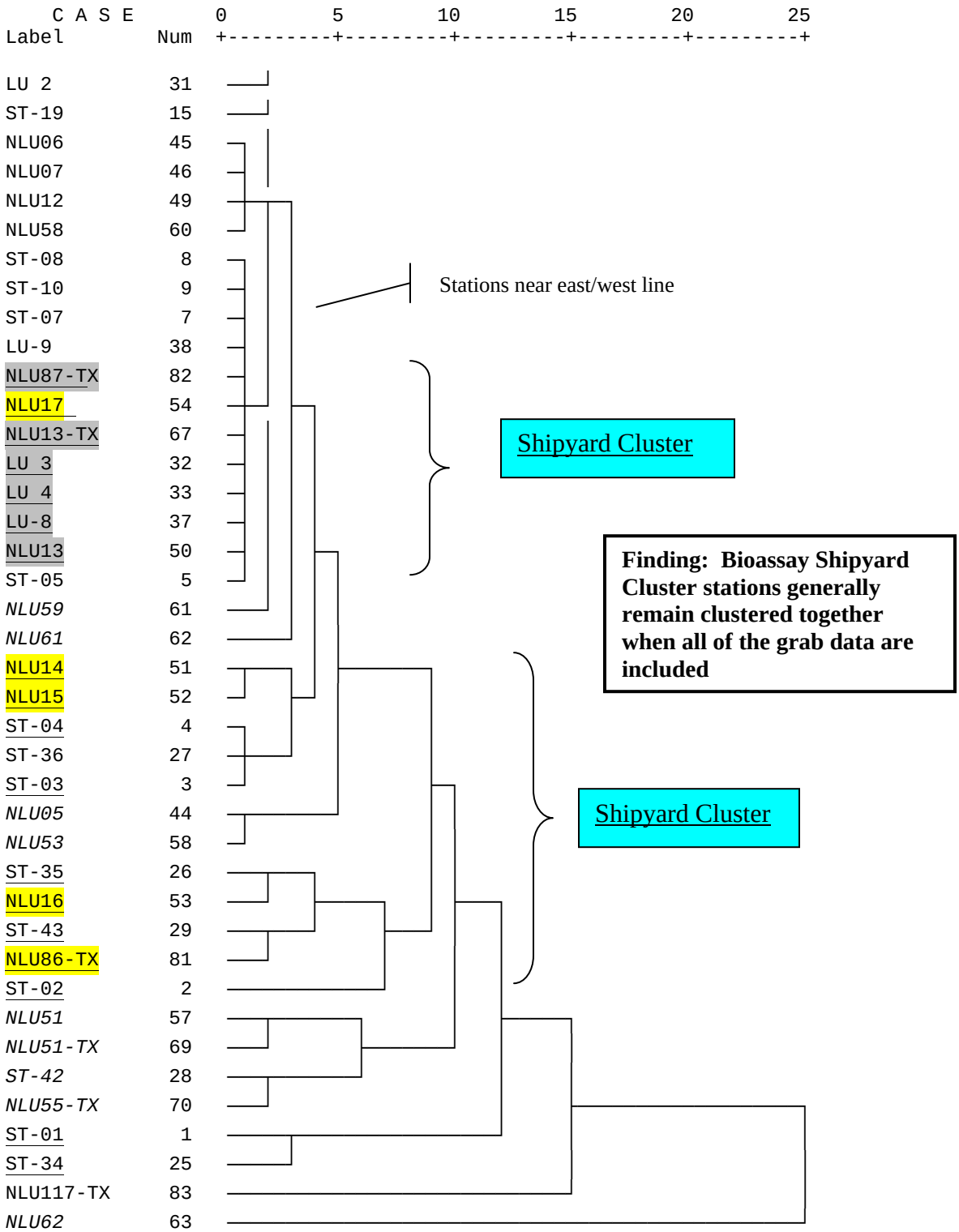


Figure I-5. Hierarchical Clustering Dendrogram: GWSA 1999-2005 Stations



Yellow = Shipyard Cluster (Bioassay stations only, Appendix F)
Gray = Extended Shipyard Cluster (Bioassay stations only, Appendix F)
Underline = Shipyard Area (commingled with metals, stippled area on maps)
Italics = Eastern Study Area (featured as needed for differentiation)

APPENDIX I
ATTACHMENT 1
Confidence Analysis — Model Evaluation

Stepwise Regression Model Quality Control
H. azteca, C. tentans, and Microtox®

PSE10-18628-610
08-16-05

This attachment serves as a quality control (QC) check of the regression model assumptions and data subset derived in *Appendix F – Initial Screening*. The more focused secondary statistical analysis will try to better assess the Gas Works Sediment Area (GWSA) chemical and bioassay inter-relationships using stepwise regression. Such analysis can be sensitive to "overfit," wherein too many variables are included for meaningful conclusions to be drawn. Using correlation and preliminary stepwise regression analyses of the Phase 3 data in the Initial Screening (Appendix F), specific metals and organics that appear to be representative of their counterparts were selected for the proposed subset.

In this QC, a combination of forward and stepwise regression is used to see if the proposed subset encompasses the majority of the variance in the data, or if other potentially relevant variables have been omitted from the model. The QC was run on the Phase 3 dataset in two ways:

(1) The subset of metals (arsenic, chromium, copper, mercury, zinc) was entered, by default, into the model (the "forward" regression), then the model was run to see if other remaining variables were added to the model (the stepwise regression). If not, then the project team has confidence that the five selected metals adequately address the influence of metals on bioassay response.

(2) The subset of organics (TPAH) was entered, by default into the model, with all remaining variables then being considered stepwise.

These two QC checks developed in consultation with a statistician were designed to improve the confidence in the model output. In addition, a third QC check was added to the analysis. Since several parameters were selected for transformation due to departure from normality (i.e., outliers), the question was posed regarding removal of outliers instead of transformation. Did the conclusions change if the outlier stations, in this case NLU51 and NLU86, were removed from the model? This third QC check tries to account for the outliers by excluding them from the data set rather than transforming non-normal variables.

SPSS version 10.0 was used for all analyses.

Proposed Data Subset

Conventionals: sulfide, ammonia, Log10(cyanide)

Organics: TPAH dw

Metals: arsenic, chromium, copper, mercury, zinc

Physical: percent fines

Bioassays: *Hyalella azteca* 10-day survival; *Chironomus tentans* 20-day survival and growth; Microtox® luminescence porewater test

Question #1: Does the subset of five metals adequately represent the metals group?

Forward: Metals Subset, Phase 3 only, all stations, transformed data as appropriate.

H. azteca

With metals defaulted into the regression model, Log10(TOC) and total solids also emerged as significant relative to *H. azteca*. The parameter total solids in and of itself does not necessarily have predictive relevance, so the analysis was re-run without this variable. Following that, a final model containing TPAH, dibenzofuran, and carbazole was generated (Table I-A1). The metals accounted for 66% of the variance.

C. tentans Survival

In analyzing *C. tentans* 20-day survival, TPAH was the only other parameter included into the model after inclusion of the five metals (Table I-A1). The metals accounted for 71% of the variance.

C. tentans Growth

After the five metals are included in the model, sulfide and Log10(lead) are added as relevant to the *C. tentans* growth endpoint (Table I-A1). The metals accounted for 83% of the variance.

Microtox®

No parameters other than metals are included in the Microtox® regression model once the metals subset is defaulted into it (Table I-A1). The metals accounted for 65% of the variance.

Question #2: Does the TPAH adequately represent the organics group?

Forward: Organics Subset, Phase 3 only, all stations, transformed data as appropriate.

H. azteca

With TPAH defaulted into the regression analysis, SPSS also incorporated dibenzofuran, carbazole, and total solids into the model for *H. azteca* (Table I-A1). Removal of total solids did not otherwise affect the outcome. TPAH accounted for 67% of the variance.

C. tentans Survival

For *C. tentans* survival, mercury and copper were added to TPAH in the regression model (Table I-A1). TPAH accounted for 74% of the variance.

C. tentans Growth

After inclusion of TPAH into the model, arsenic and silver are added as relevant to the *C. tentans* growth endpoint (Table I-A1). TPAH accounted for 40% of the variance.

Microtox®

The combined regression model identified percent fines as relevant to Microtox® in addition to the TPAH defaulted into the analysis (Table I-A1). TPAH accounted for 37% of the variance.

Question #3: If outlier samples are removed (NLU51 and NLU86) based on histograms, do the conclusions change?

A) Forward: Metals Subset, No transformation or outliers

H. azteca

With metals defaulted into the regression model, dibenzofuran and TBT also emerged as significant relative to *H. azteca* (Table I-A2). Metals accounted for 56% of the variance.

C. tentans Survival

Dibenzofuran was the only other parameter added to the model following addition of the metals subset when analyzed against *C. tentans* survival (Table I-A2). Metals accounted for 80% of the variance.

C. tentans Growth

After inclusion of the five metals into the model, sulfide and PCBs were added as relevant to the *C. tentans* growth endpoint (Table I-A2). Metals accounted for 76% of the variance.

Microtox®

The combined regression model identified TPAH, lead, and sulfide as relevant to Microtox® in addition to the metals subset defaulted into the analysis (Table I-A2). Metals accounted for 65% of the variance.

B) Forward: Organics Subset, No transformation

H. azteca

With TPAH defaulted into the model, TPAH-oc and total solids were identified as relevant. Since TPAH-oc is essentially redundant to TPAH, and because total solids are not themselves necessarily predictive, these two parameters were removed and the analysis re-run. Carbazole and dibenzofuran were then identified as relevant to *H. azteca* (Table I-A2). TPAH accounted for 81% of the variance.

C. tentans Survival

Relative to *C. tentans* survival, cadmium was the only other variable added to the model once TPAH was defaulted in (Table I-A2). TPAH accounted for 67% of the variance.

C. tentans Growth

After inclusion of TPAH into the model, silver and cadmium were added as relevant to the *C. tentans* growth endpoint (Table I-A2). TPAH accounted for 49% of the variance.

Microtox®

No other parameters were added to the Microtox model once TPAH was defaulted in (Table I-A2). TPAH accounted for 61% of the variance.

Conclusions

In the models including the metals, greater than two thirds of the variance was explained by just the five metals. Moreover, no other metals were ever added to the regression model. Thus, the conclusion that the subset is representative of the original suite of ten metals seems founded.

Models wherein TPAH was defaulted into the analysis incorporated a wider array of additional parameters following the stepwise regression. Those not already included in the subset include dibenzofuran, carbazole, and silver. Silver never exceeded reference sample concentrations, so may have a lake-wide distribution, making it less useful as a predictor.

Relative to the survival endpoints, TPAH was also included in the models wherein the metals were defaulted into the model. Conversely, in the metals-defaulted regressions, the *C. tentans* growth and Microtox® endpoints seem less sensitive to TPAH. These relationships are mirrored in the TPAH-defaulted models; TPAH accounted for greater than 67% of the variance relative to survival endpoints, and for no more than 40% of the variance for other endpoints.

Table I-A1. Forward & Stepwise Regression Summary: GWSA Phase 3 Dataset, All Parameters & All Stations

Parameters included:

Conventionals: sulfide, ammonia, log(TOC), log(cyanide)
Organics: TPAH, TPAH-oc, dibenzofuran, carbazole, log(PCBs)
Metals: arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), log(lead[Pb]), mercury (Hg), silver (Ag), TBT, zinc (Zn)
Physical: percent fines, total solids*

Parameter(s) Defaulted into Model		*H. azteca* 10-day Survival *	*C. tentans* 20-day Survival	*C. tentans* 20-day Growth	Microtox® Luminescence
As, Cr, Cu, Hg, Zn	Model	As, Cr, Cu, Hg, Zn (66%) TPAH (26%) Dibenzofuran (6%) Carbazole (1%)	As, Cr, Cu, Hg, Zn (71%) TPAH (23%)	As, Cr, Cu, Hg, Zn (79%) sulfide (11%) Log(Pb) (4%)	As, Cr, Cu, Hg, Zn (65%)
	Total Variance Explained	99%	94%	94%	65%
	Strength of Relationship	0.994	0.969	0.969	0.808
TPAH	Model	TPAH (67%) Dibenzofuran (25%) Carbazole (6%) Total Solids (0.4%)	TPAH (74%) Hg (13%) Cu (5%)	TPAH (40%) As (22%) Ag (16%)	TPAH (37%) % Fines (31%)
	Total Variance Explained	98%	92%	78%	68%
	Strength of Relationship	0.992	0.960	0.883	0.827

NOTES

Only the final model produced by the stepwise regression analysis is summarized.
Listwise exclusion was used for all regression analyses.
Additional variance explained (R-squared) given in ( ) after each model parameter.
Strength of relationship = regression coefficient (R); the closer the value is to 1, the stronger the relationship.
* total solids was excluded from analysis with metals defaulted into model

Table I-A2. Forward & Stepwise Regression Summary: GWSA Phase 3 Dataset, All Parameters, No Outliers or Transformations

Parameters included:

Conventionals: sulfide, ammonia, TOC, cyanide
Organics: TPAH, TPAH-oc, dibenzofuran, carbazole, PCBs
Metals: arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead(Pb), mercury (Hg), silver (Ag), TBT, zinc (Zn)
Physical: percent fines, total solids

Parameter(s) Defaulted into Model		*H. azteca* 10-day Survival *	*C. tentans* 20-day Survival	*C. tentans* 20-day Growth	Microtox® Luminescence
As, Cr, Cu, Hg, Zn	Model	As, Cr, Cu, Hg, Zn (56%) Dibenzofuran (39%) TBT (3%)	As, Cr, Cu, Hg, Zn (80%) Dibenzofuran (9%)	As, Cr, Cu, Hg, Zn (76%) sulfide (16%) PCBs (4%)	As, Cr, Cu, Hg, Zn (65%) TPAH (16%) Pb (9%) sulfide (6%)
	Total Variance Explained	98%	89%	96%	96%
	Strength of Relationship	0.991	0.945	0.978	0.982
TPAH	Model	TPAH (81%) Carbazole (11%) Dibenzofuran (4%)	TPAH (67%) Cd (15%)	TPAH (49%) Ag (19%) Cd (12%)	TPAH (61%)
	Total Variance Explained	96%	82%	80%	61%
	Strength of Relationship	0.979	0.904	0.895	0.783

NOTES

Only the final model produced by the stepwise regression analysis is summarized.
Listwise exclusion was used for all regression analyses.
Additional variance explained (R-squared) given in ( ) after each model parameter.
Strength of relationship = regression coefficient (R); the closer the value is to 1, the stronger the relationship.
* total solids and TPAH-oc were excluded from analysis with TPAH defaulted into model

APPENDIX 4C
Gas Works Sediment Area
Supplement to the Cleanup Standards Document

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February 2012

Gas Works Sediment Area Supplement to the Cleanup Standards Document

Draft Final

February 2, 2012

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Supplement to the Cleanup Standards Document

Draft Final

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List of Acronyms

Acronym/Abbreviation	Definition
AB	Area Boundary
ABS	dermal absorption factor
AET	apparent effects threshold
AF	adherence factor
ALM	adult lead model
ALU	ambient Lake Union
AO	Agreed Order
AOI	Area of Investigation
ARARs	Applicable or Relevant and Appropriate Requirements
AT	averaging time
ATL	acceptable fish tissue level
AVS	acid volatile sulfide
bgs	below ground surface
BCOC	bioaccumulative chemical of concern
BTAG	biological Technical Assistance Group
BW	body weight
BTEX	benzene, toluene, ethylbenzene, and xylene
C	COPC-specific concentration
CD	Consent Decree
CDI	chronic daily intake
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CF	unit conversion factor
City	City of Seattle
COC	chemical of concern
COI	chemical of interest
COPC	chemical of potential concern
Cr III	trivalent chromium
Cr VI	hexavalent chromium
Csed	sediment concentration
CSL	chemical screening level
CSO	combined sewer overflow
CT	central tendency
CTL	critical tissue level

List of Acronyms

Acronym/Abbreviation	Definition
DDD	dichlorodiphenyldichloroethane
DDT	dichlorodiphenyltrichloroethane
DEQ	Department of Environmental Quality
DF	dietary fraction
DNAPL	dense non-aqueous phase liquid
DNR	Department of Natural Resources
Ecology	Washington State Department of Ecology
ED	exposure duration
EF	exposure frequency
EIM	Environmental Information Management
EPA	United States Environmental Protection Agency
ERED	Environmental Residue-Effects Database
ESA	Endangered Species Act
FI	fractional intake
FIR	food ingestion rate
GWSA	Gas Works Sediment Area
GWS-ESA	Gas Works Sediment Eastern Study Area
GWS-WSA	Gas Works Sediment Western Study Area
Harbor Patrol	Seattle Police Department Harbor Patrol
HEAST	Health Effects Summary Table
HI	hazard index
HPAH	high-molecular weight polycyclic aromatic hydrocarbon
HQ	hazard quotient
IEUBK	Integrated Exposure Uptake Biokinetic Model
IR	ingestion rate
IRIS	Integrated Risk Management System
LAET	Lowest Apparent Effects Threshold
2LAET	Second Lowest Apparent Effects Threshold
LDWG	Lower Duwamish Waterway Group
LOAEL	Lowest Observed Adverse Effect Level
Locks	Hiram M. Chittenden Locks
LOED	Lowest Observed Effective Dose
LPAH	low-molecular weight polycyclic aromatic hydrocarbon
LWG	Lower Willamette Group

List of Acronyms

Acronym/Abbreviation	Definition
MGP	manufactured gas plant
MIT	Muckleshoot Indian Tribe
MTCA	Washington State Model Toxics Control Act
NCP	National Contingency Plan
NOAEL	No Observed Adverse Effect Level
NOED	No Observed Effective Dose
NLSY	Northlake Shipyard Site
NOAA Fisheries	National Oceanic and Atmospheric Administration National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
Oregon DEQ	Oregon Department of Environmental Quality
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCP	pentachlorophenol
ppm	part per million
PRG	preliminary remedial goal
PSE	Puget Sound Energy
QA	quality assurance
RAO	remedial action objective
RfD	reference dose
RME	reasonable maximum exposure
RSET	Regional Sediment Evaluation Team
RSL	regional screening level
RL	reporting Limit
RI/FS	remedial investigation/feasibility study
SA	surface skin area exposed
SCSL	site-specific cleanup screening level
SEF	Sediment Evaluation Framework
SEDQUAL	Sediment Quality Information System
SF	slope factor
SIR	sediment ingestion rate
SLV	screening level value
SMS	Sediment Management Standards
SPU	Seattle Public Utilities

List of Acronyms

Acronym/Abbreviation	Definition
SQS	sediment quality standards
SQV	sediment quality value
SSQL	site-specific sediment quality level
SVOC	semivolatile organic compound
TBT	tributyltin
TEF	toxic equivalency factor
TOC	total organic carbon
TPAH	total polycyclic aromatic hydrocarbons
TPH	total petroleum hydrocarbons
TRV	toxicity reference value
TTL	target tissue levels
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VOC	volatile organic compound
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WSDOH	Washington State Department of Health

Executive Summary

Introduction and Document Objectives

The Gas Works Sediment Area (GWSA; the Site) is located along the northern shore of Lake Union, which is located north of downtown Seattle, Washington. Historical operations at the adjacent Gas Works Park Uplands (Uplands) resulted in environmental contamination; the Uplands have been investigated, remedial actions have been implemented, and monitoring is ongoing, as documented in a formal Consent Decree (CD). The investigation of Lake Union sediments offshore from the Uplands are being addressed in a separate process under an Agreed Order (AO) between the Washington State Department of Ecology (Ecology), Puget Sound Energy (PSE), and the City of Seattle (City).

The AO focuses on sediments impacted by releases from Uplands historical activities. The AO defines two study areas for which Remedial Investigation/Feasibility Study (RI/FS) documents are being prepared, the Gas Works Sediment Western Study Area (GWS-WSA) and the Gas Works Sediment Eastern Study Area (GWS-ESA). The overall objective of both RI/FS documents is to address GWSA sediment impacts associated with historical Uplands activities by protecting human health and aquatic receptors under MTCA.

The previously completed *Gas Works Sediment Area Cleanup Standard Determination* document (RETEC 2005a) contains a detailed analysis of synoptic sediment physical, chemical and bioassay datasets that supported the identification of total polycyclic aromatic hydrocarbons (TPAH) as the chemical of concern (COC) for the site. This document presented the site-specific cleanup standard, which included the cleanup level for TPAH and the area within which sediment remedial actions associated with the GWSA will be evaluated.

Since issuance of the GWSA Cleanup Standard Determination document and draft GWS-ESA and GWS-WSA RI/FS documents (RETEC 2006; Floyd|Snider 2007), a number of agencies and stakeholders have reviewed these documents and provided comments that expressed concerns with the chemical of potential concern (COPC) screening process, the focus on a cleanup level based solely on TPAH, and the need for a site-specific human health and ecological risk evaluation. This Supplement to the Cleanup Standards Document is designed to address these agency and stakeholder concerns and has the following objectives:

- Fulfill agency and stakeholder requests for a more comprehensive site-wide COPC screening process
- Fulfill agency and stakeholder requests for a site-specific quantitative evaluation of risks to human health and ecological receptors
- Revisit the TPAH-based site-specific sediment quality level (SSQL) in the context of the results of the revised COPC screening process and site-specific risk evaluation
- Revisit the remedial action area and consider an alternative approach to defining the lateral extent of the remedial area so that concentrations in the remedial area are indistinguishable from concentrations associated with ambient Lake Union (ALU) conditions.

This document is a companion to the *Cleanup Standard Determination* document (RETEC 2005a). Like the original Cleanup Standard document, this Supplement to the Cleanup Standards work will be carried forward into the revised RI/FS reports for the GWS-WSA and GWS-ESA, discussed further below.

COPC Screening Results

Available validated sediment data and tissue data was utilized for COPC screening. The maximum detected sediment concentration or reporting limit was compared to an extensive list of screening criteria, including freshwater sediment, soils, or tissue screening values. Exceedances were further refined to generate a list of 59 COPCs which were carried forward into site-specific human health and ecological risk evaluations.

Human Health Risk Evaluation Results

Potential exposure pathways were then identified for the human health risk evaluation. These pathways included direct contact (dermal absorption and incidental ingestion) with sediments by children and adults via beach play/ wading and netfishing (Tribal population). Although wading was not specifically assessed as an individual exposure pathway, the beach play exposure scenarios encompass wading exposures and are more conservative than wading scenarios. Therefore, the beach play scenario is referred to as beach play/wading in this Supplement to the Cleanup Standards Document. Furthermore, ingestion of fish resources present in the GWSA by both the general and Tribal populations is evaluated. Both a reasonable maximum exposure (RME) scenario and central tendency (CT) scenario were developed. The RME is the highest exposure that is reasonably expected to occur and by definition, likely overestimates exposure for many individuals. To provide a measure of the range of uncertainty associated with exposure and risk, CT risk estimates were calculated to reflect average exposures as compared to the RME (the CT scenario may underestimate exposure for a number of individuals). The RME scenarios were extremely conservative, and resulted in estimated potential risks above acceptable carcinogenic risk thresholds across all RME exposure scenarios. Only four COPCs or COPC groups (e.g., carcinogenic high-molecular weight polycyclic aromatic hydrocarbons (HPAHs)) had significant exceedances of the minimum individual acceptable MTCA and EPA risk thresholds under the RME scenario including: HPAHs, arsenic, chromium VI, and polychlorinated biphenyls (PCBs). Also under the RME scenario, lead and vanadium are estimated to have low exceedances of acceptable risk thresholds, and three additional COPCs (antimony, pentachlorophenol, and chlordane) had marginal risk threshold exceedances based solely on conservative assumptions for non-detected concentrations. Estimated potential risks for the CT scenarios were about one to two orders of magnitude less than the estimated risks for the RME scenarios. Estimated potential CT risks were marginal to low for all scenarios except the tribal fish consumption pathway. For all CT scenarios, estimated potential risks above acceptable carcinogenic risk thresholds occurred only for three COPCs or COPC groups including: arsenic, HPAHs, and PCBs.

Ecological Risk Evaluation Results

Potential ecological receptors evaluated include two birds (the great blue heron and the American mallard), a mammal (northern river otter), and juvenile Chinook salmon. For all receptors, the ingestion of sediments and fish resources present in the GWSA vicinity was considered. Incidental sediment ingestion is the primary source of potential risk for all wildlife receptors. The most significant contributors to potential risk varied between ecological receptors. Tributyltin (TBT) resulted in the greatest estimated potential risk threshold exceedance for the juvenile salmonid receptor, with low risk threshold exceedances estimated for four other COPCs: arsenic, vanadium, HPAHs, and bis(2)-ethylhexylphthalate. Slight risk threshold exceedances were estimated for two COPCs: benzo(a)pyrene and HPAH for the American mallard and Northern river otter receptors, respectively.

Risk Driver Assessment

Certain risk exposure scenarios and COPCs result in estimated potential risks that are orders of magnitude higher than those predicted from other exposure scenarios and COPCs. Consistent with MTCA and EPA guidance, the exposure scenarios and COPCs that are driving a need for remedial action are referred to as "risk drivers." Of the 21 COPCs or COPC groups exceeding risk thresholds under the RME scenario, the risk driver assessment identified three risk drivers for human health: TPAH (including benzo(a)pyrene and HPAH), arsenic and PCBs, and one risk driver for the salmon ecological receptor, tributyltin. Risk drivers were not identified for the blue heron, mallard, or otter ecological receptors.

Identification of GWSA Indicator COCs

For the 21 COPCs exceeding risk thresholds, chemicals were identified as GWSA COCs if their GWSA concentration was statistically higher than their ALU concentration. Conversely, COPCs that exceeded risk thresholds but were statistically higher in Lake Union than the GWSA were identified as ALU COCs (e.g. TBT, PCBs, and arsenic). GWSA COCs that were also identified as risk drivers were identified as GWSA Indicator COCs. The final list of GWSA Indicator COCs includes HPAH, TPAH, and benzo(a)pyrene because they were identified as both having concentrations that were statistically higher than ALU concentrations and comprise the majority of the risk. Identification of GWSA Indicator COCs will facilitate the remedial analysis in the FSs by focusing on GWSA risk reduction. Ambient Lake Union risk driver COCs (arsenic, PCBs, and TBT) will be further evaluated as part of the subsequent FS.

Integration with Revised RI/FSs

The complexity of determining the lateral extent of cleanup in the GWSA is directly related to its urban setting. The GWSA exists within a continuum of impacted sediments with a "working lake" history. This complicates the determination of a cleanup approach that is protective of both human and ecological health, since all of the COCs that drive risk (and nearly all of the COPCs) are ubiquitous urban pollutants. Many of these urban pollutants are not associated with historical Upland activities.

Both the draft GWS-ESA and -WSA RI/FS documents evaluated remedial alternatives based primarily on the GWSA cleanup standard for TPAH that is protective of ecological (benthic) health based on MTCA and SMS guidance. This Supplement (consistent with MTCA and EPA guidance) identifies additional exposure scenarios and COCs that drive ecological and human health risk threshold exceedances within the GWSA. In addition, this Supplement provides a complimentary approach to the Area Boundary line, identifying how far offshore remedial actions may need to extend to address GWSA Indicator COCs by comparing the Indicator COC concentrations within the GWSA to concentrations in the rest of the lake. While this information does not establish a new cleanup standard, it augments the previously established site-specific cleanup standard, and provides additional information that will be incorporated in the revised RI/FSs and used to evaluate the proposed remedial alternatives. The GWSA remedial effort will not address potential risks associated with the rest of Lake Union (i.e. ambient Lake Union risks); ambient Lake Union conditions will need to be addressed in a future process separate from the GWSA.

Summary

In summary, this Supplement to the GWSA Cleanup Standards Determination document fulfills all of the intended objectives identified for this document by providing: a more comprehensive site-wide

COPC screening process; a site-specific quantitative evaluation of risks to human health and ecological receptors; a review of the TPAH-based site-specific sediment quality level (SSQL) in the context of these results; and the development of an alternative approach to defining the lateral remedial extent.

Use of these supplemental results in the revised RI/FSs will result in the determination of a remedial GWSA extent that is statistically indistinguishable—or better—than ALU conditions. The RI/FSs will evaluate the ALU COCs within the GWSA despite the fact that they are associated with the rest of Lake Union and not historical Upland activities. Ambient Lake Union potential risks outside of the GWSA will need to be addressed as part of a future process distinct from the GWSA remedial action. Thus, this Supplement compliments the GWSA Cleanup Standards Determination document and associated Cleanup Standard focus on TPAH as the primary COC and will be incorporated into the revised RI/FSs being prepared for the Eastern and Western Study Areas by PSE and the City, respectively.

1.0 Introduction and Context

This section provides important information on the Gas Works Sediment Area, including the GWSA cleanup objectives, site setting, derivation of the Area of Investigation for the site, and derivation of the site-specific cleanup levels. Additionally, it describes how this document is designed to address stakeholder comments on the site-specific cleanup level process and how it relates to the RI/FS documents.

1.1 Gas Works Sediment Area Cleanup Objectives

The Gas Works Sediment Area (GWSA; the Site) is located along the northern shore of Lake Union, which is located north of downtown Seattle, Washington. The Site is adjacent to a City of Seattle (City) park; both the Site and the park are named after the historical manufactured gas plant (MGP or Gas Works). Historical operations at the park have resulted in environmental contamination, primarily by residual materials associated with the MGP and an adjacent tar refinery as well as other industrial activities. The Gas Works Park Uplands (Uplands), which includes the City park as well as the adjacent Seattle Police Department Harbor Patrol facility (Harbor Patrol), have been investigated, remedial actions have been implemented, and monitoring is ongoing, as documented in a formal Consent Decree (CD; No. 99-2-52532-9SEA) between the Washington State Department of Ecology (Ecology), Puget Sound Energy (PSE), and the City (Ecology 1999).

The investigation of Lake Union sediments offshore from the Uplands are being addressed in a separate process under an Agreed Order (AO; No. DE 2008; Ecology 2005) between Ecology, PSE, and the City. This AO focuses on sediments impacted by releases from Uplands historical activities. The AO covers the preparation of a remedial investigation and feasibility study (RI/FS) consistent with Washington's Model Toxics Control Act (MTCA) regulations (Washington Administrative Code [WAC] 173-340) for the GWSA. The AO defines two study areas: the Gas Works Sediment Western Study Area (GWS-WSA) and the Gas Works Sediment Eastern Study Area (GWS ESA). The preparation of the GWS-ESA RI/FS is being led by PSE, while the GWS-WSA RI/FS is being led by the City.

The overall objective of both RI/FS documents is to address sediment contamination found within the GWSA associated with Uplands sources by protecting human health and aquatic receptors from exposure to contamination that exceeds the site-specific cleanup level(s) as defined for the site under MTCA and the Sediment Management Standards (SMS). A complexity of the GWSA is the urban setting: the GWSA exists within a continuum of impacted sediments with a "working lake" history. This complicates the derivation of site-specific cleanup standards and how to establish cleanup levels protective of both human and ecological health, since some of the bioaccumulative chemicals of greatest concern are ubiquitous urban pollutants.

Certain AO requirements—such as development of site-specific cleanup standards—are site-wide concerns. These site-wide documents are being developed jointly by PSE and the City. These documents are intended to meet the requirements of an RI/FS under MTCA (WAC 173-340) and of a Cleanup Study Report under Washington's SMS (WAC 173-204). It is anticipated that public review of the GWS-ESA and GWS-WSA RI/FS documents and supporting material will be conducted in one process to assist site-wide coordination of the proposed remedial actions.

1.2 GWSA Setting

The GSWA is located along the northern shore of Lake Union. Lake Union is part of a series of urban waterways and embayments that connect the western marine waters of Puget Sound to the eastern fresh waters of Lake Washington. These water bodies are collectively referred to as the Lake

Washington Ship Canal, or Ship Canal system. The Ship Canal system consists of Shilshole Bay, the Hiram M. Chittenden Locks (Locks), Salmon Bay Waterway, the Fremont Cut, Lake Union, Portage Bay, the Montlake Cut, and Union Bay.

The GWSA is defined as those sediments offshore of the Uplands that have been impacted by historical industrial practices and historical Uplands activities. An Area of Investigation (AOI) line, as shown on Figure 1-1, encompasses these impacted sediments. In 2004, the AOI was developed to identify the spatial extent of the sediments likely to have been impacted by the historical Uplands activities. The AOI is the area where the RI/FS evaluations of the sediments are focused, including evaluations contained within this Supplemental Cleanup Standard Document. Derivation of the AOI line is discussed in greater detail in the following section.

Based on information contained in the draft RI/FS documents, the historical industrial uses of the Lake Union shoreline are well documented. A 1943 publication from the State Pollution Commission listed industrial businesses that operated along the shores of Lake Union and the Ship Canal (Foster 1943). The MGP on North Lake Union was described along with a range of other industries around the lake, including 10 machine shops and metal foundries; 10 lumber and plywood mills; 12 fuel and oil storage and service facilities; 8 sand, gravel, concrete and/or asphalt facilities; and a municipal power plant (Foster 1943; Tomlinson et al. 1977). Additionally, Lake Union is, and has historically been, a central location for marine and boating activities, including houseboats. Marinas, boats, and houseboats also discharged wastes into the lake (Foster 1943; Tomlinson et al. 1977).

Lake Union, as a whole, also received discharges from combined sewer overflows (CSOs), private sewage outfalls, and storm drainage from the urbanizing Seattle. Private industrial outfalls also discharged to the lake, such as MGP outfalls identified by the State Pollution Commission (Foster 1943). Between 1943 and 1977, the number of City sewer overflow pipes grew from 10 to 19, new storm drains were added (such as those carrying drainage from Interstate 5), and private sewage outfalls were intercepted and rerouted by City sewer service (Tomlinson et al. 1977). Metro King County was founded in 1958 and was charged with addressing water quality issues in the Lake Washington system caused by raw sewage. Additional, many individual National Pollutant Discharge Elimination System (NPDES) permits have been granted for Lake Union or Ship Canal discharges. Most current NPDES permits for Lake Union and the Ship Canal relate to boatyard/shipbuilding industry.

Over the past several decades, Lake Union development has expanded to include more marinas, houseboats, offices, restaurants, and shoreline residences—in addition to its historical industrial and marine-oriented commercial uses (City of Seattle 1986). Today Lake Union's shores are primarily lined with marinas, houseboat moorage, commercial docks, dry docks, and industries (King County DNR 2001).

Other MTCA cleanup sites that are physically adjacent to the GWSA and/or within the GWSA include the Northlake Shipyard Site (NLSY; formerly UNIMAR) and the Metro Lake Union facility, or Facilities North/Metro Lake Union Site, formerly known as the Chevron Bulk Fueling Terminal #100-1327. Both are on the west side of the GWSA (see Figure 1-1).

1.3 AOI and GWSA Cleanup Standards Determination Document

1.3.1 AOI and Ambient Lake Union Conditions

In June 2004, the City and PSE proposed to Ecology the AOI defining the GWSA. The AOI was defined as the area where the RI/FS of the sediments would focus. The AOI was developed based on an assessment of existing data, to identify the spatial extent of the sediments likely to have been impacted by historical Uplands activities (RETEC and FSM 2004).

As part of the AOI determination, the ambient condition of the surface sediments in Lake Union was investigated based on existing data. A variety of sediment impacts were documented throughout Lake Union. Available information from other sediment sites and a variety of studies by the U.S. Environmental Protection Agency (EPA), King County, and others, document urban lake conditions resulting from historical industrial and municipal practices that, through a variety of likely release mechanisms, have contributed to poor sediment quality and elevated ambient concentrations of chemicals. This is particularly true for polycyclic aromatic hydrocarbons (PAHs) and metals. Historical studies have documented elevated metals concentrations in the middle of Lake Union, PCBs in sediments throughout the lake, and moderate PAH concentrations in areas of the lake away from the vicinity of the GWSA. A *Survey of Contaminants in Sediments in Lake Union and Adjoining Waters* concluded that Lake Union sediments are relatively uniformly contaminated (Cubbage 1992). As part of the AOI derivation process, an ambient lake-wide TPAH concentration of approximately 100 ppm TPAH was calculated.[1]

Historical studies also document that the highest concentrations of TPAH in Lake Union are observed immediately offshore of Gas Works Park (Hansen et al. 1994, Cubbage 1992). TPAH contamination in the GWSA is significantly higher than ambient lake-wide conditions due to impacts from the historical Uplands activities. Sediments in the GWSA have surface concentrations of TPAH ranging up to 11,100 ppm and exhibit acute toxicity to benthic organisms. The objective of the GWSA cleanup is to remediate this area of the lake sediments associated with historical Uplands activities.

As part of the AOI determination, a weight of evidence approach was used to evaluate the spatial extent of Uplands impacts. Such lines of evidence included the concentration of PAHs in sediments relative to ambient lake conditions (i.e., where TPAH concentrations present were higher or lower than ambient conditions), the types of PAHs present, an evaluation of metals from adjacent sources, and physical factors such as slope and bathymetry in the North Lake Union vicinity.

1.3.2 GWSA Cleanup Standard Determination Process

Currently, there are no freshwater sediment criteria promulgated under MTCA. Sediment cleanup standards under MTCA are regulated by the SMS promulgated under Section 173-204 WAC. The SMS delineate a sediment cleanup decision process for identifying contaminated sediment areas and volumes and for determining the appropriate cleanup responses. The SMS provide numeric analytical and biological criteria for the evaluation of marine sediments, but for freshwater sediments leave sediment criteria methods and procedures to be developed on a site-specific basis (WAC 173-204-340).

In 2002, synoptic chemical, physical, and bioassay data were collected (RETEC 2004a and 2004b) as part of the initial RI/FS investigation. Supplemental bioassay studies were conducted in parallel with the 2004-2005 RI/FS investigations in both study areas. These bioassay studies were used to develop site-specific sediment cleanup standards in accordance with the SMS. Biological testing (i.e., bioassays) can be used to determine site-specific cleanup standards for a contaminated site on the basis of the observed toxicity of the sediments.

[1] In 2004, as part of the AOI determination, an area background analysis was conducted using Ecology's MTCAStat software to determine the ambient Lake Union TPAH concentration (RETEC and FSM 2004). The sample population consisted of results obtained from Ecology's SEDQUAL database, as well as data for samples collected by PSE and Ecology between 1999 and 2002. Following a quality control evaluation of the results, ambient data were selected following steps to ensure that the data were representative of ambient conditions (e.g., away from nearshore sources). MTCAStat calculations of the 90th percentile on this preliminary Ambient Lake Union data set indicated that ambient TPAH concentrations were approximately 100 mg/kg.

Observed sediment toxicity can be correlated with chemical concentrations to identify:

- Chemicals that are "driving" observed toxicity by determining the strength of correlations between biological effects and chemical concentrations
- Site-specific cleanup levels less than which sediment toxicity should not be observed, and greater than which sediment toxicity may be observed.

Remediating sediments with contaminant levels above the site-specific cleanup number(s) thus protects the sediment benthic community from sediment toxicity associated with elevated chemical concentrations, particularly TPAH. Sediment cleanup levels established in this manner in accordance with the SMS are intended to have "no adverse effects on biological resources and correspond to no significant health risk to humans" (WAC 173-204-300). The scope of the 2005 bioassay investigation was focused on the derivation of site-specific cleanup standard(s) for the entire GWSA—both the eastern and western study areas.

1.3.3 Derivation of Site-specific Cleanup Levels

The supplemental bioassay studies were conducted in accordance with the AO for both RI/FS documents and the decisions made in a series of meetings held between March and July 2005 that included Ecology, PSE, and City representatives. The scope and objectives of the supplemental study are detailed in the *Site-wide Supplemental Bioassay Sampling and Analysis Plan and Quality Assurance Project Plan* (RETEC 2005b).

Extensive synoptic bioassay and chemical testing was performed within the GWSA. Synoptic testing involves collecting sediments sufficient for chemical as well as bioassay testing in parallel, ensuring that the chemical concentrations of the test sediments are directly comparable to the biological responses. Bioassay receptors used included the freshwater amphipod *Hyallela azteca*, which is common in aquatic environments; *Chironomus dilutes*,[2] the larval stage of a non-biting midge; and the luminescent marine bacteria called Microtox®. The tests included the *H. azteca* 10-day mortality bioassay (i.e., how many amphipods survived after 10-day exposures to GWSA sediments), the *Chironomus dilutus* 20-day growth and mortality bioassay (i.e., observed growth and survival of larvae in 20-day exposures to GWSA sediments); and the Microtox® porewater test (i.e., changes in light output of the Microtox® during exposure to extracted GWSA sediment porewater). The bioassay results were compared to Ecology's draft freshwater bioassay decision criteria (Avocet/SAIC 2003) to identify passes and failures.

Chemicals associated with Uplands historical activities were measured in GWSA sediments and used for interpretation of the bioassay results. Uplands COCs include 10 PAHs, as well as several volatile organic compounds (VOCs) and arsenic. Other chemicals that might be found in North Lake Union were also measured, including metals, PCBs, and TBT. These chemicals were measured in the same sediments used for bioassays; therefore, observed biological effects could then be correlated with chemical concentrations to determine which chemicals, and at what levels, cause effects.

The overall methodology used to interpret GWSA bioassay data and derive a site-specific cleanup number involved a series of sequential statistical steps performed in collaboration with Ecology. These steps included tools such as: 1) multivariate evaluation of data, 2) aggregation of parameters into several key variables that explain toxicity, 3) clustering of data stations into groups, and 4) use of Apparent Effects Threshold (AET) and concentration-response relationships to derive protective chemical concentrations for purposes of establishing cleanup levels. The outcome of these

[2] The midge *Chironomus dilutus* was formerly known as *Chironomus tentans* (Shobanov et al. 1999).

evaluations resulted in an understanding of what chemicals were “driving” observed benthic toxicity, how sediment areas related to each other based on the types of chemicals present, and site-specific cleanup standards below which biological effects were not expected to occur.

The site-specific cleanup standard for TPAH was derived using the following parameters:

- The impacts of non-Uplands nearby sources of chemicals such as metals from shipyards
- Site-specific sediment bioassay and chemistry results
- Determination of TPAH effects concentrations.

Based on the range of observed bioassay results for 31 samples primarily impacted by TPAH, two site-specific TPAH sediment cleanup levels were determined to be representative of SMS Sediment Quality Standards (SQSs) and chemical screening levels (CSLs). The site-specific sediment quality level (SSQL) thus corresponds to the chemical standard less than which no adverse effects, including no acute or chronic adverse effects, were observed. The site-specific cleanup screening level (SCSL) corresponded to a level greater than which adverse effects were observed. Thus, for example, sediment TPAH concentrations that exceeded the SCSL standard would be expected to cause toxicity or other adverse effect to benthic biota; sediment TPAH concentrations less than the SSQL standard would be expected to have no adverse effects on benthic biota.

These two criteria were determined using a ranking approach similar to the AET approach used in the SMS. The two site-specific cleanup levels are as follows:

- The SCSL for the entire GWSA is 290 mg/kg TPAH dry weight
- The SSQL for the entire GWSA is 170 mg/kg TPAH dry weight.

Importantly, for purposes of evaluating whether sediments must be remediated in the RI/FS process, the SSQL (170 mg/kg TPAHs) is used as the GWSA cleanup level.

1.3.4 Identification of TPAH as the Site COC

Overall, non-carbon normalized TPAH, the total sum of 16 individual PAH compounds, was found to be the variable which explained most of the toxicity observed among biological endpoints observed (such as growth and mortality). Furthermore, the distribution of GWSA-related chemicals was explored to ensure that a cleanup standard could confidently be based on TPAH. Several lines of evidence indicate PAHs are an appropriate COC for the GWSA:

- PAHs were associated with the historical Uplands activities
- PAHs were identified as COC(s) for the Gas Work Park Uplands
- TPAH were also found to spatially overlap other preliminary Gas Works Upland-related COPCs so that if a site-specific cleanup level was applied to the contaminated sediments, it would address the occurrence of other Uplands COPCs
- Bioassay results indicated similar responses across a suite of bioassay tests, study events, and TPAH concentrations, indicating that the observed relationship between TPAH concentrations and toxicity was valid.

In summary, the detailed analysis of these synoptic sediment physical, chemical, and bioassay data sets supported the identification of TPAH as the COC for the Site. Statistical analysis showed that TPAH was the appropriate chemical upon which to focus a remedial action.

Details of these results are provided in the *Gas Works Sediment Area Cleanup Standard Determination* (RETEC 2005a) prepared by PSE and the City. This document presented the site-specific cleanup standards for TPAH and defined the area within which sediment remedial actions associated with the GWSA would be evaluated in the RI/FS documents. The site-specific cleanup standards for TPAH and the area to evaluate remedial actions were derived based on bioassay results and concentrations of TPAH in surface sediments (in order to laterally bound the potential impacts to biological communities from PAHs).

Ecology approved the *Gas Works Sediment Cleanup Standard Determination* (RETEC 2005a), including the site-specific sediment cleanup standard and the remedial evaluation area, with the exception of the far western portion of that boundary (Keeling 2006). Because the far western portion of the GWSA bisects an area of elevated TPAHs and metals, Ecology requested additional technical analysis to support the establishment of the boundary in this area. The *Gas Works Sediment Area Western Boundary Technical Memorandum* (Floyd|Snider 2006) was developed in response to Ecology's request, and the proposed western boundary was approved by Ecology (Keeling 2006).

1.4 Supplement to the Cleanup Standards Document

Since issuance of the draft GWS-ESA RI/FS and draft GWS-WSA RI/FS documents, a number of agencies and stakeholders have reviewed the draft RI/FS documents and provided comments on the documents. These include the Muckleshoot Indian Tribe (MIT), Department of Natural Resources (DNR), EPA, Washington Department of Fish and Wildlife (WDFW), and National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA Fisheries).

Stakeholder comments expressed concern as to whether the COPC screening process in the draft RI/FS documents adequately screened risks to human health and ecological endpoints. Furthermore, they expressed concerns that a cleanup standard based on benthic toxicity would address all risks to human health and ecological receptors. The focus on TPAH and the "exclusion" of other COPCs was criticized. There were concerns regarding the absence of a baseline risk evaluation. Finally, because COPCs were identified slightly differently in the GWS-ESA RI/FS and GWS-WSA RI/FS, a comprehensive, uniform COPC screening process for the GWSA was requested.

This Supplement to the Cleanup Standards Document is designed to: 1) be a companion document to the GWSA Cleanup Standard Determination document; and 2) address agency and stakeholder concerns about COPC screening and evaluation of risks to human health and ecological receptors. This additional evaluation was conducted by performing a new COPC screening process and evaluating site-specific ecological risks and human health risks from beach play/wading at Gas Works Park from Tribal netfishing, and the consumption of Lake Union fish resources. The additional quantitative ecological risk evaluation that was conducted as part of this supplemental work compliments the bioassay work conducted to identify thresholds that are protective of the benthic invertebrate populations per the SMS and as summarized in the bioassay report (RETEC 2004b).

This Supplement to the Cleanup Standards Document was conducted using existing data, where available, to perform COPC screenings and risk evaluations. No new sediment or tissue analytical data was collected as part of this work.

1.5 Relationship to Eastern and Western Study Areas RI/FS Documents

As noted above, this document is a companion to the original GWSA Cleanup Standard Determination document. Like the original Cleanup Standard document, this Supplement to the Cleanup Standards work will be carried forward into the RI/FS process for the GWSA. Draft RI/FS documents have been submitted for both the Eastern and Western GWSA study areas; final RI/FS documents will be prepared for each area.

2.0 Data Review

To address the EPA and Tribal comments on the draft RI/FS documents, PSE, and the City have re-evaluated COPCs in the GWSA, as described in Section 3. This section (Section 2) describes the Lake Union data sets used for the COPC re-evaluation (Section 3), the risk evaluation (Section 4), and the determination of indicator COCs (Section 5).

Lake Union has been studied since the 1960s (Hansen 1994), and a variety of researchers have investigated various parameters including sediment quality and biota (including bioassay testing and tissue analysis). Sediment and tissue chemistry data are the focus of this effort. Available sediment data are reviewed in Section 2.1. These data were re-evaluated for quality and completeness as described in Section 2.2; those data deemed valid for use in this evaluation were compiled into a final Lake Union data set, described in Section 2.3. Tissue data are reviewed in Section 2.4.

2.1 Available Sediment Data

All available Lake Union sediment chemistry data collected since 1977 were evaluated for use in this study. Some studies were not used due to data quality problems as described in the *Gas Works Park Sediment Area AOI Package* (RETEC and FSM 2004) and summarized in Table 2-1. Project data (data collected by PSE and the City as part of the GWSA RI/FS process) sources included sediment investigations conducted by PSE in 1999, 2002, and 2004; a sediment investigation conducted by the City in 2005; and a joint PSE and City sediment investigation conducted in 2005. Non-project data sources (i.e., sources other than sediment investigations conducted by PSE or the City) included Ecology's project files, King County files, and Ecology's inventory of freshwater sediment quality studies formerly maintained in Ecology's Sediment Quality Information System (SEDQUAL) and currently in the Environmental Information Management (EIM) database. Much of the available non-project data were retrieved from Ecology's SEDQUAL database. Figure 2-1 shows all of the sediment studies and locations considered for use in the evaluation.

The Lake Union data set was split into two subsets: the GWSA data set, and the Ambient Lake Union (ALU) data set. The GWSA data set included most samples collected within the study area or the AOI defined in the March 11, 2005, Agreed Order (No. DE 2008) between PSE, the City, and Ecology (Ecology 2005), and is further described in Section 2.3.2. The ALU data set included samples outside the study area, and is further detailed in Section 2.3.1.

2.2 Sediment Data Evaluation

Both project and non-project sediment data were reviewed prior to incorporation into the final Lake Union data set. In 2004, PSE and the City undertook an evaluation of available data for the development of the AOI boundary (RETEC and FSM 2004). Based on this review, PSE and the City made recommendations to Ecology for the use (or exclusion) of available data. In some cases, an entire study was deemed problematic (e.g., incomplete list of PAHs, high occurrence of data qualifiers) and was excluded from the data set. In other cases, specific samples were excluded rather than entire studies. Samples were excluded if they were composited from multiple locations or represented reference stations outside Lake Union.

During the course of the data evaluation, it was recognized that, due to the presence of very soft surface sediments, over-penetration of surface sediments may have occurred during sampling, potentially resulting in incorporation of deeper sediment in some surface sediment samples. Because the chemical analysis data quality was deemed acceptable for these samples and they are thought to generally represent surficial/shallow sediment, they were retained for use the in Lake Union data set.

However, their use in the RI/FS for selecting a final remedial alternative may be qualified. More information on these data sets will be provided in the revised RI/FS documents.

Since completion of the AOI report, additional data were discovered from studies conducted by King County in 2001 and 2008 (R. Jack, personal communication, 2009), and from a study conducted by Ecology at NLSY in 2009 (Ecology & Environment, Inc. 2009). After a review, these King County and Ecology data were integrated into the project database to generate the final Lake Union data set used in this study.

Project data collected by PSE and the City underwent data validation and quality assurance (QA) checks prior to incorporation in the Lake Union data set. These data quality reviews are provided in the draft Eastern and Western Study Area RI/FS documents (RETEC 2006 and Floyd|Snider 2007, respectively).

In summary, the final Lake Union data set incorporated those studies and samples recommended for use following the AOI data evaluation in 2004, the project data collected between 1999 and 2005, the recently discovered King County data from 2001 and 2008, and NLSY data from 2009. Both surface and subsurface samples collected since 1999 were included in the Lake Union data set. The Lake Union data set is described in additional detail in the following section.

2.3 Lake Union Sediment Data Set

The final Lake Union data set is comprised of 400 sample locations, with samples collected between 1986 and 2009. All studies comprising the Lake Union sediment data set are summarized in Table 2-1 and shown on Figure 2-2. For the purposes of this study, the final Lake Union data set was divided into the ALU data set and the GWSA data set. The complete sediment data with the exceptions of the King County and Ecology data discussed above are provided in the draft Eastern and Western Study Area RI/FS documents (RETEC 2006 and Floyd|Snider 2007, respectively). These data sets are described in further detail below.

2.3.1 Ambient Lake Union Data Set

The ALU data set is comprised of those stations that are located outside the GWSA boundary that are believed to be representative of general Lake Union surface sediment conditions and reflect lake-wide sources but not specific near-shore sources. To meet this objective, the data set excludes those stations that occur within 300 feet of the shoreline and those stations near potential nearshore impacts (e.g., NLSY). The purpose of the data exclusions is to remove stations where sediment quality is more likely to have been affected by nearshore or upland sources. These stations are collectively referred to as “Nearshore” in this document. After excluding the Nearshore samples, the ALU data set is comprised of 56 sample locations (Figure 2-3 and Table 2-2).

The majority of the data included in the ALU data set are from non-Gas Works-related studies, many of which were conducted at a somewhat earlier timeframe. Data dating back to 1986 were used to ensure a more robust data set and sufficient spatial coverage. Although some of these data may not be representative of current surface sediment conditions due to ongoing sedimentation, the selected data set characterizes the general ambient sediment quality of Lake Union over the past 23 years.

Samples within the ALU data set were typically analyzed for semivolatile organic compounds (SVOCs), SMS metals, and, to a certain extent, PCBs and select VOCs (benzene, toluene, ethylbenzene, and xylene [BTEX]). Analysis for pesticides, non-SMS metals, and many VOCs was less frequent.

2.3.2 GWSA Data Set

The GWSA has sufficiently dense data coverage such that use of more recent data provides adequate sample coverage. Data collected since 1994 were used to provide a data set representative of more recent site conditions. Due to the potential for commingled impacts from NLSY, locations within and adjacent to the NLSY Consent Decree Boundary are excluded.

For this supplemental cleanup standard evaluation, the GWSA data set was handled two ways:

- For the revised COPC screening detailed in Section 3, all GWSA samples (i.e., surface and subsurface) were used. By including subsurface data, the COPC screening was more inclusive because it accounted for additional historic contamination in the study area. The GWSA data set used for the COPC screening is comprised of 232 sample locations (Figure 2-4).
- For the risk evaluations (Section 4), the GWSA data set was restricted to surface sediment only and contains 130 sample locations (Figure 2-5 and Table 2-3). This is because exposure would come from the surface sediment. Data used for exposure point concentrations in these calculations are discussed further in Section 4. The determination of indicator COCs (Section 5) also restricted the GWSA data set to surface sediment because they are most representative of current conditions.

Samples within the GWSA data set were typically analyzed for SVOCs, SMS metals, select VOCs (BTEX), and, to a certain extent, PCBs. Analysis for pesticides, non-SMS metals, and many VOCs was somewhat less frequent.

2.4 Tissue Data

A literature review was conducted to identify all available crayfish and fish tissue data from Lake Union. All of the studies included here had tissue data collection locations within the GWSA or North Lake Union vicinity. Although these studies may also include data from other locations, data from outside the GWSA or North Lake Union vicinity were not evaluated further. Relevant studies all occurred between 1984 and 1999. The data were evaluated to determine the suitability of the data set to be employed in the human health and ecological risk evaluations. Tissue data were analyzed for nearly all COPCs discussed in Section 3.0. No tissue data were available for the VOCs as they are not typically analyzed for in tissue samples due to their lack of bioaccumulation. Studies in Lake Union have focused on crayfish and a variety of finfish (perch, northern pike minnow, smallmouth bass, largemouth bass, catfish, bullhead, sucker, crappie, and sculpin). Both crayfish and finfish tissue data studies are discussed in further detail below.

2.4.1 Crayfish Tissue Data Availability and Inclusion in Risk Evaluation

Crayfish tissue data for North Lake Union are available from three studies conducted in or near the GWSA. These studies are summarized below:

- *Analysis of Chemical Contaminants in Lake Union and Lake Washington Crayfish* by F. Frost 1984. Seattle-King County Health Department (data tabulated in Hansen 1994).

  Crayfish collection was conducted in September 1984 offshore of Gas Works Park, Montlake, and the Ship Canal where researchers caught 126, 58, and 400 crayfish, respectively, for a total of 584 crayfish. The crayfish ranged in size from 3 to 7 inches, with half of the crayfish 3 to 4 inches, indicating one year of age. Crayfish

from each collection location were kept separate, but randomly divided into two groups. The first group was homogenized whole and raw, and the other group was cooked with only the tail meat used in the analysis (to represent likely human exposure). The raw and cooked samples from each collection location were separately composited, resulting in six samples total. Each of these six samples was split, with half having organic analysis and the other half metals analysis (Hansen 1994). Samples were analyzed for some metals (arsenic, cadmium, copper, mercury, lead, selenium), various PAHs, and PCBs. Corresponding sediment samples were not collected during this study.

- *Lake Union: 1987 Crayfish PCB Study*, 1988, Seattle City Light (Trial 1988; data also tabulated in Hansen et al. 1994).

  Crayfish were collected offshore of the old Lake Union Steam Plant, South Lake Union, offshore of Gas Works Park (approximately 230 crayfish), and Portage Bay and analyzed for PCBs. Crayfish were divided into size classes for analysis of raw and cooked tail tissue. Cooked and uncooked tissues were composited separately for each sampling station (Hansen et al. 1994). Based on the summary provided, it is unclear whether there was one composited sample or multiple samples per location based on composited size classes. Water, sediment, and crayfish tissue were analyzed for PCBs, but results were only reported for cooked fish and cooked crayfish.

- University Regulator CSO Control Project (unpublished King County crayfish data collected between 1991 and 1997; data received from King County database in 2009).

  The purpose of these studies was to assess initial conditions in North Lake Union prior to construction of a proposed stormwater control system (the University Regulator Stormwater outfall), which began discharging into the lake in 1995. The crayfish were collected with crayfish/crab pots generally deployed next to pilings and piers during the summer commercial harvest season. The crayfish were collected in various nearshore locations in North Lake Union ranging from just west of the I-5 bridge to the Seattle Harbor Patrol dock in the western portion of the GWSA. Multiple collection locations were required in order to obtain an adequate number of crayfish to have a sufficient composited mass of tissue for analyses. Following removal from the pots, the crayfish were put into coolers and taken directly to the laboratory where they were handled in accordance with King County Laboratory protocols for tissue handling, analysis, and quality control (Houck 2010). Further details of the King County data collection dates, methods, and locations are provided in Table 2-4 (King County 2009). These studies resulted in the collection of four crayfish in 1991 and 45 crayfish in 1997 from the GWSA location.

Available crayfish tissue data collected within the GWSA or North Lake Union vicinity are summarized in Table 2-5. For the purposes of the risk evaluation, cooked crayfish data have been excluded, as limited cooked crayfish tissue data are available and the use of raw data is considered more conservative since certain analytes can be destroyed during heating. The remainder of the data summarized above and included in Table 2-5 represents tissue from 405 individual crayfish and has been included in the human health and ecological risk evaluations.

2.4.2 Finfish Tissue Data Availability and Inclusion in Risk Evaluation

Finfish tissue data for North Lake Union are available from one study previously conducted in or near the GWSA. This study is summarized below:

- University Regulator CSO Control Project (unpublished King County finfish data collected between 1991 and 1997; data received from King County database in 2009).

  As described above in Section 2.4.1, the purpose of these studies was to assess initial conditions in Lake Union prior to construction of a proposed stormwater control system (the University Regulator Stormwater outfall), which began discharging into the lake in 1995. Details of the King County data collection dates, methods, and locations are provided in Table 2-4 (King County 2009).

Available finfish tissue data collected within the GWSA or North Lake Union vicinity are summarized in Table 2-6. All finfish from 527 sample locations were collected along the eastern shoreline of Gas Works Park (no more than 20 meters offshore ranging in location from the northeastern shoreline of GWP to approximately 100 meters to the northeast). The fish samples were taken with a hand-deployed net, put into coolers, and taken directly to the laboratory where they were handled in accordance with King County Laboratory protocols for tissue handling, analysis, and quality control (Houck 2010).

For the purposes of the risk evaluation, data from six composite finfish samples (including perch, sculpin, largemouth bass, crappie, and catfish) were employed. Data were determined to be suitable for inclusion in the human health and ecological risk evaluations if the samples were collected within the GWSA or North Lake Union vicinity and the number of fish composited into the sample was greater than three, indicating the sample results represent more than an individual fish. The data summarized above and included in Table 2-6 represent tissue from 103 individual finfish (33 yellow perch, 56 sculpin, 4 largemouth bass, 4 catfish, and 6 crappie), and were included in the human health and ecological risk evaluations.

3.0 Revised GWSA-wide COPC Screening

COPCs for sediments in the GWSA were originally identified as part of the *Draft Remedial Investigation/Feasibility Study* (RI/FS) screening processes undertaken by PSE and the City, and were summarized in the draft RI/FS documents for the GWS-ESA and GWS-WSA, respectively (RETEC 2006; Floyd|Snider 2007). Recently, the EPA and other stakeholders, including the MIT, requested re-evaluation of the COC selection process and a more conservative COPC screening process for the GWSA. In response to these requests, COPCs were screened across the entire GWSA using additional screening criteria as described in this section.

The means by which COPCs were originally identified in the draft RI/FS documents are summarized below, followed by a description of the revised COPC screening performed to address EPA and MIT comments.

3.1 Draft RI/FS Documents COPC Screening Processes

COPCs were previously selected for each study area independently as described in the draft RI/FS documents. These COPCs determined the analytical requirements for the sediment investigations and were the focus of the draft RI/FS documents. A comparison of COPCs identified for the two GWSA study areas is attached as Table 3-1.

3.1.1 GWSA-ESA

For the GWS-ESA draft RI/FS, COPC screening was conducted consistent with the SMS (Ecology 1995). The COPC screening process was conducted as follows:

- Any chemical that was a COC for the Uplands was automatically included in the COPC list
- Chemicals exceeding a five percent (5%) frequency of detection threshold were compared to six sets of freshwater screening levels, with greatest emphasis put on Ecology's 2003 recommended Sediment Quality Values (SQVs)—SQSs and CSLs—that were the most recent of the six freshwater screening levels
    - Chemicals with an exceedance frequency of less than 5% (for all screening guidelines) were generally not carried forward as COPCs
    - Any detected chemical with an exceedance frequency greater than 5% (for all screening guidelines) was subject to the next screening step.
- Chemicals with a greater than 5% exceedance frequency were compared to chemicals potentially associated with former Uplands operations
    - Chemicals that exceeded at least one screening level more than 5% of the time and were potentially associated with former Uplands operations were included in the COPC list
    - Chemicals that exceeded at least one screening level more than 5% of the time, but were not likely to be associated with historical Uplands activities were classified separately into the "Supplemental Suite" (i.e., they were associated with neighboring facilities such as marinas, shipyards, or other sources; or were specifically requested for inclusion by Ecology).

3.1.2 GWSA-WSA

Preliminary chemicals of interest (COI) were identified for the GWS-WSA RI/FS based upon the following: 1) known chemicals of concern from soil, groundwater, and/or sediments from the Uplands and adjacent MTCA sites; 2) State 303(d)-listed parameters for Lake Union surface water; 3) State Category 2-listed parameters for Lake Union surface water and sediments; and 4) individual constituents of sampled summed parameters that were not individually identified from the above-listed sources (e.g., individual PAHs). These COI were then subjected to the following four criteria to establish a list of COPCs:

- Detected concentrations exceeded guidelines; analytes were compared to two freshwater and one comparable marine screening levels
- Parameter was persistent in sediment
- Parameter was relevant for investigation purposes
- Parameter was associated with historic Uplands releases and/or uses.

COI that exceeded at least one criterion more than 5% of the time were retained. Parameters that were Uplands COCs were retained if they were persistent in sediment. Total organic carbon (TOC) and sulfide were added as COPCs because of their usefulness for investigation purposes. Parameters not associated with historical potential releases from adjacent upland areas were excluded.

3.2 Derivation of TPAH as the Site COC

COPCs identified in the respective work plans were the focus of the sediment investigations and draft RI/FS documents. In accordance with the SMS, as part of the Cleanup Standards derivation process, described in Section 1.0, extensive synoptic chemical and bioassay toxicity testing were performed throughout the GWSA. Detailed statistical analyses were conducted with Ecology oversight to compare bioassay results to individual and summed PAHs and other COPCs to determine the primary driver of bioassay toxicity in the GWSA. The best correlation between elevated chemical concentrations and bioassay toxicity was observed with TPAH. Based on statistical analyses of these synoptic data results, TPAH was identified as the primary driver of toxicity within the GWSA. The spatial distribution of TPAH and other COPCs was also evaluated to ensure that areas of TPAH-impacted sediment overlapped areas with elevated concentrations of other COPCs. The results of these spatial analyses indicated that addressing TPAH-impacted sediment would also address elevated concentrations of other COPCs in the GWSA. Therefore, the draft RI/FS documents focused on TPAH as the GWSA COC. A more detailed description of this evaluation and conclusions are contained in the *Gas Works Sediment Area Cleanup Standards Determination* (RETEC 2005a).

3.3 Revised COPC Screening Objectives

This Supplement to the Cleanup Standards document presents the revised COPC screening that was conducted in response to EPA and other stakeholder comments on the draft RI/FS documents' screening processes that identified TPAH as the Site COC. COPCs have been re-evaluated throughout the GWSA (including both the GWS-ESA and GWS-WSA), using a conservative process that includes human health sediment and tissue consumption screening endpoints and additional ecological sediment and tissue consumption screening endpoints, as described below. Although the screening criteria used in this more conservative revised evaluation are not all necessarily considered appropriate (e.g., soil screening criteria are not representative of sediment exposure scenarios), the objective was to ensure that all possible COPCs were included in the screening process, and that those chemicals most likely to pose the majority of risk were identified for further evaluation. The overall screening process is consistent with the objectives of MTCA as well as EPA risk evaluation

guidelines for focusing risk evaluations when a large number of chemicals are present (EPA 1989 and 2004).

3.4 Revised COPC Sediment Screening Process

The revised COPC sediment screening process, which is summarized in Figure 3-1, was conducted using those analytes that were measured in samples collected within the geographic area and date range described in Section 2.3.2 (i.e., within the GWSA between 1994 and 2009). For the revised screening effort, all non-detects in the data set were represented by a concentration equal to one-half the reporting limit. Conventional parameters (e.g., TOC, sulfides, ammonia, total solids) were used for statistical analyses and evaluating bioassays (RETEC 2004b; RETEC 2005c), but are not otherwise included in this re-screening process. A statistical summary of the GWSA surface and subsurface sediment data evaluated in the revised screening process is provided in Table 3-2.

Consistent with EPA guidance (EPA 1989a, 1989b, and 1993), chemicals with less than a 5% frequency of detection threshold were not carried through the screening process. However, these infrequently detected chemicals were further evaluated in Section 3.7.2. This approach was more inclusive than the approach taken for the Lower Duwamish Waterway RI, which used a frequency of detection threshold of greater than ten percent (10%; Windward 2007). This 5% frequency of detection threshold was used to identify infrequently detected chemicals that may be artifacts in the data due to sampling, analytical, or other problems; or chemicals whose concentrations rarely exceeded standards or guidelines. To be thorough, each infrequently detected chemical was further evaluated to determine whether or not it was valid to exclude it as part of the screening, as detailed in Appendix A (Table A-1). This evaluation also included an assessment of those chemicals whose reporting limits (RLs) were above the screening level (Appendix A, Table A-1), and chemicals lacking screening criteria (Appendix A, Table A-2).

The expanded list of criteria used for comparison against the remaining chemicals is described below and shown in Table 3-3. This list of criteria is comprehensive and was assembled in response to agency requests. For instance, MTCA Methods A and B uplands soil criteria are included, despite the fact that these criteria are based on year-round direct soil exposure, not on infrequent incidental contact with sediment. The screening approach is intended to be inclusive in order to identify all possible COPCs for further analysis in the risk evaluation.

- GWSA sediment concentrations were screened against values protective of ecological receptors by comparing them to the following freshwater screening criteria:
  - Ecology's SQVs, including the Lowest Apparent Effects Threshold (LAET) and Second Lowest Apparent Effects Threshold (2 LAET; Ecology 2003)
  - Regional Sediment Evaluation Team Interim Sediment Quality Guidelines for Freshwater Sediment including SL1 and SL2 (RSET 2006)
  - EPA Region 3 Biological Technical Assistance Group (BTAG) Freshwater Sediment Screening Benchmarks, (EPA Region 3 2006).
- GWSA sediment concentrations were screened against values protective of human health direct contact by comparing them to the following screening criteria:
  - MTCA Methods A and B upland soil criteria for unrestricted land use scenarios (Ecology 2007)
  - EPA Regional Screening Levels (RSLs; last updated in December 2009) for residential direct contact (total exposure; EPA Regions 3, 6, and 9 2009).

- GWSA sediment concentrations were screened against values protective of bioaccumulation in ecological and human health receptors by comparing them to the following screening criterion:
    - Oregon Department of Environmental Quality (Oregon DEQ) Screening Level Values (SLVs) for freshwater fish, birds, mammals, and humans (general population and subsistence population fish consumption) from *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment* (Oregon DEQ 2007).

3.4.1 Ecological Risk COPC Sediment Screening Criteria

Currently, there are no freshwater sediment criteria promulgated under MTCA (Ecology 2007). Sediment cleanup standards under MTCA are regulated by the SMS, which were promulgated under WAC 173-204. The SMS define a sediment cleanup decision process for identifying contaminated sediment areas and volumes, and for determining appropriate cleanup responses. The SMS provide numeric analytical and biological criteria for the evaluation of marine sediments, but leave sediment criteria methods and procedures for freshwater sediments to be developed on a site-specific basis. To screen for ecological receptors, three screening criteria were included, as described below.

3.4.1.1 Ecology's Freshwater Sediment Quality Values

Ecology developed freshwater SQVs for use in their sediment management programs based on an apparent effects thresholds approach (Avocet/SAIC 2003). The first phase of this effort was completed in December 2002 (SAIC and Avocet 2002), and included compilation of existing freshwater SQVs in North America and an assessment of their reliability in predicting effects in Washington state. The results of this work indicated that additional work was needed to update existing freshwater AETs (previously summarized by Ecology [Ecology 1997]) and calculate more reliable SQVs for Washington state, as none of the existing guidelines were adequately predictive of toxicity in the Washington state data set.

The second phase of the work updated Ecology's 1997 freshwater AETs, including additional tests and endpoints, and conducted reliability testing to identify which SQVs were most predictive of toxicity in the Washington state data set. In addition, the Phase II work made recommendations regarding the use of these SQVs in accordance with the SMS.

The following Ecology-recommended freshwater sediment SQVs were used for ecological risk screening in the GWSA because they were determined to be the most applicable existing freshwater SQVs for Washington: 1) the LAET, also known as the SQS; and 2) the 2LAET, also referred to as the CSL. This approach is consistent with the previous screening process documented in the draft RI/FS documents. The use of these SQVs is in accordance with the MTCA and SMS.

3.4.1.2 Regional Sediment Evaluation Team Interim Freshwater Sediment Quality Guidelines

The Regional Sediment Evaluation Team (RSET), a multi-state and federal collaboration (including the U.S. Army Corps of Engineers [USACE], Oregon DEQ, Ecology, EPA, Idaho DEQ, NOAA, USFWS, and Tribes), applied a statistical approach consistent with current literature to data sets from Washington, Oregon, and Idaho to develop screening levels to guide disposal options for dredged sediment. An interim final sediment evaluation framework report summarizing this analysis was released in 2006 providing final marine sediment quality guidelines and interim freshwater sediment quality guidelines (RSET 2006). A final sediment evaluation framework report was produced in spring 2009; however, it did not include final freshwater sediment quality guidelines (RSET 2009). These were expected to be released in fall 2009 and form the basis for Washington state freshwater chemical and biological standards. However, this report has been delayed, and discussions between

Ecology and the Oregon DEQ are ongoing. The anticipated timeframe for the final freshwater sediment quality guidelines to be released is spring of 2011 (Ecology, personal communication, 2009 and 2010). Because the final freshwater sediment quality guidelines have not yet been released, the interim sediment quality guidelines were used.

3.4.1.3 EPA Region 3 Biological Technical Assistance Group (BTAG) Freshwater Sediment Screening Benchmarks

EPA Region 3 freshwater sediment screening criteria were developed using a wide-variety of North American and regional freshwater sediment screening criteria, including values based on: equilibrium partitioning, directly measured toxicity effects, and consensus-based approaches. The hierarchy for the selection of the freshwater benchmarks was as follows:

- Preference was given to benchmarks based on chronic exposure, non-lethal endpoint studies designed to be protective of sensitive species
- Absent chronic exposure benchmarks, values based on acute studies for multiple species adjusted with acute to chronic safety factor ratios were selected
- Food chain modeling values for water from the EPA Great Lakes Water Quality Initiative were included based on the extent of benchmark evaluation process and the approval of models for DDT, mercury, and PCBs
- Other food chain modeling values were given preference over directly measured toxicity values only if the direct toxicity value was for a marine environment.

3.4.2 Human Health Risk COPC Sediment Screening Criteria

In addition to the screening criteria required by the SMS and those used to further screen for ecological receptors, the GWSA sediment data were screened using human health risk screening criteria for direct contact with sediment. COPC screening for direct contact with sediment used the MTCA Methods A and B upland soil criteria for unrestricted land use (residential) human health risk scenarios (Ecology 2007) and EPA Regional Screening Levels (RSLs) for residential human health risk direct contact (EPA Regions 3, 6 and 9 2009). MTCA Method B and the EPA RSLs both use reasonable maximum exposure (RME) assumptions.

3.4.2.1 Ecology MTCA Methods A and B

MTCA Methods A and B cleanup levels were established using applicable state and federal laws and human health risk thresholds and other requirements specified in WAC 173-340-720 through 173-340-760. MTCA Method A values were selected by Ecology to be conservative for routine, simpler sites. The basis of the Method A values ranges from Applicable or Relevant and Appropriate Requirements (ARARs), to protection of direct contact, to protection of soil leaching to groundwater used for drinking water (the majority of the values were based on this latter endpoint). MTCA Method B values were calculated using a standard equation and generic RME default assumptions to derive cleanup levels. For individual carcinogens, standard MTCA Method B cleanup levels were based upon the upper bound of the estimated excess lifetime cancer risk of one in one million (1×10^{-6}). For individual non-carcinogenic substances, standard MTCA Method B cleanup levels were set at concentrations that are anticipated to result in no acute or chronic toxic effects on human health (that is, hazard index [HI] of one [1] or less) and no significant adverse effects on aquatic and terrestrial organisms. In all cases where they were available, concentrations were screened against both MTCA Methods A and B with the exception of Method A values for total petroleum hydrocarbons (TPH) since the hazardous components of TPH (PAHs and BTEX) were evaluated individually, as is typically done in accordance with Ecology guidance for more complex sites such as the GWSA.

3.4.2.2 EPA Regional Screening Levels

The EPA RSLs are generic risk-based concentrations derived from standardized RME equations combining exposure assumptions with chemical-specific toxicity values. RSLs correspond to either a one in one million (1×10^{-6}) risk level for carcinogens or a HI of 1 for non-carcinogens. EPA guidance (EPA Region 3 1993) recommends that the non-carcinogen screening levels be adjusted from a HI=1 to HI=0.1 to account for additive effects when using these values for screening. Consequently, sediment concentrations were compared to non-carcinogenic RSLs at both the HI=1 and HI=0.1 levels. RSLs are considered by the EPA to be protective for humans (including sensitive groups) over a lifetime.

3.4.3 Bioaccumulative COPC Sediment Screening Criteria for Ecological and Human Health Receptors

In addition to the sediment screening criteria required by the SMS and those used to further screen for ecological and human health receptors, the GWSA sediment data were also screened against a bioaccumulative screening criterion. Although numerous lists of bioaccumulative compounds have been developed by a variety of agencies, few numerical screening criteria exist to address bioaccumulative COPCs. Oregon DEQ identified bioaccumulative compounds using a consensus-based process with the RSET and a review of more recent fish tissue testing results from the lower Willamette basin. From this evaluation, Oregon DEQ developed SLVs specific to freshwater fish, birds, mammals, and humans (general population and subsistence population fish consumption; ODEQ 2007).

Bioaccumulative COPCs are of particular concern as they result in a net accumulation of the chemical by an organism as a result of uptake from all routes of exposure. Generally, bioaccumulation includes bioconcentration (net accumulation of a dissolved chemical directly from water by an aquatic organism) and biomagnification (process by which chemicals tend to accumulate to higher concentrations at higher levels in the food web due to dietary accumulation). Bioaccumulation of chemicals from sediments to benthic organisms and their subsequent transfer through the food web provides an exposure pathway to higher-level organisms. Because sediments can contain significantly higher concentrations of some chemicals than the overlying water, it is important to evaluate the potential for such chemicals to accumulate in aquatic organisms.

Use of the SLVs enables identification of those COPCs that have the potential to bioaccumulate to the point where they may adversely affect the health of fish, shellfish, and other aquatic prey animals, or the wildlife or humans that consume them.

3.5 Human Health Risk and Ecological COPC Tissue Screening Criteria

In addition to revising the approach to screening sediment concentrations in the GWSA, the revised COPC screening process, which is summarized in Figure 3-1, also incorporated the use of the GWSA tissue data for finfish and crayfish. These data, which were measured in tissue samples collected within the GWSA or vicinity between 1984 and 1999, were screened against three conservative bioaccumulative screening criteria protective of aquatic, wildlife, and human (including various consumption levels) receptors, as described below. The GWSA tissue data for both finfish and crayfish and a brief statistical summary are provided in Tables 2-5 and 2-6.

Adding a tissue screening step to the sediment-only screening approach further expanded the list of criteria used for comparison, making the screening process more robust. Tissue screening also provided an added level of conservativeness that further addressed bioaccumulative COPCs and responded to stakeholder requests to identify all possible COPCs for further evaluation in the risk evaluation. To screen GWSA tissue data for the presence of bioaccumulative compounds of concern

relative to tissue consumption by both human and ecological receptors, three tissue screening criteria were included:

- EPA Region 3 Fish Tissue Screening Levels protective of human consumption of fish (EPA Region 3 2009)
- RSET Interim Freshwater Sediment Quality Tissue Guidelines (Target Tissue Levels [TTLs]) protective of human consumption of fish for a range of consumption rates (RSET 2009)
- Oregon DEQ Acceptable Fish Tissue Levels (ATLs) and Critical Tissue Levels (CTLs) for protection of aquatic, wildlife, and human receptors (ODEQ 2007).

3.5.1 EPA Region 3 Fish Tissue Screening Levels

In addition to the EPA RSLs for soil screening described above, the EPA Region 3 also developed screening levels that are protective of risks to human health for fish tissue consumption. As with the soil screening levels, the tissue consumption RSLs are generic RME risk-based concentrations derived from standardized equations combining exposure assumptions with chemical-specific toxicity values.

3.5.2 Regional Sediment Evaluation Team Interim Freshwater Sediment Quality Tissue Guidelines

In addition to the RSET screening levels described for sediment, RSET also developed screening levels for fish tissue that are protective of risks to human health for fish and shellfish consumption. Three separate tissue screening levels were developed for protection of both carcinogenic and non-carcinogenic toxic effects. These screening criteria were developed to be representative of a range of fish consumption rates from recreational to tribal:

- TTL1 is protective of the general population, and should only be used in areas that are not tribal or urban subsistence areas and which do not have active recreational or commercial fisheries
- TTL2 is protective of recreational anglers, most Asian and Pacific Islander groups, and mid-range Tribal consumption rates
- TTL3 is protective of high-end Tribal consumption; for example, those who obtain most of their protein or food intake from fishing or shellfish collection.

3.5.3 Oregon DEQ Acceptable Fish Tissue Levels and Critical Tissue Levels

In addition to the bioaccumulative sediment screening levels described above, Oregon DEQ also developed screening levels for fish tissue that are protective of risk to humans and wildlife that eat fish, and to the fish themselves due to bioaccumulation. These screening values include ATLs and CTLs and are described in more detail below (ODEQ 2007):

- ATLs for humans are concentrations of bioaccumulative chemicals in fish tissue that are protective of humans who consume fish within a range of ingestion rates. They include values for carcinogens and non-carcinogens assuming different fish consumption rates. The ATLs are assumed to be applied to resident fish.
- ATLs for wildlife are concentrations of bioaccumulative chemicals in fish tissue that will not cause significant adverse effects to bird and mammal populations that consume the fish.

- CTLs are concentrations of bioaccumulative chemicals in tissue that will not cause significant adverse effects on the health of fish, shellfish, and other aquatic organisms. The freshwater CTLs included in this screening were developed to be protective of populations and individuals of threatened or endangered species.

3.6 Summary of Preliminary COPC Screening Results

Table 3-4 provides a complete summary of the revised COPC GWSA sediment screening results, and shows the percent exceedance for each chemical and screening criterion discussed above. Exceedances due to detected concentrations in sediment are differentiated from exceedances due to non-detects.

Chemicals that exceed at least one sediment criterion are summarized in Table 3-5. Those chemicals that did not exceed any of the sediment screening criteria were eliminated from further evaluation. As shown in Table 3-5, 58 chemicals (or chemical groupings, such as TPAH) had detected concentrations that exceeded at least one of the above-listed sediment criteria. In addition, four chemicals (isopropylbenzene; chloroform; 1,1,1-trichloroethane; and 2-hexanone) exceeded sediment criteria due to non-detect concentrations; these chemicals were detected at least 5% of the time but only had exceedances due to elevated reporting limits for non-detects, and are further evaluated in Section 3.7.2. These 62 chemicals comprise the preliminary list of COPCs.

The results of the tissue screening are shown in Tables 3-6a and 3-6b. The tissue screening identified a subset of the COPCs identified in the sediment screening process shown in Table 3-5, including 15 COPCs for finfish and 17 COPCs for crayfish (the finfish and crayfish tissue COPC list has considerable overlap). A comparison of Tables 3-6a and 3-6b with Table 3-5 shows that the tissue screening process confirmed, but added no additional COPCs to, those identified in the sediment screening process.

3.7 Additional COPC Screening

Following the revised conservative screening process that resulted in the preliminary list of COPCs, several additional screening steps were conducted to address the following:

- Natural background soil metals
- Infrequently detected chemicals
- Chemicals with reporting limits above criteria
- Chemicals without screening criteria
- Chemicals that are Uplands COCs
- Chemicals that may be typically associated with historical Uplands activities.

These additional screening steps are described below.

3.7.1 Comparison of Metals to Natural Background

The GWSA sediment metals data were compared to regional natural background soil concentrations to evaluate whether any metals were present in GWSA sediment at concentrations similar to that of natural background soil. The source for evaluating natural background concentrations was Ecology's *Natural Background Soil Metals Concentrations in Washington State* (Ecology 1994). This source provided background values for all metals on the preliminary COPC list except antimony, cobalt, selenium, silver, and vanadium.

The maximum GWSA sediment metals concentrations were compared to the natural background soil concentrations of these metals. As seen in Table 3-7, the maximum iron sediment concentration is below natural background soil concentrations. Therefore, iron was eliminated from the preliminary COPC list. Although the maximum sediment concentration for aluminum was not below natural background soil concentrations, the average concentration for aluminum was below the 90th percentile concentration. More specifically, 95 of the 96 samples analyzed for aluminum were below the 90th percentile Puget Sound Group natural background soil concentrations; only one older USEPA sample from 1995 exceeds this threshold. Therefore, aluminum was also eliminated from the preliminary COPC list.

3.7.2 Evaluation of Infrequently Detected Chemicals, Chemicals with Reporting Limits above Criteria, and Chemicals without Screening Criteria

3.7.2.1 Evaluation of Infrequently Detected Chemicals Including All Chemicals with Reporting Limits above the Lowest Screening Criteria

Chemicals that were infrequently detected (i.e., less than 5% of the time) and not subject to the above criteria screening or whose RLs were above the lowest screening criteria were further evaluated to determine whether or not they should be retained as COPCs for the risk evaluation. One hundred and six infrequently detected chemicals and four non-detect-driven COPCs (see Section 3.6) were further evaluated. The results, including the rationale for retaining the chemical as a COPC or not, are summarized in Appendix A (Table A-1). The following are some of the considerations that were collectively used in this assessment; the specific rationale (i.e., which of these considerations were used to determine whether or not to retain each chemical) is provided in Table A-1).

- Is the chemical frequently detected?
- Is maximum RL greater than the lowest screening criterion more than 10% of the time or is the maximum RL greater than three times the lowest screening criterion?
- Is the RL elevated due to interference from other chemicals? (i.e., is the RL greater than three times the Practical Quantitation Limit (PQL)?
- Is the elevated RL associated with older data (i.e., older than 1999) that may not be representative?
- Is the elevated RL associated with surface sediment samples only?
- Is the elevated RL associated with insufficient sample population data (i.e., less than 8 to 10 samples) that may not be representative (see rationale in Table A-1)?

Generally, chemicals that had elevated RLs across the GWSA were associated at least in part with more recent surface sediment results (e.g., 2002 and newer), and detected concentrations in excess of the lowest screening criterion were retained for further evaluation. As a result of this assessment, four of the chemicals (di-n-octyl phthalate, PCP, chlordane, and DDT) that were infrequently detected or had exceedances solely due to RLs above the lowest screening criteria were identified as COPCs.

3.7.2.2 Evaluation of Chemicals Lacking Screening Criteria

Twenty-four chemicals for which no screening criteria could be found were further evaluated to determine whether or not they should be retained as COPCs for the risk evaluation. The results, including the rationale for retaining the chemical as a COPC or not, are summarized in Appendix A (Table A-2).

The following considerations were collectively used to make this assessment; the specific rationale (i.e., which of these considerations were used to determine whether or not to retain each chemical) is provided in Table A-2):

- Is the chemical with no criteria associated with older data (i.e., older than 1999) that may not be representative?
- Is the chemical frequently detected?
- Is the chemical an Uplands COC?

No chemicals lacking screening criteria were Uplands COCs, most were rarely (if ever) detected, and most were associated with samples collected during or before 2002. As a result of this assessment, none of the 24 chemicals lacking screening criteria were identified as COPCs.

3.7.3 Comparison to Gas Works Park Uplands COCs

As described in Section 3.1, any chemical that was identified as a COC for the Uplands was automatically included in the COPC list for the draft RI/FS screening processes. This logic was retained for the revised COPC screening process. The COCs for the Uplands soil and groundwater are as follows:

Uplands Chemicals of Concern (Parametrix 1998)

Retained as COC	Surficial Soil	Groundwater
Inorganic Chemicals		
Arsenic	X	
cPAHs		
Benzo(a)anthracene	X	X
Benzo(b)fluoranthene	X	X
Benzo(k)fluoranthene	X	X
Benzo(a)pyrene	X	X
Chrysene	X	X
Dibenzo(a,h)anthracene	X	X
Indeno(1,2,3-cd)pyrene	X	X
Other PAHs		
Fluoranthene	X	X
Fluorene		X
Naphthalene	X	X
Pyrene	X	X
Volatile Organic Compounds		
Benzene		X
Ethylbenzene		X
Toluene		X

A comparison of this list and Table 3-5 demonstrates that all of the Uplands COCs were included in the revised preliminary sediment COPC list.

As an additional line of evidence, the preliminary COPC list was also compared against COPCs typical of one of the main Uplands industries, the MGP. A list of typical MGP-related chemicals was compiled from 33 MGP sites (GRI 1996). In general, chemicals were considered potential MGP site COPCs if:

- They are regulatory chemicals of concern
- Approved analytical methods exist
- They have been found on MGP sites during environmental site investigations
- They may be present at an MGP site based upon the nature and characteristics of typical MGP process residuals.

The list contained 42 chemicals that were identified as possible chemicals at MGP sites, including 16 metals; and 26 organic chemicals comprised of 4 volatile aromatics, 4 phenolics, 16 PAHs, cyanide, and dibenzofuran. Although a number of conventional chemicals such as sulfur, ammonia, and nitrates were also identified, as discussed previously, conventionals were used in the GWSA primarily for bioassay evaluation and statistical purposes and were not identified as COPCs. Not all of the identified chemicals are present at all MGP sites. The specific chemicals present at an MGP site depends on operating practices, site history, and site characteristics. Some chemicals may not have been present at the site, may not have been released to the site, were released only in small amounts or at low concentrations that have long since attenuated or degraded, or may occur at or below natural background concentrations. The list of chemicals included is provided below.

Potential COPCs for MGP-Related Activities (GRI 1996)

Other	Metals	Volatiles	Phenolics	PAHs
Dibenzofuran	Aluminum	Benzene	Phenol	Acenaphthene
Cyanide	Antimony	Ethylbenzene	2-Methylphenol	Acenaphthylene
	Arsenic	Toluene	4-Methylphenol	Anthracene
	Barium	Total Xylenes	2,4-Dimethylphenol	Benzo(a)anthracene
	Cadmium			Benzo(a)pyrene
	Chromium			Benzo(b)fluoranthene
	Copper			Benzo(g,h,i)perylene
	Iron			Benzo(k)fluoranthene
	Lead			Chrysene
	Manganese			Dibenzo(a,h)anthracene
	Mercury			Fluoranthene
	Nickel			Fluorine
	Selenium			Naphthalene
	Silver			Phenanthrene
	Vanadium			Pyrene
	Zinc			2-Methyl naphthalene

All of these chemicals were included in this GWSA revised COPC screening process, and all but five of these chemicals were identified as GWSA COPCs. These five were either below natural background soil concentrations (aluminum and iron), or present at concentrations below all screening criteria (barium, manganese, and 2-methylphenol). 2-Methylphenol was also infrequently detected (less than 5% of the time). The remaining 37 chemicals (except the five below natural background or screening criteria thresholds) were included in the risk evaluation.

3.8 Identification of COPCs for Risk Evaluation

The revised and more conservative COPC screening of GWSA data resulted in a list of 59 COPCs (Table 3-8), which are the primary focus of further evaluations in this document. Table 3-8 also compares the revised COPC list to previous COPC lists for the GWS-ESA and GWS-WSA draft RI/FS documents (from Table 3-1). The previous COPC list for the GWS-ESA had 51 COPCs and the previous COPC list for the GWS-WSA had 38 COPCs. Although the addition of the more conservative screening criteria was not necessarily appropriate (e.g., soil screening criteria are not representative of sediment exposure scenarios), screening with these criteria resulted in the retention of additional COPCs for further evaluation.

All 59 COPCs resulting from this revised conservative COPC screening process were further evaluated in both the human health and ecological risk evaluation steps described in Section 4.

4.0 Risk Evaluation

Since issuance of the draft GWS-ESA RI/FS and draft GWS-WSA RI/FS documents, a number of agencies and stakeholders have reviewed the draft GWSA RI/FS documents and provided written comments on them. These agencies and stakeholders include the Muckleshoot Indian Tribe (MIT), DNR, EPA, WDFW, and NOAA Fisheries.

In general, these comments expressed concerns with the COPC screening process and the focus on TPAH as a sole COC; these concerns are addressed in Section 3.0. Furthermore, commenters expressed the need for a quantitative site-specific risk evaluation that addressed specific exposure pathways to supplement the qualitative risk evaluation provided in the draft RI/FS documents and the bioassay work summarized in the *Gas Works Park Sediment Area Bioassay Report* (RETEC 2004b) and used in the *Gas Works Sediment Area Cleanup Standard Determination* (RETEC 2005a).

To address these risk evaluation concerns, Section 4.0 provides additional evaluations of ecological risks and human health risks relating to GWSA exposures. Based on EPA and MIT input, the evaluation focused on several potential human health exposure pathways at the Site: Tribal netfishing, beach play/wading at Gas Works Park, and the consumption of GWSA fish resources. To address the potential for exposure to COPCs by ecological receptors, four representative wildlife receptors of concern were identified, including two bird species, one mammal species, and one fish species. The species were all resident in Lake Union and may have been exposed to high COPC concentrations due to feeding behaviors or food web trophic levels. The COPC list derived in Section 3.0 was used for these risk evaluations.

4.1 Introduction

An overall summary of the site-specific risk evaluation approach is presented below and in Figure 4-1 as a conceptual site model indicating primary sources, secondary sources, and transport mechanisms that lead to the impacted exposure media. The two exposure media of interest in this evaluation are the GWSA sediments and crayfish/finfish tissue. Complete exposure pathways evaluated in this document are shown in the conceptual site model (Figure 4-1). Complete and insignificant pathways have not been evaluated, but are further discussed in the uncertainty analysis of the human health and ecological risk evaluations. Incomplete pathways have not been evaluated in this risk evaluation and are not indicated on the figure.

Sections 4.2 and 4.3 present the site-specific human health risk evaluation—focusing on seafood consumption, beach play/wading, and netfishing scenarios—and the site-specific ecological risk evaluation. The two risk evaluations were conducted based on regulatory guidance including: Ecology 2007, *Risk Assessment Guidance for Superfund: Parts A-E* (EPA 1989 and 2004), *Interim Final Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (EPA 1997b), and *EPA Region 10 Supplemental Ecological Risk Assessment Guidance for Superfund* (EPA 1997c).

A risk assessment is “an analysis of the potential adverse health effects (current or future) caused by hazardous substance releases from a site in the absence of any actions to control or mitigate the releases” (EPA 1989b, 2004). The human health and ecological risk evaluations presented explore the range of potential risk estimates for various scenarios where people or ecological receptors may be exposed to COPCs found in sediment and in fish tissues from the GWSA. To evaluate a range of potential risks related to the uncertainty associated with intensity and frequency of hypothetical GWSA use by humans**,** two levels of exposure were assessed: RME and the central tendency (CT). The RME scenarios evaluate potential risk posed by the highest exposure that is reasonably expected to

occur at the GWSA. The CT exposure scenarios are intended to reflect potential risk posed by average exposures at the GWSA.

The human health and ecological risk evaluations determined those COPCs that were estimated to have the highest contribution to the potential risk at the Site. A more focused analysis was then conducted in Section 5 on GWSA COC concentrations and their relationship to the ambient concentrations of the COPCS in Lake Union. This analysis, in turn, will be useful in development of RAOs, and may be considered in the process of identifying cap performance standards to be identified in the RI/FS.

The human health and ecological risk evaluations include the following sections:

- **Objectives:** This section presents the overall objectives of the risk evaluation.
- **Exposure Scenarios:** This section first identified potential exposed populations including adults and children from both the Tribal and general population, and various ecological receptors representing different trophic levels in the food web. These ecological receptors included a carnivorous mammal (northern river otter), piscivorous and herbivorous birds (great blue heron and American mallard), and a threatened fish species (juvenile Chinook salmon). Potential exposure pathways were then identified. These pathways included: (1) direct contact (dermal absorption and incidental ingestion) with sediments by people via beach play/wading (general population) and netfishing (Tribal population), (2) ingestion of fish resources present in the GWSA by both the general and Tribal populations, and (3) ingestion of sediment and fish resources by ecological receptors. Exposures associated with surface water were not evaluated as Lake Union water is not considered a media for the GWSA. Exposure scenarios were identified through professional judgment and input from the MIT and the EPA, in coordination with Ecology.
- **Data Selection:** Site data were collected historically and were previously evaluated in Section 2.0. Data employed in these evaluations included surface sediment, crayfish tissue, and finfish tissue. Following the Site data evaluation, 59 hazardous substances at the Site were identified as COPCs using an approach described in Section 3.0. Data were then further evaluated in Sections 4.2.3 and 4.3.3 to determine appropriate concentrations for each potential exposure scenario. For the human health risk evaluation, beach play/wading concentrations included the arithmetic mean (CT scenario) and the maximum (RME scenario) COPC concentrations from surface sediments along the eastern shoreline and nearshore areas to a depth of 16 feet off of Gas Works Park. Netfishing concentrations included the maximum COPC concentrations from surface sediment across the GWSA for the RME scenario, and the mean sediment concentrations for the CT scenario. Fish ingestion concentrations used for both the human health and ecological risk evaluations included the maximum COPC concentrations in fish tissue collected in North Lake Union for the RME scenario, and the mean fish tissue concentrations for the CT scenario. For the ecological risk evaluation, sediment concentrations for both the northern river otter and juvenile Chinook salmon included maximum surface sediment concentrations from across the GWSA, while concentrations for the great blue heron and American mallard were maximum surface sediment values from the Gas Works Park shoreline only where the birds were likely to contact sediment.
- **Exposure Evaluation:** This section first presents descriptions of the parameters employed for each potential exposure scenario. These parameters were used to

describe the frequency, duration, and magnitude of the potential exposures and characteristics of the receptor populations. Exposure parameters encompass current and future site use and are developed based on conservative RME estimates as well as a CT estimate providing a less conservative measure intended to reflect average exposures. This section then presents the calculation of the chronic daily intake/dietary dose of COPCs based on these exposure parameters, and using equations derived from EPA risk assessment guidance (EPA 1989, 1991, 1997a, 1997b).

- **Risk Characterization:** The overall risk characterization approach was presented for COPCs classified in accordance with their toxic effects (carcinogenic versus non-carcinogenic [with lead as a special case], and various toxic endpoints for ecological health). The risk characterization was the quantitative determination of whether the exposure to the COPC may cause an increase in the incidence of an adverse health effect. The relationship between the intake of the COPC and the incidence of adverse health effects was evaluated using either slope factors (carcinogenic effects), reference doses (non-carcinogenic effects), or toxicity reference values (ecological risk). These values described the magnitude of toxicity for each COPC and were derived from animal and human studies on toxic effects. For carcinogenic COPCs, the magnitude of risk was calculated by multiplying the predicted exposure by the slope factor, with the result compared to a risk threshold. For non-carcinogenic COPCs and ecological risk, health risks were estimated by comparing the predicted exposure to the acceptable reference dose or toxicity reference values.
- **Results:** This section presented the risk conclusions for each exposure scenario, including the COPCs estimated to have the highest contribution to potential risk. For human health, risk estimates for carcinogenic COPCs were presented as the potential lifetime excess risk of cancer (beyond "background" cancer risk). Potential risks were initially estimated separately for each COPC. These potential risks were then summed for all COPCs to obtain the potential lifetime excess cancer risk for each exposure scenario. As defined by MTCA 173-340-745 (Ecology 2007), the human health risk level for individual carcinogens may "not exceed one-in-a-million. If more than one type of hazardous substance is present, the total risk level at the site may not exceed 1 in 100,000 (1×10^{-5})." EPA's National Contingency Plan (NCP; 40 CFR 300 [EPA 1990]) establishes a cancer risk in excess of one-in-a-million as a "point of departure" for establishing remediation goals. Excess cancer risks between 10^{-6} and 10^{-4} represent a range for consideration of the need for remedial action. For non-carcinogens, COPCs with Hazard Quotients (HQs) calculated as greater than 1 are identified as the COPCs that have the potential to exert an adverse health effect on human receptors. For ecological risk, COPCs with HQs calculated as greater than 1 are identified as the COPCs that have the potential to exert an adverse health effect on ecological receptors.
- **Uncertainty Analysis:** This section discussed the uncertainties that are inherent in performing human health and ecological risk evaluations, and evaluates potential effects of these uncertainties on the risk conclusions. There is uncertainty present in all phases of the risk evaluation, and risk is evaluated conservatively to minimize the overall effect of uncertainty on the results of the evaluations.

Following the human health and ecological risk evaluations, an assessment of the relative contribution of the COPCs to overall risk was conducted. This assessment was utilized to focus COPC analysis in Section 5.0 by identifying major risk drivers.

4.2 Human Health Risk Evaluation

4.2.1 Objectives

The objective of this evaluation is to characterize the potential risks to human health that may be posed by exposure scenarios to COPCs in the GWSA. These potential exposure scenarios include: dermal contact and incidental ingestion of contaminated sediment while playing on the beach or netfishing, and ingestion of COPCs present in crayfish and finfish collected from the GWSA and/or North Lake Union. The overall purpose is to determine which COPCs have the potential to cause or increase the carcinogenic and non-carcinogenic risk to human receptors. COPCs that exceed risk thresholds will be further evaluated in Section 5.0.

The specific objectives of this evaluation were as follows:

- Identify potential exposure scenarios in the GWSA
- Determine the potential exposure to COPCs in the GWSA based on established RME and CT exposure parameters and available GWSA sediment data and GWSA-vicinity tissue data
- Perform and document a site-specific risk evaluation of GWSA COPCs that ultimately will be further evaluated in Section 5.

4.2.2 Exposure Scenarios

Adults and children from both the general population and the Tribal population have the potential to be exposed to COPCs during their activities within the GWSA. Several potential exposure scenarios were evaluated in this risk evaluation and are further described below. These scenarios included the general population playing on the beach sediments along Gas Works Park, both Tribal and recreational populations eating fish caught from within the GWSA-vicinity, and netfishing by Tribal populations. The potential exposure scenarios evaluated here for all scenarios include an RME scenario, or the highest exposure that was expected to occur at a site, as well as a CT scenario representing a less conservative estimate and intended to reflect average potential exposure. The RME is a conservative exposure and likely overestimates potential exposure for many individuals; the CT is designed to be a more representative of potential exposures.

4.2.2.1 Beach Play/Wading

The shoreline sediments of the eastern and southern portions of the GWSA can be accessed by recreational users of Gas Works Park, which may lead to potential direct contact exposure to those sediments (refer to Figure 4-2). The RME beach play/wading exposure scenarios were developed to evaluate the potential worst-case potential risk to both adults and children who may contact and ingest accessible GWSA shoreline sediments. The CT scenarios were developed to evaluate the potential average risk to adults and children who may contact and ingest accessible GWSA shoreline sediments. Beach play/wading could include scenarios such as children digging in beach sediments, building sand castles or wading offshore. It did not incorporate such in-water exposures as swimming, and instead focused on beach and nearshore sediments as the source of potential exposure. Lake Union surface water is not considered a media for the GWSA. As the RME scenarios were conservative, they should be protective of other potential beach users, including City Parks and Recreation employees, intensive Park users, and transients.

Currently, the potential exposure area for beach play/wading in the shoreline area of the GWSA is an accessible strip of a mostly gravel bank and shoreline sediment area along the eastern shore and wrapping around to the southeastern side of the Park to just east of the concrete bulkhead. Potential risk was evaluated using data from this area where recreational use occurs and supplemented with

nearshore sediment data. The remainder of the GWSA shoreline area is comprised of either concrete bulkhead or large rip rap and thus direct shoreline sediment contact is not currently possible.

In this shoreline exposure area, two potential complete exposure pathways were addressed. These pathways included dermal contact and ingestion of shoreline and nearshore sediments. Nearshore sediments were included as shoreline data is limited and to include potential exposure while wading. Consistent with EPA Region 10 Superfund sites performing beach play/wading evaluations, inhalation as a potential exposure pathway was considered unlikely. Chemicals are not expected to volatilize from wet sediments. Furthermore, most GWSA COPCs are hydrophobic compounds that readily partition to sediments—which is why they were detected in elevated concentrations in the sediments. These COPCs are mostly not volatile.

As mentioned previously, the evaluation of potential risks due to beach play addressed potential risks posed by wading and associated launching of small water craft in the sediments, as well. In both the beach play and wading scenarios, the receptor is exposed to contaminated sediments in two ways: by incidental ingestion of sediments and by dermal contact with sediments.[3] For incidental ingestion of sediments, it could be assumed that the same amount of sediment is ingested per day in each scenario. This assumption is conservative, considering that beach play would likely result in much greater interaction with the sediments (for example, building sand castles) and, consequently, greater ingestion would be expected. For dermal contact with sediments, however, risk posed by wading would be less than that posed by beach play. This is due to the assumed body area exposed to sediments during each scenario. The adult and child body surface area (5,700 cm^2 and 2,800 cm^2, respectively) evaluated in beach play assumes exposure to head, forearms, hands, and lower legs; roughly equivalent to wearing shorts, a short-sleeved shirt, and shoes (USEPA 2004). This body surface area is much greater than the body surface area that would be exposed in a potential wading exposure scenario (i.e., feet and lower legs only). Therefore, with the combined risks of ingestion and dermal contact, the overall exposure to sediments while wading would pose a lower risk than exposure to sediments during beach play. Since beach play exposure assumptions encompass potential exposure during wading and is more conservative than a wading scenario, the scenario is referred to as beach play/wading in this text.

4.2.2.2 Fish Ingestion

Various fish resources are resident in the GWSA, and there is the possibility that these resources will be ingested by either recreational fishers or the Tribal population. In the process of the development of the human health risk evaluation, a review of fish resources in Lake Union was completed. This review focused the fish ingestion assessment to address those fish present in North Lake Union with readily available tissue data. The fish resources review is included in Appendix B. The RME fish ingestion exposure scenarios were developed to evaluate the potential worst-case potential risk to both recreational fisher and Tribal adults and children who may ingest resident fish tissue derived from the GWSA and/or North Lake Union. Fish ingestion included the scenario where fish exposed within the GWSA were consumed by recreational fishers or the Tribal population every day. For recreational fishers, this scenario was highly conservative as recreational fishing is restricted both seasonally and with a daily catch limit. Tribal users were evaluated more conservatively in this evaluation than recreational fishers as they were expected to consume more fish.

For CT fish ingestion scenarios, ingestion rates have been lowered for both tribal and recreational fishers based on available data to represent likely average consumption rates. Frequency of consumption remained daily. Tribal fishers are still assumed to consume more fish than recreational fishers in the CT scenarios.

[3] As noted in Section 4.1, exposure to surface water during either beach play or wading is not evaluated since Lake Union water is not considered a media for the GWSA.

With regard to the Tribal fish consumption scenarios, the EPA's Tribal seafood consumption framework (EPA 2007a) has been applied, resulting in the use of Tulalip seafood consumption survey data to characterize consumption for both the RME and CT scenarios. Characterizing exposure to recreational fishers was conducted using the MTCA framework (MTCA 173-340-730; Ecology 2007) to identify fish consumption scenarios for the RME scenario, and site-specific data provided by Paramatrix (2003) for the CT scenario.

The fish resources evaluated in this exposure scenario consisted of crayfish and several species of finfish present in the GWSA and/or North Lake Union, including perch, sculpin, largemouth bass, catfish, and crappie. These resident finfish and crayfish were the focus of the human health risk evaluation because they are sport fish, and they do not migrate, potentially exposing them year-round to GWSA contamination. Both crayfish and finfish have been observed in the Lake Union/Lake Washington system in several studies (Frost and McCallum 1984; Landolt and Busch 1991; King County 2009; Kerwin 2001; Washington State Department of Health [DOH] 2004; Tabor 2006).

In accordance with stakeholder and agency input, anadromous salmonid species are not incorporated in the human health risk evaluation. The risk to human health posed by salmon was not evaluated as the migrating salmon's exposure to chemicals in GWSA sediment is minimal due to the limited time they spend in the GWSA. Of note, the MIT currently only fishes for salmon in Lake Union. Tribal ingestion of resident finfish and crayfish species is therefore a hypothetical future scenario, not based on current tribal fishing practices.

4.2.2.3 Netfishing

Incidental sediment ingestion and dermal contact scenarios were developed to address the potential upper range of possible site exposure (RME) and average (CT) risk posed to Tribal adults while netfishing in the GWSA. Dermal contact with the body including the head, hands, and forearms was assumed to occur while netfishing, as well as incidental ingestion of sediments.

4.2.3 Data Selection

In the first step of the risk evaluation, a COPC screening was performed to identify the COPCs to be evaluated. The COPC screening is discussed in Section 3. Sixty chemicals were identified as GWSA COPCs. The COPCs were then evaluated using available sediment and tissue data. At least one data point was available for all identified GWSA COPCs. Data selection for each exposure scenario is discussed below.

4.2.3.1 Beach Play/Wading

Shoreline surface sediment data available in this area included three samples (95042153, 95042155, and NLU60-SS-0010 [EPA 1995; RETEC 2006], respectively) that were used in this risk evaluation to calculate potential risks to both adults and children who may use the beach recreationally. The three shoreline samples had relatively low concentrations of COPCs (mean TPAH concentration of 65 mg/kg) compared to COPC concentrations in the samples collected from the nearshore areas (mean TPAH concentration of 423 mg/kg) at water depths of 1.2 to 16.4 feet with a mean water depth of 8.1 feet.

Because the shoreline samples were limited in number, several nearshore surface sediment samples (0–10 cm bgs) were incorporated into the evaluation (refer to Figure 4-2 for sample locations; RETEC 2006). These samples included all of the surface sediment samples within approximately 50 feet of the beach play/wading area. Incorporating these samples into the evaluation resulted in a more conservative evaluation of potential exposure because these samples generally have higher COPC concentrations. They were composed of four samples comprised of mostly sand and gravel and two samples comprised of mostly silt. Subsurface samples were not employed in this evaluation as humans are unlikely to encounter sediment substantially below the surface in the beach play/wading

potential exposure scenario. The arithmetic mean and maximum COPC concentrations employed in this evaluation are summarized in Table 4-1 (called “eastern shoreline”). Importantly though, the nearshore data represented sediments at greater water depths than what is reasonable for a beach play/wading scenario.

4.2.3.2 Fish Ingestion

Historical tissue data collected in the Gas Works Park vicinity and the northeast arm of Lake Union from several studies including the University Regulator Pre- and Post-Separation Studies (King County 2009) were used in the risk calculations. A total of six finfish samples and four crayfish samples were used. However, collectively, the finfish samples represent 103 individual finfish; and crayfish samples represent 405 individual crayfish. Finfish species employed in this evaluation included perch, sculpin, largemouth bass, catfish, and crappie. The tissue analyzed for all finfish was raw fillet, and for crayfish was tail only. Tables 2-5 and 2-6 present a summary of crayfish and finfish information, respectively. At least one data point was available for all identified COPCs between the crayfish and finfish data with the exceptions of cobalt, vanadium, retene, total cyanide, and all volatile organic COPCs, which are non-standard analytes for tissue data.

Importantly, all priority bioaccumulative chemicals (EPA 2008a) identified as GWSA COPCs were evaluated for potential risk, including benzo(a)pyrene, chlordane, dichlorodiphenyldichloroethane (DDD), dichlorodiphenyltrichloroethane (DDT), mercury, and PCBs. All data was derived from the analysis of raw crayfish and finfish because it was conservatively assumed that COPC concentrations will not decrease upon cooking or food preparation.

Maximum concentrations available for each COPC were used in the evaluation of potential risks due to fish ingestion for the RME scenario, and the arithmetic mean was used in the CT scenario. The data employed are found in Tables 4-2 and 4-3.

4.2.3.3 Netfishing

For the RME while netfishing, all 59 COPCs identified in Section 3 were evaluated conservatively employing the maximum concentrations available from surface (0–10 cm) sediment data across the GWSA as netfishing may occur in any area within the GWSA. For the CT scenario, the means of all surface sediment COPCs were calculated using Ecology’s statistical analysis program MTCA Stat. These data are presented in Table 4-4.

4.2.4 Exposure Evaluation

4.2.4.1 Exposure Parameters

Upon identification of COPCs and suitable data, the potential exposure evaluation then identifies parameters used to quantify potential exposures to COPCs; these parameters are summarized below for each exposure scenario.

<u>Beach Play/Wading</u>

Quantification of potential oral and dermal exposure consisted of an estimate of the COPC intake (chronic daily intake) people might experience during beach play/wading. This was calculated from the sediment data for each COPC as well as several conservative parameters regarding potential exposure to the COPCs.

The potential exposure frequency selected for the beach play/wading RME scenario (81 days per year for adults and 65 days per year for children) was based on a survey conducted by King County of parks adjacent to lakes and represents the 95th percentile of exposure frequency for children up to 6 years old who play in sand/sediments near the water, and adults playing on the beach for 30 years (Parametrix 2003). The potential exposure frequency for the beach play/wading CT scenario (8 days

per year for adults and 10 days per year for children) was based on the King County survey as well and represents the 50th percentile of exposure frequency for children who play in sand/sediments near water for up to 3 years, and adults playing on the beach for 9 years. This potential exposure frequency was assumed to occur solely in the GWSA nearshore area over the course of a year, resulting in a GWSA use fraction of 1 (or 100% use). This assumption was very conservative as it is unlikely that every day spent at the beach in a year will be at the Gas Works Park (GWP) shoreline. The remaining parameters for the evaluations of potential risk from both ingestion and dermal contact were generally EPA-recommended values for both the RME and CT scenarios. These exposure parameters are summarized in Tables 4-5 and 4-6.

Fish Ingestion

Quantification of potential oral exposure consisted of an estimate of the COPC intake (chronic daily intake) people might experience during consumption of crayfish and finfish. This was calculated from the crayfish and finfish tissue concentration data for each COPC as well as several highly conservative parameters regarding potential exposure to the COPCs.

For recreational fishers, exposure parameter values for crayfish and finfish consumption were based primarily on parameters set forth in EPA (1989) and MTCA (Ecology 2007) guidance documents. The CT consumption rates were based on the King County human use survey conducted at Lakes Union, Washington, and Sammamish (Parametrix 2003). For Tribal consumption, parameters were derived from EPA's *Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia* (2007a). Parameters not addressed in EPA 2007a were based on EPA 1989 and 2004.

The MTCA standard recreational adult fish ingestion of 54 g/day was used for the RME scenario calculations. This 54 g/day value includes all types of fish. For purposes of this evaluation, it was assumed that the 54 g/day is split evenly between crayfish and finfish (i.e., 27 g/day was ingested for each fish type). For the recreational CT scenario, the 50th percentile consumption rate for Lake Washington was used (5.7 g/day), again split between crayfish and finfish. In both scenarios, the ingestion rate of children was assumed to be 40% of the adult ingestion rate, as per EPA guidance (2007a). For the Tribal consumption RME scenario, the 95th percentile rate of adult shellfish (crabs, clams, and mussels) tissue ingestion for the Tulalip tribe was 81.9 g/day, and the 95th percentile tissue ingestion rate of finfish (excluding salmon) was 15.6 g/day. Children were again assumed to ingest approximately 40% of the adult ingestion rate (EPA 2007a). According to the Tulalip survey, this approximated three 8-ounce meals per week for adult Tribal consumers in the Puget Sound Region. These consumption rates were intended to be protective of current and future GWSA uses. The CT scenario used an ingestion rate of 12.5 g/day for shellfish and 2.5 g/day for finfish, based upon communications between LDWG and EPA (Windward 2007), with children ingesting 40% of the adult ingestion rate.

For this evaluation, it was conservatively assumed for the recreational fisher RME scenario that 50% of their diet was derived from the GWSA, and that 25% of their diet was derived from the GWSA for the CT scenario. The assumption for the recreational fisher was considered an appropriate assumption as the area of the GWSA is relatively small (the GWSA is approximately 56 acres) and fishing seasons promulgated by the WDFW restrict fishing within Lake Union. For the potential Tribal RME exposure scenario, it was conservatively assumed that 100% of their diet was derived from the GWSA, although the MIT fish in many other areas, including "locations on the upper Puyallup, the Carbon, Stuck, White, Green, Cedar and Black Rivers, the tributaries to these rivers (including Soos Creek, Burns Creek and Newaukum Creek) and Lake Washington, and secondarily in the saltwater of Puget Sound" (United States of America Puyallup Indian Tribe v. Muckleshoot Indian Tribe 2000). For the potential Tribal CT exposure scenario, it was conservatively assumed that 50% of their diet was derived from the GWSA. The Tribal exposure was also highly conservative as the fish species evaluated in the human health risk evaluation were resident fish which the Muckleshoot Tribe does not currently catch.

All parameters for the evaluation of fish consumption are presented in Table 4-7 for recreational fishers and Table 4-8 for the Tribal population.

Netfishing

Quantification of potential dermal and oral exposure consisted of an estimate of the COPC intake (chronic daily intake) people might experience by dermal contact with sediment and incidental consumption of sediment while netfishing. This was calculated from the surface sediment concentrations across the GWSA for each COPC, as well as several highly conservative parameters regarding potential exposure to the COPCs.

Exposure parameters for contact with sediment were based primarily on parameters recommended by EPA (1989) and EPA (2007a) for both the CT and RME scenarios. Additionally, parameters including potential exposure frequency and duration for both the CT and RME scenarios were included from the Lower Duwamish Waterway Group *(LDWG)* human health risk assessment (Windward 2007). Parameters from this LDWG assessment were developed based on site-use information from the MIT. As in North Lake Union, the MIT carry out commercial fishing for salmon in the Lower Duwamish Waterway.

For netfishers, the incidental sediment ingestion rate of 50 mg/day while netfishing was derived from EPA (1991). This rate was the recommended rate for a commercial/industrial exposure scenario and was appropriate for the evaluation of a commercial netfishing scenario. This consumption rate was conservative and intended to be protective of current and future GWSA uses.

For incidental sediment ingestion and dermal contact, it was assumed that the sediment contact frequency within the GWSA was 25% of the total sediment contact frequency within Lake Union, as recommended by EPA Region 10 at the Quendall Terminals Site (Anchor and Aspect 2009).

All parameters for the evaluation of netfishing are presented in Table 4-9 for incidental ingestion of sediment, and Table 4-10 for dermal contact with sediment.

4.2.4.2 Calculation of Chronic Daily Intake

The potential exposure to COPCs in tissue or sediment during consumption was expressed as the chronic daily intake (CDI), the mass of a substance ingested per unit body weight per unit time, averaged over the exposure duration (EPA 1989 and 2004; Ecology 2007). The CDI was calculated for each of the potential exposure scenarios previously described in Sections 4.2.2.

The CDI for fish or incidental sediment ingestion (EPA 1989 and 2004; Ecology 2007) was calculated as:

$$CDI = \frac{C \times EF \times ED \times IR \times FI \times CF}{AT \times BW}$$

Where:

- CDI = chronic daily intake from oral exposure route (mg/kg-day)
- C = COPC-specific tissue or sediment concentration (mg/kg)
- EF = exposure frequency (days/year)
- ED = exposure duration (years)
- IR = fish or sediment ingestion rate (g/day or mg/day, respectively)
- FI = fractional intake of fish or sediment derived from GWSA (unitless)
- CF = unit conversion factor (1×10^{-3} kg/g or 1×10^{-6} kg/mg for fish and sediment, respectively)
- AT = averaging time (days), equivalent to a 70-year lifetime for carcinogenic COPCs, and ED for non-carcinogenic COPCs multiplied by 365 days per year
- BW = body weight (kg).

The CDI for dermal contact while playing on the beach, wading, or netfishing (EPA 2004) was calculated as:

$$CDI = \frac{C \times EF \times ED \times SA \times AF \times ABS \times FI \times CF}{AT \times BW}$$

Where:

CDI = chronic daily intake from dermal exposure route (mg/kg-day)
C = COPC-specific sediment concentration (mg/kg)
EF = exposure frequency (days/year)
ED = exposure duration (years)
SA = surface skin area exposed (cm^2)
AF = sediment to skin adherence factor by event (mg/cm^2 event)
ABS = COPC-specific dermal absorption factor (unitless), see Table 4-11
FI = fractional intake of sediment derived from GWSA (unitless)
CF = unit conversion factor (1×10^{-6} kg/mg)
AT = averaging time (days), equivalent to a 70-year lifetime for carcinogenic COPCs, and ED for non-carcinogenic COPCs multiplied by 365 days per year
BW= body weight (kg).

The CDI was calculated for each COPC in the GWSA, for all potential exposure receptors. These intakes were in turn used in the potential risk characterization, discussed in the section below. Results for the CDI for beach play/wading CT and RME are summarized in Appendix C, Tables C-1 and C-2; for fish ingestion CT and RME in Tables C-3 and C-4; and for netfishing CT and RME in Tables C-5 and C-6.

4.2.5 Risk Characterization

4.2.5.1 Toxicity Evaluation

Potential carcinogenic risks and non-carcinogenic risks were evaluated separately because of the differences in the toxicological effects mechanism. EPA toxicity values (slope factors [SFs] for evaluation of potential carcinogenic risks or reference doses [RfDs] for evaluation of potential effects other than cancer) were identified for the majority of the COPCs, and are summarized in Table 4-12. Toxicity values were obtained from the hierarchy of sources presented in EPA 2003 which included: 1) the EPA's Integrated Risk Information System (IRIS) Database, the EPA's Provisional Peer Reviewed Toxicity Values (PPRTVs), and 3) other sources (i.e., California EPA [Cal EPA], ATSDR MRLs, and HEAST). SFs are an upper-bound estimate of a chemical's probability of causing cancer over a 70-year lifetime. The RfD is an estimate of a chronic oral daily exposure to the human population, including sensitive subgroups such as children, which is not likely to cause harmful effects during the exposure duration. Note, toxicity values have not been developed for the dermal exposure route. Therefore, the oral toxicity values were conservatively applied to assess the dermal pathway. Lead is a special case as it has no toxicity factors available, and is discussed in further detail below.

Lead

The risk characterization approach for lead was unique because a RfD value for lead is not available. The toxicokinetics of lead are well understood however, and the distribution of blood lead concentrations was used to evaluate potential risks posed by lead exposure. The U.S. Center for Disease Control and Prevention (CDC 1991) considers a blood lead level of 10 µg/dL to be a level of concern for children. For each exposure scenario, the maximum lead sediment concentration was compared to regulatory criteria promulgated by Ecology and the EPA (MTCA Method A Cleanup Level [250 mg/kg] for beach play/wading, and EPA Regional Screening Level [800 mg/kg, industrial soils] for netfishing). MTCA Method A was developed to prevent unacceptable blood lead levels, and the EPA

Regional Screening Level was developed to be protective of the fetus in a pregnant woman (a highly conservative scenario that should be protective of Tribal netfishers).

For fish ingestion, the absence of toxicity factors makes evaluation of acceptable tissue levels difficult. The EPA addressed this issue during the evaluation of data from the Columbia River basin fish contamination survey (EPA 2002). They modeled lead exposure using the Integrated Exposure Uptake Biokinetic (IEUBK) model and the Adult Lead Model (ALM). These models take into account lead exposure from a variety of sources (including site sources, and in this case, dietary fish sources), and calculate blood lead levels. The EPA determined that at a lead concentration of 500 µg/kg (0.5 mg/kg) in fish, there was a less than 5% chance that blood lead levels would exceed the acceptable level of 10 µg/dl in children. The EPA also found that a lead concentration of 700 µg/kg (0.7 mg/kg) in fish tissue consumed by a pregnant woman results in less than a 5% chance that blood lead levels in a fetus will exceed acceptable levels. The calculations included high fish consumption rates typical of Columbia River tribes. Oregon DEQ used 0.5 mg/kg as an acceptable concentration of lead in fish tissue to protect humans (ODEQ 2007). In this evaluation, maximum finfish and crayfish tissue concentrations were compared to 0.5 mg/kg per Oregon DEQ.

Carcinogenic Risk Calculations

EPA guidance (1989a and 1989b) states that a carcinogenic risk evaluation assuming a threshold for toxic effects is inappropriate. Instead, the EPA assumes that a limited amount of a toxicant may be able to exert carcinogenic or mutagenic effects in cells, and there is no dose at which a chemical has zero probability of exerting toxicity. Cancer SFs have been established for many of the COPCs (refer to Table 4-12), and the potential lifetime excess risk of cancer (beyond "background" cancer risk) can be calculated by multiplying the cancer SF by the CDI (expressed in units of mg/kg-day) of a COPC:

$$\text{Risk} = \text{CDI} \times \text{SF}$$

Potential risks were initially estimated separately for each COPC. These potential risks were then summed for all COPCs to obtain the potential excess lifetime cancer risk for each exposure scenario. As defined by MTCA (Ecology 2007) 173-340-745, the human health risk level for individual carcinogens may "not exceed one-in-a-million. If more than one type of hazardous substance is present, the total risk level at the site may not exceed 1 in 100,000 (1×10^{-5})." EPA's National Contingency Plan (NCP; 40 CFR 300) establishes a cancer risk in excess of one-in-a-million as a "point of departure" for establishing remediation goals. Excess cancer risks between 10^{-6} and 10^{-4} may be acceptable depending on site-specific factors.

Non-carcinogenic Risk Calculations

The EPA assumes that there is a threshold concentration of the chemical below which no health effects will occur. This threshold varies from chemical to chemical. The potential for non-carcinogenic adverse health effects is expressed as a Hazard Quotient (HQ), with a HQ of greater than 1 indicating a potential health risk. Toxicity RfDs have been established for many of the COPCs (refer to Table 4-12), and the HQ is calculated by the ratio of the chronic daily intake of a COPC to its route-specific reference dose:

$$\text{Risk} = \text{CDI}/\text{RfD}$$

The EPA (2001) states that HQs should be combined for pollutants that cause adverse effects by the same toxic mechanism. HQs were summed as part of the risk driver analysis (Appendix D).

4.2.6 Results

4.2.6.1 Beach Play/Wading

Adult

For the RME scenario, the potential cumulative excess cancer risk associated with exposure to sediments in the GWSA under the adult recreational beach play/wading scenario is 2×10^{-4} (Table 4-13). This level exceeds the MTCA cumulative acceptable risk threshold of 1×10^{-5} indicating that the potential for unacceptable excess cancer risk may exist to this receptor. Arsenic and individual carcinogenic high molecular weight PAHs (HPAHs[4]) excluding chrysene are above the MTCA individual threshold, or the EPA "point of departure," of 1×10^{-6}. The majority of the risk is attributed to benzo(a)pyrene, at 1×10^{-4}.

The CT scenario indicates a much lower risk level, with a cumulative risk of 6×10^{-7}. Thus the risk does not exceed either the EPA "point of departure" or the MTCA cumulative acceptable risk thresholds and therefore the CT scenario is unlikely to pose unacceptable excess cancer risk. .

As indicated on Table 4-14, the adult recreational beach play/wading scenario for both RME and CT resulted in no HQs greater than 1.

Child

The cumulative excess cancer risk associated with exposure to sediments in the GWSA under the child recreational beach play/wading RME scenario is 2×10^{-4} (Table 4-13). This level exceeds the MTCA cumulative acceptable risk threshold of 1×10^{-5} indicating that the potential for unacceptable excess cancer risk may exist to this receptor. Arsenic and individual carcinogenic HPAHs excluding chrysene are above the MTCA individual threshold, or the EPA "point of departure," of 1×10^{-6}. The majority of the risk is attributed to benzo(a)pyrene, at 2×10^{-4}.

The CT scenario indicates a much lower risk level, with a cumulative risk of 2×10^{-6}. Thus the risk is slightly greater than the EPA "point of departure," but is lower than the MTCA cumulative acceptable risk threshold and therefore the CT scenario is unlikely to pose unacceptable excess cancer risk. The majority of the potential risk is attributed to benzo(a)pyrene at 1×10^{-6}. No individual COPC exceeds risk thresholds.

As indicated on Table 4-14, the child recreational beach play/wading RME scenario resulted in an HQ of 4 for vanadium, indicating the potential for non-carcinogenic risk. For the CT scenario, there were no HQs greater than 1.

Lead in Beach Sediments

The maximum concentration of lead in the beach play/wading samples, 240 mg/kg, is less than MTCA Method A criterion for lead in soils and is therefore assumed to not pose significant risk.

[4] Carcinogenic PAHs are typically identified in risk evaluations as "cPAHs" but are identified here as HPAHs for consistency throughout the document. This risk assessment incorporates the relative carcinogenic potency of individual cPAHs by using individual cancer SFs for cPAHs. This approach is quantitatively the same as applying TEQs to each individual cPAH and obtaining benzo(a)pyrene equivalents.

4.2.6.2 Fish Ingestion

Recreational Fishers

Adult

The potential cumulative excess cancer risk associated with exposure to fish tissue in the GWSA under the adult recreational fisher ingestion RME scenario is 1×10^{-4} (Table 4-15). This level exceeds the MTCA cumulative acceptable risk threshold of 1×10^{-5} indicating that the potential for unacceptable excess cancer risk may exist to this receptor. Arsenic, chromium VI, all carcinogenic HPAHs with the exception of chrysene, PCB Aroclor 1254, PCB Aroclor 1260, and total PCBs are above the MTCA individual threshold, or the EPA "point of departure," of 1×10^{-6}. The greatest portion of the risk is attributed to arsenic, at 8×10^{-5}.

The cumulative excess cancer risk for the CT scenario is 2×10^{-6}. Thus, the potential risk is slightly greater than the EPA "point of departure," but is lower than the MTCA cumulative acceptable risk threshold and therefore the CT scenario is unlikely to pose unacceptable excess cancer risk. No individual COPCs exceed risk thresholds

As indicated on Table 4-16, the adult recreational fisher ingestion scenario for both RME and CT resulted in no HQs greater than 1.

Child

The potential cumulative excess cancer risk associated with ingestion of fish tissue in the GWSA under the child recreational fisher ingestion RME scenario is 5×10^{-5} (Table 4-15). This level exceeds the MTCA cumulative acceptable risk threshold of 1×10^{-5} indicating that the potential for unacceptable excess cancer risk may exist to this receptor. Arsenic, benzo(a)pyrene, PCB Aroclor 1254, PCB Aroclor 1260, and total PCBs are above the MTCA individual threshold, or the EPA "point of departure," of 1×10^{-6}. The greatest portion of the risk is attributed to arsenic, at 3×10^{-5}.

The potential cumulative excess cancer risk for the CT scenario is 1×10^{-6}. Thus the risk does not exceed either the EPA "point of departure" or the MTCA cumulative acceptable risk thresholds and therefore the CT scenario is unlikely to pose unacceptable excess cancer risk.

As indicated on Table 4-16, the child recreational fisher ingestion RME scenario resulted in an HQ of 2 for PCB Aroclor 1254, indicating the potential for non-carcinogenic risk. The CT scenario resulted in no HQs greater than 1.

Tribal Fishers

Adult

The potential cumulative excess cancer risk associated with exposure to fish tissue in the GWSA under the Tribal RME ingestion scenario is 2×10^{-3} (Table 4-15). This level exceeds the MTCA cumulative acceptable risk threshold of 1×10^{-5} indicating that the potential for unacceptable excess cancer risk may exist to this receptor. Arsenic, chromium VI, all carcinogenic HPAHs, PCP, chlordane, PCB Aroclor 1254, PCB Aroclor 1260, and total PCBs are above the MTCA individual threshold, or the EPA "point of departure," of 1×10^{-6}. The greatest portion of the risk is attributed to arsenic at 9×10^{-4}. It is important to note that the marginal threshold exceedances for both PCP and chlordane are based on the incorporation of non-detect values into the calculation, which is further discussed in the Uncertainty Analysis section (Section 4.2.7) below.

The potential cumulative excess cancer risk associated with exposure to fish tissue in the GWSA under the Tribal CT ingestion scenario is 3×10^{-5} (Table 4-15). This level exceeds the MTCA cumulative acceptable risk threshold of 1×10^{-5} indicating that the potential for unacceptable excess

cancer risk may exist to this receptor. Arsenic, benzo(a)pyrene, PCB Aroclor 1254, PCB Aroclor 1260, and total PCBs are above the MTCA individual threshold, or the EPA "point of departure," of 1×10^{-6}. The greatest portion of the risk is attributed to arsenic at 2×10^{-5}.

As indicated on Table 4-16, the adult Tribal fisher ingestion RME scenario resulted in HQs of 2 and 6 for arsenic and PCB Aroclor 1254, respectively, indicating the potential for non-carcinogenic risk. The CT scenario resulted in no HQs greater than 1.

Child

The potential cumulative excess cancer risk associated with exposure to fish tissue in the GWSA under the child Tribal ingestion RME scenario is 3×10^{-4} (Table 4-15). This level exceeds the MTCA cumulative acceptable risk threshold of 1×10^{-5} indicating that the potential for unacceptable excess cancer risk may exist to this receptor. Arsenic, chromium VI, all carcinogenic HPAHs with the exception of chrysene, PCB Aroclor 1254, PCB Aroclor 1260, and total PCBs are above the MTCA individual threshold, or the EPA "point of departure," of 1×10^{-6}. The greatest portion of the risk is attributed to arsenic, at 2×10^{-4}.

The potential cumulative excess cancer risk associated with exposure to fish tissue in the GWSA under the child Tribal ingestion CT scenario is 1×10^{-5} (Table 4-15). Thus the risk is greater than the EPA "point of departure," but is equal to the MTCA cumulative acceptable risk threshold and therefore the CT scenario is unlikely to pose unacceptable excess cancer risk. Arsenic and total PCBs are above the MTCA individual threshold, or the EPA "point of departure," of 1×10^{-6}. The greatest portion of the risk is attributed to arsenic, at 9×10^{-6}.

As indicated on Table 4-16, the child Tribal fisher ingestion RME scenario resulted in HQs in excess of 1 for antimony, arsenic, and PCB Aroclor 1254, indicating the potential for non-carcinogenic risk. It is important to note that the calculated HQ for antimony is based on the incorporation of non-detect values into the calculation, which is further discussed in the Uncertainty Analysis section (Section 4.2.7) below. The CT scenario resulted in no HQs greater than 1.

Lead in Fish Tissue

The maximum concentration of lead in crayfish tissue is greater than the Oregon DEQ acceptable level of 0.5 mg/kg, indicating the potential for an unacceptable adverse health effect. It is important to note, however, that the remaining two crayfish tissue samples with lead results and all finfish samples have lead concentrations well below 0.5 mg/kg.

4.2.6.3 Netfishing

The potential cumulative excess cancer risk associated with exposure to sediments in the GWSA under the adult Tribal netfishing RME scenario is 1×10^{-3} (Table 4-17). This level exceeds the MTCA cumulative acceptable risk threshold of 1×10^{-5} indicating that the potential for unacceptable excess cancer risk may exist to this receptor. Arsenic and all carcinogenic HPAHs are above the MTCA individual threshold, or the EPA "point of departure," of 1×10^{-6}.

The potential cumulative excess cancer risk associated with exposure to sediments in the GWSA under the adult Tribal netfishing CT scenario is 9×10^{-6} (Table 4-17). Thus, the risk is greater than the EPA "point of departure", but less than the MTCA cumulative acceptable risk threshold and therefore the CT scenario is unlikely to pose unacceptable excess cancer risk. Arsenic and benzo(a)pyrene are above the MTCA individual threshold, or the EPA "point of departure," of 1×10^{-6}.

As indicated on Table 4-18, the adult Tribal netfishing scenario for both RME and CT resulted in no HQs greater than 1.

Lead in GWSA Sediments

The maximum concentration of lead in the GWSA sediment samples, 1,120 mg/kg, is greater than the EPA Regional Screening Level for industrial exposure, indicating the potential for an unacceptable adverse health effect.

Of note, arsenic, lead, and vanadium are known natural background chemicals across Washington State and the western United States. Arsenic has a 90th percentile background concentration of 7 mg/kg in Puget Sound (Ecology 1994), which may contribute to the overall potential risk posed by arsenic. Lead has a 90th percentile background concentration of 24 mg/kg in Puget Sound (Ecology 1994). Vanadium is present in background soils in the western United States at concentrations ranging up to 500 mg/kg and the mean background soil concentration is 88 mg/kg (Shacklette and Boerngen 1984).

4.2.7 Uncertainty Analysis

There is a degree of uncertainty in any quantitative risk evaluation. Many assumptions are made in the process, including the assumptions about data (such as inclusion of undetected COPCs, data availability, and representativeness of data), and exposure and toxicity assumptions (appropriate EPA exposure parameters and COPCs lacking guidance for toxicity). Therefore, the calculated potential risk estimates also carry some degree of uncertainty. This section discusses briefly the factors in this evaluation likely to cause some degree of uncertainty in the resultant potential risk estimates, and the degree of their potential impacts.

One approach to addressing the inherent uncertainty in the risk evaluation process is to evaluate a range of potential risks related to the intensity and frequency of hypothetical GWSA use by humans. In this evaluation, two levels of exposure were assessed: the RME and the CT. The use of RME and CT scenarios spans the spectrum from an estimated high-end to average exposures that may reasonably occur. The difference between the RME and CT risk estimates provides an initial evaluation of the degree of variability or uncertainty associated with individual exposure.

4.2.7.1 Data Selection

Use of Historical Data to Represent Biota Consumed

A source of uncertainty in the evaluation of potential fish ingestion risk is the use of historically gathered data, from varying fish species, in risk calculations. The number of samples is typically about five individuals per fish species, which is unlikely to be representative of the entire population. However, collectively, the finfish represented 103 individual finfish; and crayfish samples represented 405 individual crayfish. The sample collection methodology, data quality control, and precise sampling locations have some uncertainties associated with them. For a more detailed discussion of these factors, see Section 2 and accompanying tables. The uncertainty associated with the fish tissue data may act to either over- or underestimate potential risks.

Use of Maximum Detected Concentration for the RME Scenario

Various statistical evaluations of data may be used in a risk evaluation; typically the RME scenario uses the 95 Percent Upper Confidence Limit on the mean. However, in the RME evaluation, the maximum concentrations detected for all COPCs were used as a conservative estimate of the exposure point concentrations. This approach provides an extremely conservative estimate of potential risk, and therefore is protective of human health but likely overestimates potential risk. Average concentrations were used in the CT risk scenario calculations, and provide a more realistic exposure concentration than the RME risk scenario calculations. Thus, the CT calculations provide an indication of the range of potential risks when compared to those calculated for the much more conservative RME scenario.

Furthermore, for beach play/wading RME and CT scenarios, available beach data had low concentrations of COPCs, and therefore sediment data from farther away from shore was also included in the exposure evaluation. This sediment would not ordinarily come into contact with humans using the beach because it was collected from areas with water depths ranging from 1.4 feet to over 16 feet, but to be conservative, these data were incorporated. The nearshore data also included in the exposure evaluation ranged in TPAH concentrations from lower than the maximum beach data concentration to seven times higher than the maximum beach data concentration and therefore generally adds to the conservative nature of this evaluation. Overall, the conservative nature of the evaluations increases the calculated potential risk.

Use of Estimated Sediment Data Results

All analytical data met the data quality review requirements required by the analytical methods and laboratory control limits, with the exception of antimony and lead. The sediment samples were analyzed slightly past the holding time and detected concentrations were less than the calculated reporting limit and greater than the method detection limit. Therefore, the antimony and lead detections received a "J" qualifier indicating estimated values. The data were determined to be of acceptable quality for use, as qualified. The use of qualified data for antimony is unlikely to significantly affect the overall risk conclusions as the HQ for antimony only marginally exceeds the acceptable threshold for one exposure pathway. The use of qualified data for lead may have underestimated or overestimated risks. However, lead has been determined to potentially cause an unacceptable risk in other exposure scenarios, and therefore the overall conclusions of the evaluation are not affected.

Incorporation of Undetected COPCs

For the incorporation of undetected COPCs in the evaluation, half of the maximum detection limit was used, as recommended by Ecology (2007) and EPA (1989a and 1989b). Therefore, the evaluation incorporates all COPCs identified in Section 3, providing a very conservative estimate of potential risk. Incorporation of undetected COPCs increases the overall potential risk estimates for the GWSA.

In three cases, non-detected COPCs (antimony, PCP, and chlordane) have been shown to cause a potential risk associated with the RME Tribal fish ingestion scenario. However, the risks of these COPCs were calculated solely using half of the non-detect values, as they were not detected in fish tissue. Again, incorporation of these non-detect COPCs is a highly conservative measure, and increases the overall potential risk estimate for the GWSA.

Data Availability

One COPC, 1,2,4-trimethylbenzene, has not previously been analyzed in the samples included in the beach play/wading evaluation. However, 1,2,4-trimethylbenzene has been analyzed within the GWSA, with a maximum non-detected surface sediment concentration of 34 mg/kg . Potential exposure at one–half the reporting limit (17 mg/kg) would not cause an unacceptable non-carcinogenic risk to humans; therefore, it is assumed that the availability of data in the shoreline areas will not affect the overall risk evaluation.

Nine of the GWSA COPCs (total cyanide, cobalt, vanadium, retene, and the volatile organics), have not been analyzed in any fish tissue samples, and are therefore not assessed for potential risk in the fish ingestion exposure scenarios. Volatile organics and total cyanide are non-standard analytes for tissue samples as they are not bioaccumulative due to their volatility and solubility. These volatile compounds are not expected to accumulate in tissue to a degree high enough to pose potential risk via tissue consumption, and are therefore the lack of this data in fish tissue is unlikely to affect any risk conclusions. Potential human health risk from fish ingestion from the GWSA is driven largely by carcinogenic effects from arsenic and HPAHs, among others, and the absence of cobalt, vanadium, and retene tissue data is also not likely to affect any risk conclusions.

Basis of Chromium Ratio

All chromium data for the GWSA has been reported as "total chromium." However, total chromium risk cannot be assessed as it has no established toxicity value. Instead, risk can be assessed based on the components of total chromium, including trivalent chromium (Cr III) and hexavalent chromium (Cr VI). Chromium VI is a highly toxic, carcinogenic compound while chromium III exhibits much lower, non-carcinogenic toxicity.

Based on a review of available literature, chromium content in GWSA surface sediment is expected to be primarily in the form of Cr III. Recent studies examining the toxicity of chromium in anoxic sediment suggest that Cr VI should not be appreciably present in the presence of acid volatile sulfide (AVS) (Berry et al., 2004; Besser et al., 2004; Becker et al., 2006; Graham et al., 2009; Driscoll et al., 2010), and EPA (2005a) suggests a benchmark for chromium based on the presence or absence of AVS. GWSA surface sediment AVS content indicates that the surface sediments are anoxic. Although these data represent a single sample event (October 2002) and seasonal fluctuation in sediment oxygen content likely occurs, sediment within the GWSA are expected to maintain a relatively low oxygen content year round.

The EPA has adopted a Cr VI to Cr III ratio of 1:6 in soil for application to dose response data (EPA 1998a). Graham et al. (2009) and Driscoll et al. (2010) indicate that Cr VI concentrations in bulk sediment were orders of magnitude below Cr_{total} concentrations, suggesting a ratio of Cr VI:Cr III exceeding 1:100. On the basis of the presence of anoxic sediment, characterized by measureable AVS, and with consideration for current understanding of chromium speciation in anoxic sediment, it would be appropriate to assume that Cr_{total} sediment data be evaluated as 100% Cr III, as Cr VI is not expected to persist given sediment conditions. Although site-specific conditions indicate that 100% Cr III is an appropriate assumption, the 1:6 ratio was still conservatively assumed in this evaluation, which likely results in an overestimate of risk results for Cr VI.

4.2.7.2 Exposure Evaluation

Beach Play/Wading and Netfishing Parameters

For beach play/wading, the incidental sediment ingestion rates were derived from EPA guidance, and the applicability of these rates to the GWSA is unknown. However, beach play/wading parameters including potential exposure duration, body weight, skin surface area, and adherence factors are typically incorporated values derived from EPA guidance. In particular, parameters such as the amount of skin surface area exposed (used for both RME and CT scenarios) are highly conservative considering the cool climate of the Pacific Northwest and the overall likelihood of significant beach use. The skin surface exposure parameter is even more conservative when considering a wading exposure scenario. Potential beach play/wading RME exposure frequency has been sourced from a study in the vicinity of the GWSA, and is therefore expected to be a reliable maximum value (although still very conservative as the value is derived from the 95 Percent Upper Confidence Limit of use, and it is highly unlikely that any child or adult would exclusively use Gas Work Park beaches for beach play/wading).

To account for the conservatism of the beach play/wading and netfishing scenarios, a CT scenario has been evaluated, resulting in much lower calculated potential risks. For example, potential carcinogenic risks for both beach play/wading and netfishing are approximately two orders of magnitude lower in the CT scenario than the RME scenario. Therefore, the calculation of the CT scenario has allowed a range of risks to be reported and illustrates the conservatism of the RME scenario.

For both beach play/wading and netfishing, several COPCs lack guidance on dermal absorption factors. However, any resulting underestimation of potential dermal risks from COPCs lacking

absorption factors is expected to have a small effect on overall potential risk estimates, as potential dermal risks posed tend to be much lower than potential ingestion risks.

Fish Ingestion Parameters

The exposure parameters for RME and CT fish ingestion are uncertain as well. The RME parameters, however, were designed to provide a conservative estimate of potential risk, particularly the Tribal ingestion parameters. For the Tribal fish ingestion RME scenario, the 95th percentile ingestion rate was used, and consumption was assumed to occur at the same rate for 70 years. For the RME, it was assumed that 100% of the fish consumed was caught in the GWSA, which is considered a conservative evaluation based on the size of the GWSA and the extensive range of areas where the MIT fish. Also for both the RME and CT, resident fish tissue concentrations were used in the evaluation, whereas the MIT do not currently fish for resident fish. It was also assumed that there is no reduction of chemicals during cooking.

The CT scenario provides a more realistic exposure scenario, particularly for Tribal fish ingestion (i.e. the 50th percentile ingestion rate was used, and consumption was assumed to occur over 30 years). While the CT scenario still results in potential unacceptable risks, its calculation has allowed a range of risks to be reported and illustrates the conservatism of the RME scenario.

Most of the uncertainties associated with RME exposure parameters are likely to result in overestimating the potential risks associated with COPC exposure. Potential risk is reduced by one to two orders of magnitude if less conservative assumptions are used as shown by the CT scenario.

Exposure to Sediment during Fish Ingestion

This potential exposure pathway (direct sediment contact or sediment ingestion) while eating fish is unlikely and insignificant. Contact with sediment may occur if fish is not well washed prior to consumption, but overall exposure compared to the ingestion of fish is likely to be negligible.

4.2.7.3 Toxicity Evaluation

Sources of uncertainty are inherent in the toxicity values for each substance used to characterize potential risk. The toxicity factors used in this risk evaluation are based on the most recent guidance provided by the EPA (with the exception of toxic equivalency factors for several carcinogenic HPAHs, provided by Cal EPA, as presented in MTCA 173-340-900 [Ecology 2007, Table 708-2]) and are overestimates of the potential dose-response. Toxicity factors are typically derived from the results of animal studies. Extrapolation of toxicological data from animal studies to humans is a large source of uncertainty in evaluating toxicity factors; therefore, the EPA applies several safety factors to the parameters to account for sensitive sub-populations and to ensure a conservative and protective toxicity factor. Due to the application of several safety factors, the risk conclusions are unlikely to be underestimated.

Vanadium in particular has highly uncertain toxicity values, resulting in uncertainty in the risk conclusions. The RfD of 7×10^{-5} mg/kg-day for vanadium has been derived from one toxicity study with low confidence in the RfD value (EPA 2009a). Another study, presented in the Health Effects Assessment Summary Table (HEAST; EPA 1992), promulgates a RfD value two orders of magnitude higher, which would result in the calculation of much lower HQs (e.g., for child recreational exposure, the HQ is currently 4 but would be 0.04 if the higher RfD was employed in the calculation). Although this higher RfD was not used in this evaluation as it is derived from an older study, it demonstrates the variability in the toxicity values available for vanadium.

For some COPCs, where toxicity values were not available, a similar COPC was identified as a surrogate, and its toxicity value employed in risk calculations. This lends some uncertainty to the potential risk analysis, as the use of an alternative toxicity value may over- or underestimate potential

risk. However, none of the COPCs where a surrogate was employed contributed largely to risk and therefore are not expected to impact the risk conclusions.

Lead pharmacokinetics is complex and as a result dose-based toxicity data are currently not available. Instead quantitative evaluation of lead exposure in soil is based on a predictive blood concentration and the Adult Lead Model (ALM) is often considered the appropriate model for quantitatively estimating risk from exposure to lead in soils for adult receptors while the IEUBK model considers risk to children (EPA 1994 and 2003). However, for this evaluation, the default cleanup levels promulgated by Ecology and the EPA for exposure to lead in sediment and fish tissue were used rather than the models. Both the Ecology and the EPA RME default values were calculated in a similar manner and are considered protective of sensitive subpopulations (see Section 4.2.5.1). Lead concentrations in fish tissue and netfishing sediment were above these default values, indicating that potential adverse risk exists; therefore, risk to lead has not been underestimated.

4.2.8 Summary of Potential Human Health Risk

As discussed above, the conservative site-specific RME calculations indicate potential risk above acceptable thresholds for nearly all exposure scenarios evaluated in the GWSA. However, the more realistic CT scenarios indicate risks that are about one to two orders of magnitude lower than the RME scenario. The potential risk under the CT scenario for all exposure scenarios, except Tribal fish ingestion, were less than the MTCA cumulative acceptable risk threshold and therefore are unlikely to pose unacceptable excess cancer risk. (An overview of human health risks is provided in summary Table 4-30 at the end of Section 4.)

4.2.8.1 Carcinogenic Risk

- Overall, arsenic, PCBs, and carcinogenic HPAHs are the primary carcinogenic risk contributors.
- Under the conservative RME scenario, the highest calculated potential carcinogenic risk for both the beach play/wading scenarios and the netfishing scenario is associated with dermal contact and ingestion of benzo(a)pyrene and carcinogenic HPAHs, followed by arsenic.
- The highest calculated potential carcinogenic risk for both the recreational fishers and Tribal fishers RME scenarios is ingestion of arsenic, followed by carcinogenic PCBs, HPAHs, and chromium VI. Marginal risk threshold exceedances for the Tribal fishers pathway RME also occur for the non-detected COPCs, PCP, and chlordane. For the CT Tribal fishers scenario, the highest potential carcinogenic risk is ingestion of arsenic, followed by PCBs and carcinogenic HPAHs.

4.2.8.2 Non-carcinogenic Risk

- Vanadium is the only COPC that exceeded the acceptable non-carcinogenic risk threshold in the beach play/wading RME scenario. The beach play/wading CT scenario resulted in no COPC exceedances of the acceptable non-carcinogenic risk threshold.
- Potential non-carcinogenic risk is posed in the Tribal fish ingestion RME scenario by PCB Aroclor 1254, as well as a low exceedance for arsenic and a marginal exceedance of a non-detected COPC, antimony. The tribal fish ingestion CT scenario resulted in no COPC exceedances of the acceptable non-carcinogenic risk threshold.

- Potential non-carcinogenic risk was posed in the recreational fish ingestion RME scenario by PCB Aroclor 1254 only, with no potential risk posed by any COPCs in the CT scenario.
- Lead has the potential to pose an unacceptable health risk for the fish ingestion and netfishing scenarios.

4.3 Ecological Risk Evaluation

4.3.1 Objectives

As described in Section 1.0, the *Gas Works Sediment Area Cleanup Standard Determination* (RETEC 2005a) derived GWSA site-specific cleanup standards for TPAH based on bioassay results. At TPAH surface sediment concentrations below the SSQL of 170 ppm, the benthic community should not experience sediment toxicity, and at TPAH surface sediment concentrations above the SSQL of 170 ppm may experience sediment toxicity. Thus, remediating sediments above the site-specific cleanup number protects the sediment benthic community from sediment toxicity associated with elevated chemical concentrations, particularly TPAH. Toxicity to invertebrates is therefore addressed via the TPAH SSQL. Sediment cleanup levels established in this manner in accordance with the SMS are intended to have "no adverse effects on biological resources and correspond to no significant health risk to humans" (WAC 173-204-300).

However, some agency comments on the draft RI/FS documents expressed concern at the lack of an ecological risk evaluation for other receptors, such as birds, mammals, or Endangered Species Act (ESA) listed species present in Lake Union. Therefore, the objective of this ecological risk evaluation was to characterize the potential risks to these additional ecological receptors by COPCs present in sediments or bioaccumulating in the food chain. The overall purpose was to determine which COPCs have the potential to cause or increase the potential risk to ecological receptors. COPCs that exceeded risk thresholds will be further evaluated in Section 5.0.

The specific objectives of this ecological risk evaluation comprise the following:

- Identify potential ecological receptors of concern at the GWSA
- Determine the potential exposure to COPCs at the GWSA based on established exposure parameters and available sediment and tissue data
- Perform and document a highly conservative site-specific risk evaluation of GWSA COPCs to determine those COPCs that ultimately will be further evaluated in Section 5.0.

4.3.2 Exposure Scenario

To address the potential for exposure to COPCs by ecological receptors, four representative wildlife receptors of concern were identified: two bird species, one mammal species, and one fish species. These species included: the great blue heron (*Ardea herodias*), the American mallard (*Anas platyrhynchos*), the northern river otter (*Lontra canadensis*), and the juvenile Chinook salmon (*Oncorhynchus tshawytscha*). The ecological receptors are described in further detail below.

The species are all resident in Lake Union and may be exposed to high COPC concentrations due to feeding behaviors or food web trophic levels. Evaluating potential risk to these receptor species span a range of feeding behaviors and food sources such that risk conclusions are protective of other, similar species occupying similar trophic levels. Chinook salmon is listed as a threatened species by the WDFW (2009). Due to its threatened status, juvenile chinook salmon was evaluated at an individual level, while the other receptors were evaluated at a population level.

4.3.2.1 Birds

Numerous aquatic and semi-aquatic bird species use the GWSA for foraging and other activities. There is evidence from Seattle Audubon counts suggesting that both the great blue heron and the mallard are present in the GWSA or visit the GWSA and North Lake Union vicinity transitorily (Seattle Audubon 2008). For all bird species, potential exposure within the GWSA is mainly due to ingestion of chemicals in their prey or incidentally-ingested sediment. Direct contact with sediment is not expected to be a significant exposure pathway compared to ingestion of COPCs in prey and sediment (EPA 2000b). Different habitats, prey species, and feeding behaviors result in different potential for exposure to sediment- and tissue-borne chemicals. Potential exposure and risk were estimated for species that represent two different feeding behaviors: piscivorous (birds that eat primarily fish), and herbivorous/ insectivorous (birds that probe in the sediments for invertebrates and ingest aquatic plants).

Piscivorous/Omnivorous Bird

The great blue heron (*Ardea herodias*) was selected to represent the piscivorous bird category and is known to live and feed in and around Lake Union (Seattle Audubon 2009). The diet of the heron is variable, but includes mainly fish, also amphibians, reptiles, invertebrates, small mammals, and even other birds. They are susceptible to biomagnification of certain COPCs because of their trophic position and feeding habits. It is assumed that the great blue heron serves as a representative species for waterfowl and seabirds that also feed primarily on fish and aquatic invertebrates.

Insectivorous Bird

The American mallard is common in Lake Union (Seattle Audubon 2009) and was selected to represent the insectivorous bird category, as they consume a wide variety of foods, including vegetation, insects, worms, gastropods, and arthropods (although they are not restricted to these items). They usually feed by dabbling for plant food or grazing. As a result, the mallard is likely to ingest sediment during feeding. It is assumed that because of the high potential exposure through direct ingestion of sediment, protection of the mallard will also be protective of other omnivorous and benthivorous birds.

4.3.2.2 Mammals

Numerous aquatic and semi-aquatic mammal species use the GWSA, including otter, mink, and beaver (USGS 2010). For all mammal species, potential exposure in the GWSA is mainly due to ingestion of chemicals in their prey, or incidentally ingested sediment. Direct contact with sediment is not expected to be a significant exposure pathway compared to ingestion of COPCs in prey and sediment (EPA 2000b). Different habitats, prey species, and feeding behaviors result in different potential for exposure to sediment- and tissue-borne chemicals. Potential exposure and risk were estimated for a carnivorous mammal, which would represent mammals with the feeding behavior likely to cause the greater potential chemical exposure.

The carnivorous mammal evaluated by this ecological risk evaluation is the northern river otter, which was documented in Lake Union by the U.S. Geological Survey (USGS 2010). The northern river otter preys primarily on fish, but also consumes various small mammals, amphibians, turtles, and crayfish. The key exposure route for aquatic or semi-aquatic mammals is likely to be the consumption of prey associated with sediment in the GWSA, and incidental ingestion of sediment. The northern river otter is susceptible to biomagnification of certain COPCs because of its high trophic position and feeding habits. As the northern river otter is carnivorous, a higher chemical body burden would be expected (due to bioaccumulation) than the beaver, for example, a mammalian herbivore found in Lake Union. The northern river otter may be representative of a broader range of carnivorous species present in Lake Union, including mink.

4.3.2.3 Fish

Numerous fish species occur in the GWSA, including several species of salmon. In this ecological risk evaluation, juvenile Chinook salmon were selected to be representative of invertivorous salmon species present in the GWSA. As the exposure scenario for salmon in this evaluation is highly conservative (assuming 365 days per year exposure when salmon residence time in the GWSA is much lower), it is assumed to be protective of resident fish species as well, such as yellow perch and smallmouth bass. Potential exposure to juvenile Chinook salmon is mainly from ingestion of chemicals in prey, or incidentally-ingested sediment. Direct contact with sediment is not expected to be a significant exposure pathway compared to ingestion of COPCs in prey and sediment (EPA 2000b).

Research of salmon migration in the Lake Washington basin indicated that salmon use the GWSA as a part of their migration corridor to and from Lake Washington and further upstream for spawning to Cedar River, Bear Creek, Issaquah Creek, and the Issaquah and University of Washington hatcheries (USACE and SPU 2006). Chinook salmon spawn in these rivers with gravel substrate and relatively high flow asthe eggs require high oxygen concentrations. The fry generally migrate downstream between January and April. Chinook salmon are primarily shoreline-oriented during migration, but may migrate to deep areas as they increase in size. Tabor et al. (2006) observed that from February to April, juvenile Chinook salmon were only observed in water between 0 and 0.5 meters deep. Generally, the juvenile salmon progressively moved deeper until, by June, most activity was observed in water between 2 and 3 meters deep. Salmon have also been observed passing through the GWSA at depths of between 8 to 10 meters. The juvenile Chinook salmon typically migrate out of the Lake Washington watershed between May and July, through the Ship Canal and Lake Union including the GWSA, with the greatest number of salmon passing through the Ballard locks in June (Tabor et al. 2006). According to Tabor et al. (2006), the median residence time in 2005 for juvenile salmon in the GWSA was 14 hours. Most juvenile Chinook leave the Lake Washington watershed within the first year of life, migrating to saltwater.

Chinook salmon prey primarily on terrestrial and aquatic insects, amphipods, and other crustaceans. In recent years, salmon have experienced dramatic declines in abundance as a result of a number of factors, and the chinook species in the Puget Sound were designated as “threatened” in June 2005 (NOAA 2007). Additionally, the Puget Sound region falls under the “critical habitat” of the Chinook salmon, as designated by the federal government pursuant to the Endangered Species Act (US Code, Title 16 1531, 1973).

4.3.3 Data Selection

In the first step of the risk evaluation, a COPC screening was performed to identify the COPCs to be evaluated. The COPC screening is discussed in Section 3. Sixty chemicals were identified as GWSA COPCs. Potential exposure to all of the COPCs was then evaluated based on available sediment and tissue data.

Surface sediment data (collected approximately 0–10 cm) along the shoreline (see Figure 4-3) and within the GWSA (refer to Tables 4-4 and 4-19) were employed in this evaluation. For mallards and herons, shoreline sediment data were employed because the birds do not dive to great depths to obtain food (Cornell University 2009). Otters, however, are known to dive to depths of 18 meters (Smithsonian 2009), and may be exposed to surface sediments within the entire GWSA. Therefore, the data set used for the otter exposure evaluation includes all available surface samples within the GWSA, regardless of depth. Like otters, juvenile salmon may be exposed to surface sediments across the GWSA during outward migration, and therefore concentrations across the GWSA have been employed for their evaluation.

Historical tissue data collected in the Gas Works Park vicinity and the northeast arm of Lake Union from several studies including the University Regulator Pre- and Post-Separation Studies (King County 2009) were used in the calculations. A total of six finfish samples and four crayfish samples

were used. Finfish species employed in this evaluation included perch, sculpin, largemouth bass, catfish, and crappie. The tissue analyzed for all finfish was raw fillet, and for crayfish was raw tail only. Tables 2-5 and 2-6 present a summary of crayfish and finfish information, respectively. At least one data point was available for all identified COPCs between the crayfish and finfish data with the exception of cobalt, vanadium, retene, and volatile compounds including total cyanide and the volatile organics, which are non-standard analytes for tissue data. These are discussed further in the uncertainty analysis, Section 4.3.7.3.

Importantly, all priority bioaccumulative chemicals (EPA 2008a) identified as GWSA COPCs have been evaluated for potential risk, including benzo(a)pyrene, chlordane, DDD, DDT, mercury, and PCBs.

4.3.4 Exposure Evaluation

4.3.4.1 Exposure Parameters

The subsequent sections describe the following exposure parameters for each wildlife receptor:

- BW – body weight in kg.
- FIR – food ingestion rate in kg wet weight per day (kg ww/day), converted to kg dry weight per day (kg dw/day).
- SIR – sediment ingestion rate in kg dry weight per day (kg dw/day).
- DF – dietary fraction, which is unitless.
- FI – fractional intake, the fraction of sediment and fish consumed from the site, which is unitless. For all species, females are assumed to be the receptor of concern as toxicity reference values (TRVs) are often based on reproductive endpoints from exposure to female organisms.

4.3.4.2 Great Blue Heron

BW: The BW employed in risk calculations was 2.2 kg, the average weight of a female heron as presented in the *Final Regional Sediment Evaluation Framework for the Pacific Northwest* (RSET 2009).

FIR: The FIR value for females was calculated using an equation for wading birds presented in RSET (2009):

$$\log(FIR) = 0.966 \times \log(BW) - 0.640$$

The FIR for great blue herons was therefore calculated as 0.388 kg ww/day, which was converted to kg dw/day based on the average prey moisture content promulgated in EPA (1993; 79 and 72% average moisture content for crayfish and finfish, respectively), with a calculated dry weight of 0.107 kg/day.

SIR: The SIR was assumed to be 2% of the FIR (kg dw/day as per Windward [2007] and Windward [2009]), resulting in a SIR of 0.002 kg dw/day.

DF: The dietary split between finfish and crayfish was derived from Alexander (1977) as presented in EPA (1993). While crayfish are not identified specifically as a dietary fraction, crayfish are assumed to be a surrogate for the crustacean fraction 2%, while finfish comprise the remainder of the diet.

FI: Great blue herons are assumed to have a large home range, often foraging grounds four miles or more from the nesting site and migrating seasonally. The fractional intake from the GWSA was

therefore conservatively assumed to be 0.5, allowing that 50% of the prey and sediment that the heron ingests was collected from the GWSA. This approach was consistent with other regional risk evaluations, including Windward (2007) and Windward (2009).

The exposure parameters of the great blue heron are summarized in Table 4-20.

4.3.4.3 American Mallard

BW: The body weight employed in risk calculations was 1.1 kg, an average of female mallards as presented in EPA (1993).

FIR: The FIR value for female mallards was calculated using an equation for food ingestion rate of all birds derived by Nagy (1987) and presented by EPA (1993):

$$FIR = 0.0582 \times BW^{0.651}$$

The FIR for mallards was therefore calculated as 0.31 kg ww/day, which was converted to kg dw/day based on the average prey moisture content promulgated in EPA (1993), with a calculated dry weight of 0.065 kg/day.

SIR: The SIR was assumed to be 3% of the FIR (kg dw/day as per Beyer et al. [1994]), resulting in a SIR of 0.002 kg dw/day.

DF: Ducks generally do not consume fish, but consume small crustaceans, insects, and plants. As a conservative estimate, the mallard diet was assumed as 100% crayfish.

FI: As mallards are assumed to have a relatively limited home range, the fractional intake from the GWSA was conservatively assumed to be 1.0, allowing that 100% of the prey and sediment that the mallard ingests was collected from the GWSA.

The exposure parameters of the mallard are summarized in Table 4-21.

4.3.4.4 Northern River Otter

BW: The body weight employed in risk calculations was is 7.7 kg, which is the female otter mean body weight as per RSET (2009).

FIR: The FIR for the northern river otter was presented in RSET (2009) as 0.759 kg ww/day, which was converted to kg dw/day, based on the average prey moisture content promulgated in EPA (1993), with a calculated dry weight of 0.206 kg/day.

SIR: The SIR was assumed to be 2% of the FIR (kg dw/day as per Windward [2007] and Windward [2009]), resulting in a SIR of 0.003 kg dw/day.

DF: A dietary composition of 12% crayfish and 88% finfish was assumed for the northern river otter. These values were derived from data in Windward (2007) and Windward (2009), where all invertebrates were included in the 12% fraction.

FI: Although otters are assumed to have a relatively large home range—they may travel from 10 to 25 miles seasonally (WDFW 2005)—the fractional intake from the GWSA was conservatively assumed to be 1.0, allowing that 100% of the prey and sediment that the otter ingests was collected from the GWSA.

The exposure parameters of the northern river otter are summarized in Table 4-22.

4.3.4.5 Juvenile Chinook Salmon

BW: The body weight employed in calculations was 0.012 kg, the body weight determined in the Lower Willamette Group (LWG) investigation (Windward 2009) based on field-collected data.

FIR: The FIR for salmon was derived from Arnot and Gobas (2004) as presented in Windward (2009) based on the value for body weight derived from Portland Harbor:

$$FIR\ (ww) = (0.022 \times BW^{0.85}) \times e^{(0.06 \times T)}$$

in which T = 13.0°C (approximate average Lake Union value [Floyd|Snider 2007]).

Based on this calculation, the FIR was calculated as 1.14×10^{-3} kg ww/day, which was converted to kg dw/day based on the average prey moisture content promulgated in EPA (1993), with a calculated dry weight of 2.31×10^{-4} kg/day.

SIR: The SIR was assumed to be 10% of the FIR (kg dw/day based on professional judgment and accounting for the high contact with sediment of salmon while foraging for invertebrates), resulting in a SIR of 2.31×10^{-5} kg dw/day.

DF: Salmon generally do not consume fish until they are mature, but juveniles consume small crustaceans, terrestrial and aquatic insects, and amphipods. As a conservative estimate and in the absence of additional tissue or prey data, the salmon diet was assumed to be 100% crayfish.

FI: Although salmon are assumed to spend a relatively short amount of time in the GWSA during their migration to and from the open sea, the fractional intake from the GWSA was assumed to be 1.0, allowing that 100% of the prey and sediment that the salmon ingests is collected from the GWSA. This was a highly conservative assumption.

The exposure parameters of the juvenile Chinook salmon are summarized in Table 4-23.

4.3.4.6 Calculation of Dietary Dose

The potential exposure to COPCs in sediment and fish tissue during consumption was expressed as the dietary dose (dose), the mass of a substance contacted/ingested per unit body weight per unit time (EPA 1993). The dose was calculated for each of the ecological receptors individually.

The dose (EPA 1989 and 2004) is calculated as:

$$Dose = \sum_{k=1}^{m} \frac{(C_k \times IR_k \times DF_k \times FI_k)}{BW}$$

Where:

- Dose = dietary dose from oral potential exposure route (mg/kg-day)
- C = COPC-specific concentration in the k^{th} type of food (mg/kg)
- IR = food or sediment ingestion rate of k^{th} type of food (mg/day)
- FI = fractional intake of kt^{h} type of food/sediment derived from the GWSA (unitless)
- DF = dietary fraction for each food type (unitless)
- BW = body weight (kg)
- k = contaminated food type
- m= number of contaminated food types.

The dose was calculated for each GWSA COPC for each wildlife receptor. These doses were in turn used in the risk characterization, discussed in Section 4.3.5., below. The dose values for each COPC are presented for the great blue heron, American mallard, northern river otter, and juvenile Chinook salmon in Appendix E, Tables E-1, E-2, E-3, and E-4, respectively. The dose was assumed to be present in the wildlife receptor tissue without metabolism, excretion, or attenuation of any kind.

4.3.5 Risk Characterization

4.3.5.1 Toxicity Evaluation

A TRV is a toxicity threshold used in the ecological risk evaluation. It is the daily dose of a chemical in units of mg chemical per kg wet body weight per day (mg/kg bw/day) that elicits a particular biological effect, such as survival, reproductive effects, or growth effects, among others. Potential dietary exposure risks to the wildlife receptors were evaluated against two TRVs: the NOAEL and the LOAEL for dietary doses. The NOAEL is the "no observable adverse effect level" of a chemical, and the LOAEL is the "lowest observable adverse effect level." According to RSET (2009), the LOAEL is used as the basis for calculating dietary doses protective of populations of the site-specific receptor and the NOAEL is used to be protective of individuals of the site-specific receptor. At concentrations greater than the LOAEL TRV, most but not all individual organisms in the exposed populations may be affected. In this evaluation, LOAELs were the TRVs of interest for the great blue heron, mallard, and northern river otter, as health effects on the populations of these wildlife receptors present at the GWSA are of importance. Chinook salmon is listed as a threatened species, and therefore potential risk was evaluated on an individual basis using NOAELs as the TRVs of interest, consistent with EPA guidance (EPA 1998b).

Derivation of Avian and Mammalian TRVs

TRVs were selected from several published studies approved by the EPA and RSET. The following hierarchy was established in the selection of avian and mammalian TRV values for COPCs at the GWSA:

- RSET (2009) Sediment Evaluation Framework for the Pacific Northwest
- EPA (2005b, 2005c, 2005d, 2005e, 2006, 2007b, 2007c, 2007d, 2007e, 2007f, 2007g, and 2008b) Ecological Soil Screening Level (SSL) Guidance Documentation
- Literature-derived TRVs presented in Windward (2009), the Lower Willamette Group (LWG) Ecological Risk Assessment
- Literature-derived TRVs presented in Windward (2007), the Lower Duwamish Waterway Group (LDWG) Ecological Risk Assessment.
- Sample et al. 1996, Toxicological Benchmarks for Wildlife
- EPA (2010) Integrated Risk Information System (IRIS)
- USACE and EPA (2009) Environmental Residue-Effects Database (ERED).

RSET has recommended TRVs protective of ecological receptors including EPA avian and mammalian NOAEL TRVs identified in the SSL guidance documents (EPA 2005, 2007, 2009) and the Oregon DEQ (2007) avian and mammalian NOAEL and LOAEL TRV's selected for use. RSET has not recommended TRVs for all of the GWSA COPCs, however, and EPA SSL guidance has been included here as a supplement to RSET values. In Windward (2007) and Windward (2009), extensive literature reviews were completed in the process of establishing TRVs, and these documents were used as further guidance in the selection of TRVs. Windward (2009) was used in preference to Windward (2007), as it is a more recently released document. Tables 4-24 and 4-25 summarize avian

and mammalian TRVs selected for this evaluation. Additional TRVs were derived from various sources, listed above. As several COPCs did not have an LOAEL value available, an uncertainty factor of five (per EPA 1997b) was applied in these cases. There is some uncertainty inherent in this extrapolation, as discussed in Section 4.3.7.4.

Derivation of Fish TRVs

Fish TRVs were derived from data available from the USACE's Environmental Residue Effect Database (ERED; USACE 2009), and based on the data set underlying the proposed values under development in support of the LWG and LDWG (Windward 2007 and 2009). Dietary NOAEL and LOAEL TRVs were recommended based on the available literature. The purpose of these TRVs was to provide appropriately conservative threshold concentrations for use in the risk evaluation.

As presented in Table 4-26, dietary fish TRVs (NOAEL and LOAEL) were derived from ERED and LWG/LDWG compiled data by selecting applicable toxicity studies based on growth, reproduction, survival and/or behavioral endpoints for freshwater/marine species and considered multiple life stages, including juveniles and adults. Preference was given to studies specific to salmonid species. Where no such studies were available, other species were considered. In general, TRVs were based on 10^{th}%ile of the available data set for salmonids (juvenile and adults), where the number of studies was sufficient (n>2). Otherwise, the TRV was based on the minimum of the available values or the study showing the full range of dose-response (i.e., NOAEL and LOAEL), as applicable. Literature fish tissue TRV values available at ERED (2009) and other literature values presented in units of mg/kg wet weight were converted to dietary TRVs (in units of mg/kg-d) assuming 80% moisture content and the FIR (0.0011 kg/day) and BW (0.012 kg) of juvenile salmon.

Although chronic or subchronic study duration endpoints were preferred (e.g., no observed effective dose [NOED] or lowest observed effective dose [LOED]), acute and subacute studies were considered where other data were absent (e.g., LD20). Where possible, TRVs were developed as the highest no-effects tissue concentration (highest NOED), provided it was lower than the lowest LOED. Uncertainty factors were not applied to the data except in estimating a LOAEL-based TRV. Here a uncertainty factor of five (per EPA 1997b) was applied as applicable. There is some uncertainty inherent in this extrapolation, as discussed in Section 4.3.7.

Risk Calculations

The potential for adverse health effects was expressed as an HQ. The HQ approach was used to evaluate whether potential exposure concentrations were greater than or equal to a level that may impact survival, growth, reproduction, or other toxicological effects, (i.e. if the HQ was greater than 1.0, an adverse effect may be observed). TRVs have been established for many of the COPCs (described above), and the HQ was calculated by the ratio of the dietary dose of a COPC to its TRV:

$$\text{Risk} = \text{Dose}/\text{TRV}$$

Table 4-27 summarizes the calculated HQs for each COPC for the individual wildlife receptors. Those HQs that exceeded 1.0 are summarized below.

Exceedances of NOAEL TRVs are typically only of concern to individual threatened or endangered species (EPA 1998b), thus, is only noted for juvenile salmonid below.

4.3.6 Results

4.3.6.1 Great Blue Heron

No COPCs exceeding the acceptable LOAEL risk threshold were identified for the great blue heron, implying no potential risk to the overall heron population. Table 4-27 presents a summary of the calculated HQs for the great blue heron.

4.3.6.2 American Mallard

One COPC that slightly exceeded the acceptable LOAEL risk threshold was identified for the American mallard: benzo(a)pyrene. For this COPC, the dose is greater than the LOAEL, indicating an adverse health effect may be exerted on a population due to exposure to this COPC. The HQ for benzo(a)pyrene was 1.5 for the LOAEL with an evaluation endpoint of reproduction. Table 4-27 presents a summary of the calculated HQs for the American mallard.

4.3.6.3 Northern River Otter

One COPC that slightly exceeded the acceptable LOAEL risk threshold was identified for the northern river otter: Total HPAH. For this COPC, the dose is greater than the LOAEL, indicating an adverse health effect may be exerted on a population due to exposure to this COPC. The HQ for Total HPAH was 1.7 for the LOAEL with an evaluation endpoint of survival. Table 4-27 presents a summary of the calculated HQs for the American mallard.

4.3.6.4 Juvenile Chinook Salmon

One COPC, TBT (HQ = 32) predominated acceptable NOAEL threshold exceedances for juvenile Chinook salmon indicating the greatest likelihood of exerting adverse health effects. An additional five COPCs had low acceptable NOAEL risk threshold exceedances identified for juvenile Chinook salmon (HQ less than 4): arsenic, vanadium, benzo(a)pyrene, TPAHs, and bis(2-ethylhexyl)phthalate. For these COPCs, the dietary dose is greater than the NOAEL, indicating an adverse health effect may be exerted on an individual due to exposure to these COPCs. Table 4-27 presents a summary of calculated HQs for juvenile Chinook salmon.

Of note, arsenic and vanadium are known natural background chemicals across Washington state. Arsenic has a 90th percentile background concentration of 7 mg/kg in Puget Sound (Ecology 1994), which may contribute to the overall potential risk posed by arsenic. Vanadium is present in background soils in the western United States at concentrations ranging up to 500 mg/kg and the mean background soil concentration is 88 mg/kg (Shacklette and Boerngen 1984).

4.3.7 Uncertainty Analysis

4.3.7.1 Exposure Scenarios

Receptor Selection

Four wildlife receptors were selected for the ecological risk evaluation to represent species categories comprising insectivorous bird, piscivorous/omnivorous bird, carnivorous mammal, and invertivorous fish. The selection of receptors lends uncertainty to the evaluation as limited data was available describing the presence and abundance of wildlife in the GWSA area. Fractional intake data (meaning the amount of sediment and prey ingested that are derived from the GWSA) was not generally available for North Lake Union, but assumed to be 100% for the receptors (with the exception of great blue heron at 50%). Both of these fractional intakes (FIs) are highly conservative, particularly for the northern river otter, great blue heron, and juvenile Chinook salmon. For the northern river otter and great blue heron, their home ranges are known to be much larger areas than the GWSA (around 10 to 25 miles and 4 miles, respectively) so it is highly unlikely they would spend their entire lives in the

GWSA and only ingest sediment and prey from this area. The juvenile Chinook salmon only spends a small portion of its life in Lake Union (about 14 days) during their migration to the sea. The FIs used result in an overestimate of risk to these receptors in the GWSA.

Several potential factors that also may affect uncertainty here include all exposure parameters—in particular dietary composition—but also incidental sediment ingestion rate, body weight, and food ingestion rate which will vary from species to species.

Dietary composition for each of the wildlife receptors is assumed to be protective for a number of similar species. For example, the dietary composition for the great blue heron is assumed to be protective of other piscivorous birds including western grebe, which may ingest a higher fraction of shellfish. However, as the calculated ingested doses are generally based on sediment contamination, this is not likely to significantly alter the ecological risk evaluation results. Dietary composition for juvenile salmon was assumed to be 100% crayfish, based on available data.

Uncertainty resides in the incidental sediment ingestion rate, body weight, and food ingestion rate as well for all receptors. However, the ingestion rates used in this ecological risk evaluation were generally derived from previously vetted risk assessments (Windward 2007 and 2009) or resources (RSET 2009 and EPA 1993). Therefore, they are deemed appropriate for use in this ecological risk evaluation, but may have the potential to overestimate risk.

4.3.7.2 Direct Sediment Contact

Potential risks to wildlife from direct contact with sediment are considered insignificant relative to risks from incidental sediment ingestion (EPA 2000b). However, the exclusion of this pathway may result in a slight underestimate of potential risk for the wildlife receptors.

4.3.7.3 Data Selection

Use of Historical Data to Represent Biota Consumed

The primary source of uncertainty in this risk evaluation is the use of historically gathered data, from varying fish species, in risk calculations. The number of samples is typically about five individuals per fish species, which is unlikely to be representative of the entire population. The sample collection methodology, data quality control, and precise sampling locations have some uncertainties associated with them. For a more detailed discussion of these factors, see Section 2 and accompanying tables. The uncertainty associated with the fish tissue data may act to either over- or underestimate potential risks.

Data Availability

Nine of the GWSA COPCs (total cyanide, cobalt, vanadium, retene, and the volatile organics) have not been analyzed in any fish tissue samples. Volatile organics and total cyanide are non-standard analytes for tissue samples as they are not bioaccumulative due to their volatility and solubility. When calculations are completed for the remaining COPCs (cobalt, vanadium, and retene) with sediment data only, the HQ results are generally well below 1.0, often several orders of magnitude (with the exception of vanadium exposure to salmon, identified as a potential risk). Due to their low HQs, it is unlikely that the addition of fish tissue data in the determination of dietary dose would substantially affect risk conclusions.

Use of Maximum Detected Concentration

Various statistical evaluations of data may be used in a risk evaluation, typically calculating the 95 Percent Upper Confidence Limit. However, in this evaluation, the maximum concentrations detected

for all COPCs were used as conservative estimates of the exposure point concentrations to provide an extremely conservative estimate of potential risk, and therefore is protective of ecological health.

Incorporation of Undetected COPCs

For the incorporation of undetected COPCs in the evaluation, half of the maximum detection limit was used, as recommended by Ecology (2007) and EPA (1989). Therefore, the evaluation incorporates all COPCs identified in Section 3, providing a conservative estimate of potential risk.

Basis of Chromium Ratio

All chromium data for the GWSA has been reported as "total chromium." However, total chromium risk cannot be assessed as it has no established toxicity value. Instead, risk can be assessed based on the components of total chromium, including Cr III and Cr VI. As previously discussed in Section 4.2.7.1, the Cr VI to Cr III ratio of 1:6 (EPA 1998a) was conservatively assumed in this evaluation, which likely results in an overestimate of potential risk results.

4.3.7.4 Toxicity Evaluation

Toxicity Reference Values

Uncertainty associated with available TRVs for avian and mammal receptors may affect potential risk estimates. The primary uncertainties include:

- At least one TRV was identified for each COPC except carbazole, dibenzofuran, volatile organics, and PCB Aroclor 1260. The latter was adequately assessed by the use of a surrogate PCB Aroclor 1254 and/or total PCBs. These were the only COPCs for which there was not enough information available to conduct an ecological risk evaluation, but all were evaluated for human health effects. In some cases, the TRV identified was the TRV for a similar compound, used as a surrogate. This lends some uncertainty to the ecological risk evaluation, but surrogates employed were generally compounds expected to have similar or greater toxicological effects than the actual COPC, resulting in a potential overestimation of risks.
- With the exception of the salmon TRVs which were primarily specific to juvenile salmonids or similar species, very few of the laboratory studies that the TRVs are based on employed the wildlife receptors assessed here; studies are assumed to apply to all birds and all mammals.
- The laboratory studies on which TRVs are based were conducted in controlled settings using single-chemical exposures. Effects associated with multiple chemical exposure (including potential synergistic effects) were not evaluated in these studies.
- In some cases, NOAELs were not available for some COPCs, so they were estimated from LOAELs or vice versa (this approach was taken in RSET 2009).
- Varying assessment endpoints in the toxicological values add some uncertainty in the consistency of the effects assessment.

4.3.8 Summary of Potential Ecological Risk

Incidental sediment ingestion is the primary source of potential risk for all wildlife receptors. The most significant contributors to potential risk vary between ecological receptors:

- Tributylin resulted in the greatest potential risk threshold exceedance for the juvenile salmonid receptor, with low risk threshold exceedances posed by arsenic, vanadium, benzo(a)pyrene, TPAHs, and bis(2-ethylhexyl)phthalate.
- Slight risk threshold exceedances were estimated for two COPCs: benzo(a)pyrene and total HPAHs for the American mallard and Northern river otter receptors, respectively.
- Typical bioaccumulative COPCs that commonly cause some potential risk, including PCBs and DDT, were not identified as COPCs to be further evaluated in Section 5.0 for any ecological receptor (however, PCBs were identified for further evaluation in Section 5.0 based on estimated human health risk threshold exceedances).

4.4 Summary of COPCs Following the Human Health and Ecological Risk Evaluations

The revised screening process identified 59 possible COPCs, which then underwent site-specific GWSA human health and ecological risk evaluations. The results of the risk evaluation described in Section 4 are summarized in Table 4-28. Following the risk evaluation, possible COPCs were categorized as follows:

<u>COPCs Exceeding Minimum Individual Acceptable Risk Thresholds</u>

- Twenty COPCs exceed minimum acceptable EPA and MTCA individual risk thresholds for the RME scenarios (select HPAHs [9], antimony, arsenic, Cr VI, vanadium, TBT, bis(2-ethylhexyl)phthalate, PCP, chlordane, and PCBs [3]). Of these, 10 COPCs also exceed minimum acceptable EPA and MTCA individual risk threshold for the CT scenarios (select HPAHs [6], arsenic, and PCBs [3]). Lead, which is evaluated differently, also has the potential to pose an unacceptable health risk.
- Only 5 of the 20 COPCs or COPC groups had significant RME exceedances including: HPAHs, arsenic, Cr VI, TBT, and PCBs. Of these 5, both Cr VI and TBT only had a significant exceedance for one pathway and one receptor for the RME. Only arsenic and benzo(a)pyrene had significant exceedances under the CT scenario.

<u>COPCs Not Exceeding Minimum Individual Acceptable Risk Thresholds</u>

- Thirty-three COPCs do not exceed acceptable MTCA risk thresholds under the RME scenario (low-molecular weight PAHs, select HPAHs [including benzo(g,h,i)perylene, fluoranthene, pyrene], retene, benzoic acid, select phenols, select phthalates, benzene, other metals, total cyanide, DDD, and DDT).
- Six COPCs do not exceed acceptable MTCA risk thresholds for human health pathways under the RME scenario, but did not have sufficient toxicity data to be evaluated in the ecological risk evaluation (carbazole; dibenzofuran, 1,2,4-trimethylbenzene; ethylbenzene; toluene; and xylene). These six COPCs are further evaluated below, followed by a final summary of chemicals retained for further evaluation in Section 5.

It is important to note that arsenic, lead, and vanadium are known natural background chemicals across Washington State and the western United States. Arsenic has a 90th percentile background

concentration of 7 mg/kg in Puget Sound (Ecology 1994), which may contribute to the overall potential risk posed by arsenic. Lead has a 90th percentile background concentration of 24 mg/kg in Puget Sound (Ecology 1994). Vanadium is present in background soils in the western United States at concentrations ranging up to 500 mg/kg and the mean background soil concentration is 88 mg/kg (Shacklette and Boerngen 1984).

4.4.1 Qualitative Evaluation of COPCs with Limited Toxicity Data

As discussed above, six of the COPCs (dibenzofuran; carbazole; ethylbenzene; toluene; xylene; and 1,2,4-trimethylbenzene) did not exceed acceptable human health risk thresholds in the site-specific RME risk evaluations. However, these six were only evaluated for human health exposure pathways as all six COPCs lacked ecotoxicity data (no TRVs or appropriate surrogate chemicals with TRVs could be found for any of the four site-specific ecological receptors). Site-specific tissue data exists for two of the six COPCs (carbazole and dibenzofuran, Tables 2-5 and 2-6). No tissue data were available for the VOCs as they are not typically analyzed for in tissue samples due to their lack of bioaccumulation. As a result of the inability to assess these six COPCs for ecological toxicity, they were further qualitatively assessed in this section and summarized in Table 4-29.

4.4.1.1 Evaluation of Physical Characteristics, Fate, Toxicity, and GWSA Distribution

For each of the six possible COPCs with limited ecotoxicity data, further evaluation was conducted using a qualitative approach. The physical characteristics, fate, toxicity, and GWSA distribution for these possible COPCs are discussed in Appendix F, and a summary of the lines of evidence used to determine whether they should be retained or not for the comparison to ambient concentrations step (Section 5.1) is provided below.

Dibenzofuran

Dibenzofuran was not retained as a COPC based on the following lines of evidence: no human health risk threshold exceedances; physical structure and environmental behavior similar to that of LPAHs, which had no human health or ecological risk evaluation threshold exceedances; limited toxicity and generally adsorbs to sediments; and no detections in GWSA-vicinity tissue samples.

Carbazole

Carbazole was not retained as a COPC based on the following lines of evidence: no human health risk threshold exceedances; tends to adsorb to sediments; and limited detections at low concentrations in GWSA-vicinity tissue samples.

Ethylbenzene

Ethylbenzene was not retained as a COPC based on the following lines of evidence: no human health risk threshold exceedances; evidence suggesting no ecological risk (i.e., the related VOC, benzene, resulted in no ecological risk threshold exceedances); limited detects within the GWSA; and fate and transport characteristics that indicate limited persistence (including rapid dispersion and biodegradation) and low bioconcentration potential.

Toluene

Toluene was not retained as a COPC based on the following lines of evidence: no human health risk threshold exceedances; the related VOC, benzene, resulted in no ecological risk threshold exceedances; limited detects within the GWSA; and fate and transport characteristics that indicate limited persistence (including rapid dispersion and biodegradation) and low bioconcentration potential.

Xylene

Xylene was not retained as a COPC based on the following lines of evidence: no human health risk threshold exceedances; the related VOC, benzene, resulted in no ecological risk threshold exceedances; limited detects within the GWSA; and fate and transport characteristics that indicate limited persistence (including rapid dispersion and biodegradation) and low bioconcentration potential.

1,2,4-Trimethylbenzene

1,2,4-Trimethylbenzene was not retained as a COPC on the basis of the following lines of evidence: no human health risk threshold exceedances; the related VOC, benzene, resulted in no ecological risk threshold exceedances; and no detects within the GWSA.

4.4.1.2 Qualitative Evaluation Summary

Based on a review of the physical characteristics, fate, toxicity and GWSA distribution of these six possible COPCs as detailed in Appendix F and summarized above, none were retained as COPCs.

4.4.2 Summary of Retained COPCs

A summary of COPCs retained for further evaluation in Section 5 are listed by category in Table 4-30.

4.5 Evaluation of Relative Contribution to GWSA Risk

The purpose of this section is to determine the overall risk drivers for the GWSA. Certain risk exposure scenarios and COPCs result in risks that are orders of magnitude higher than risks from other exposure scenarios and COPCs within the GWSA. Although this is true under both the RME and CT scenarios, this evaluation focuses on the RME calculations because they resulted in potential risk estimates that were one to two orders of magnitude higher than the CT calculations. Consistent with EPA guidance (1999), the exposure scenarios and COPCs that drive a need for remedial action are referred to as "risk drivers." This section presents the rationale for the identification of the exposure scenarios and COPCs that are the risk drivers for human health and ecological risk. The COPCs identified as risk drivers based on the RME scenarios represent a subset of the COPCs exceeding acceptable risk thresholds for both the RME and CT.

The term "risk drivers" is synonymous with the term "indicator hazardous substances" under MTCA (WAC 173-340-703; Ecology 2007) which states:

> *"When defining cleanup requirements at a site that is contaminated with a large number of hazardous substances, the department may eliminate from consideration those hazardous substances that contribute a small percentage of the overall threat to human health and the environment. The remaining hazardous substances shall serve as indicator hazardous substances for purposes of defining cleanup requirements."*

Other factors that were considered in addition to the three primary factors considered in Section 4.5.2, where risk drivers were identified, include additional criteria identified in WAC 173-340-703 for designating an indicator hazardous substance such as distribution, thoroughness of testing, natural background concentrations and frequency of detection (previously considered in Section 3).

Furthermore, other factors such as comparison of risks within the GWSA to risks from ambient Lake Union for similar exposure scenarios (considered in Section 5) were evaluated. Chemical and physical characteristics that govern a substance's persistence, degradation byproducts, and mobility in the environment were evaluated to some extent based on the screening process in Section 3, but were

not fully included in this section. These fate and transport characteristics will be further addressed in the draft RI/FS documents.

4.5.1 Risk Driver Evaluation Process

Only those RME exposure scenarios and COPCs that resulted in a cancer risk greater than 10^{-6} or an HQ greater than 1 were considered in the selection of risk drivers. The evaluation of risk drivers relied on several primary factors:

- Toxicological characteristics that influence a chemical's ability to adversely affect human health or the environment at the concentration present at the Site
- The relative percentage of each chemical's contribution to the total human health and ecological risk
- Magnitude of RME risk exceedances above MTCA's target risk range for managing risk of 10^{-5} to 10^{-6}.

As part of the evaluation process, chemical groups are represented by the sum of the individual chemicals in the group so that they are not double counted. This approach applies to both TPAH (which represents individual HPAH results) and PCBs (which represents individual PCB results).

4.5.2 Risk Driver Evaluation Results

For each RME exposure scenario exceeding human health carcinogenic risk thresholds, the percent contribution of individual COPCs (or of the overall chemical group in the case of TPAH and PCBs) to cumulative RME risk for that pathway was calculated (see Appendix D, Table D-1). As shown on Table 4-31 and in Figure 4-4, for the human health carcinogenic RME risk estimates:

- TPAH comprised the majority of the risk (82–92%) for netfishing and beach play/wading scenarios, with the remaining risk driver being arsenic (8–18%)
- Arsenic drives the majority of risk (52–57%) for general and Tribal fish ingestion scenarios, followed by PCBs (26–31%) and TPAH (11–20%).

For each RME exposure scenario with non-carcinogenic human health or ecological risk threshold exceedances, the HQs of individual COPCs were evaluated (see Appendix D, Table D-1). As shown in Table 4-19:

- PCBs predominate the HQ exceedances for individual COPCs with HQs of 6 and 11, respectively, for general and Tribal fish ingestion scenarios for human health non-carcinogenic RME risk estimates
- TBT had a HQ of 32 for the salmon exposure evaluation; all other ecological risk evaluation scenario HQs for individual COPCs are considered to be relatively low (below 5).

4.5.3 Risk Driver COPC Summary

Table 4-31 summarizes the COPC risk drivers for all three of the human health RME risk scenarios (beach play/wading, recreational and Tribal fish ingestion, and Tribal netfishing).

- For human health carcinogenic RME risk estimates, risk drivers include:
  - TPAH as a surrogate for benzo(a)pyrene and HPAH

  - Arsenic
  - Total PCBs as a surrogate for Aroclors 1254 and 1260.
- For human health non-carcinogenic RME risk estimates, risk drivers include:
  - Total PCBs as a surrogate for Aroclors 1254 and 1260.
- For ecological risk estimates, only one COPC for one exposure scenario (salmon) was identified as a risk driver:
  - TBT.

4.5.4 Non-risk Driver COPC Summary

The remaining 12 non-risk driver COPCs (six HPAHs, antimony, Cr VI, vanadium, bis(2-ethylhexyl)phthalate, PCP, and chlordane) comprise a very small percentage of the cumulative human health carcinogenic RME risk for each pathway as follows (see Appendix D, Table D-1):

- For the beach play/wading scenarios, all 12 other COPCs combined comprise less than one-half of one percent of the cumulative risk for the pathway for both adults and children
- For the fish ingestion scenarios, all 12 other COPCs combined comprise less than one percent of the cumulative risk at the Tribal ingestion rate for both adults and children; and about two percent at the general ingestion rate for both adults and children
- For the netfishing scenario, all 12 other COPCs combined comprise less than one tenth of one percent of the cumulative risk for Tribal adults.

These 12 non-risk driver COPCs also have HQs that range from less than 1 to less than 5 for both the human health non-carcinogenic risk and ecological risk pathways (see Appendix D, Table D-1).

Note that although lead is also a non-risk driver COPC, it is not included in the above analysis because the risk from lead is evaluated separately.

4.6 COC Summary

Based on the RME risk evaluation results presented in this section, the eight risk driver COPCs (arsenic, TPAH [three], PCBs [three], and TBT) and the 13 non-risk driver COPCs (six HPAHs, antimony, Cr VI, lead, vanadium, bis(2-ethylhexyl)phthalate, PCP, and chlordane) are now considered COCs and are further assessed in subsequent sections of this document. Note that this designation for antimony, PCP, and chlordane is based only on non-detected results.

5.0 Identification of GWSA Indicator COCs

As previously discussed, this document was prepared in response to comments by the EPA and other stakeholders on the draft RI/FS documents, who requested a more comprehensive process for the determination of COCs. Section 3 detailed a more robust COPC screening process, from which 59 chemicals were identified as possible COPCs. The maximum and mean surface sediment concentration of each possible COPC was then entered into site-specific ecological and human health RME and CT risk evaluations, respectively, to identify the subset of these COPCs that exceeded acceptable risk thresholds, as described in Section 4. Section 4 further identified the subset of COPCs exceeding acceptable RME risk thresholds that comprise the majority of risk to the GWSA. Those chemicals determined in Section 4 as exceeding acceptable RME risk comprise the list of COCs to be further evaluated. Table 5-1 summarizes those COCs that, based on the conservative RME risk evaluations detailed in Section 4, were identified as risk driver COCs:

- TPAH as a surrogate for benzo(a)pyrene and HPAH
- Arsenic
- TBT
- Total PCBs as a surrogate for Aroclors 1254 and 1260.

Table 5-1 also summarizes those COCs that, based on the RME risk evaluations detailed in Section 4, were identified as non-risk driver COCs.

The purpose of this section is to identify Indicator COCs for the GWSA, as summarized in the decision matrix flowchart shown in Figure 5-1. The main decision points of the Indicator COC identification process are summarized below (detailed information is provided in the accompanying tables):

- The concentrations of each COC in the GWSA and ALU were statistically evaluated to assess whether the two independent sample populations have similar concentrations or not. This comparison resulted in dividing the COCs into two categories:
  - Those COCs where GWSA and ALU surface sediment concentrations were found to be statistically equivalent or where the GWSA sediment concentrations were found to be statistically lower were identified as ALU COCs; or
  - Those COCs that had statistically higher concentrations in the GWSA compared to concentrations for the COCs in ALU (outside of the GWSA boundary) were identified as GWSA COCs.

  Note that each of the above categories (ALU COCs and GWSA COCs) includes risk drivers and non-risk drivers as defined at the end of Section 4.

- Those analytes that constitute both risk driver COCs at the conclusion of Section 4 and GWSA COCs at the end of decision point 1b (above) are identified as GWSA Indicator COCs.

5.1 Statistical Comparison of COC Concentrations between the GWSA and Ambient Lake Union

As discussed in Section 1.0, industrial activity has been taking place on and around Lake Union since the late 1890s. Over time, the lake and its shoreline have hosted sawmills, shipyards, a MGP, a tar refinery, house boats, and other activities. As such, Lake Union sediment quality reflects over a century of anthropogenic influence. The activities described in Section 1.0 have resulted in elevated concentrations of COCs across Lake Union as reflected in the ALU concentrations. The GWSA occupies approximately 52 acres (or 9%) of Lake Union, and has been affected by both historical and on-going activities.

This section covers the first step in the GWSA Indicator COC identification process summarized in Section 5.0. The risk evaluation, including the evaluation of those COCs that comprise the majority of risk and the qualitative evaluation of chemicals with limited toxicity data (Section 4), generated a list of confirmed site COCs (Table 5-1). To then determine which of these COCs are GWSA COCs, COC concentrations within the GWSA were statistically compared to ALU concentrations, as described in this section. Statistical comparisons of concentrations between the GWSA and ALU were conducted for nearly all COCs since each COC (except vanadium, which is further discussed below) had an ALU data set of at least 10 samples, as detailed below. Those COCs that exceeded risk thresholds and were statistically higher than ambient concentrations constitute GWSA COCs. Those COCs that exceeded risk thresholds and were statistically equivalent to or lower than ambient concentrations constitute ALU COCs.

5.1.1 GWSA Sediment Data Set Characteristics

The GWSA data set was defined in Section 2.3.2 and is summarized here. Surface sediment data collected prior to 1994 were excluded so that the data set is representative of more current site conditions. Summary statistics for COCs within the GWSA are presented in Table 5-2. PAHs and other SVOCs tended to have the greatest number of samples. Chlordane, PCBs, and some metals tended to have fewer samples.

5.1.2 Ambient Lake Union Sediment Data Set Characteristics

The ALU data set, as defined in Section 2.3.1, is comprised of those stations that are located outside the GWSA boundary that are believed to be representative of general Lake Union surface sediment and reflect lake-wide conditions but not specific nearshore sources. Samples that occur within 300 feet of the shoreline and those stations close to potential nearshore impacts are excluded so that the data set is not affected by samples less likely to represent ambient conditions. ALU summary statistics are shown in Table 5-3. As with the GWSA data set, chlordane, PCBs, and some metals tended to have fewer samples than PAHs and other SVOCs.

5.1.3 Data Evaluation, Statistical Methods, and Findings

Statistical comparisons between the GWSA and ALU were performed for all COCs for which the ALU data set has at least ten samples (a sufficient number of samples for a natural background calculation).[5] Vanadium is evaluated separately, as discussed below, because there were only three

[5] Generally, it is recommended that data sets should have at least 10 samples for statistical analysis (e.g., ProUCL guidance). Ecology recommends minimum numbers of background samples of 10 soil samples for natural background and 20 for area background (Ecology 2007 [WAC 173-340-708(11)(d)]; Ecology 1992). Only the COCs antimony, chlordane, TBT, and vanadium had fewer than 20 samples in the ALU (19, 10, 14, and 3 samples, respectively). Statistical comparison to ALU concentrations was done for all COCs except vanadium, which had too few ALU samples for a meaningful comparison.

ALU samples. Data distributions were evaluated prior to statistical analysis using quantile-quantile (Q-Q) plots, which compare a dataset graphically against the theoretical normal distribution (Appendix G, Figure G-1). In all cases, data were non-normally distributed. Consequently, for these comparisons, the non-parametric Mann-Whitney 2-sample hypothesis test was conducted using SPSS 13.0 software rather than a parametric t-test.

The Mann-Whitney test (also known as the Wilcoxon-Mann-Whitney or Wilcoxon rank-sum test) is the non-parametric counterpart of the t-test. Like the t-test, Mann-Whitney tests the null hypothesis that two independent samples come from the same population. In other words, the test assesses whether two independent sample populations have the same distribution or whether they are distinctly different. Rather than being based on parameters of a normal distribution like the mean and variance, the Mann-Whitney statistics are based on ranks. Of the available non-parametric two-independent-samples tests (e.g., Mann-Whitney, Kolmogorov-Smirnov, Wald-Wolfowitz), Mann-Whitney is the most commonly used test.

As shown in Table 5-4, applying the Mann-Whitney test identified significant differences between the GWSA and ALU for most COCs. COC metals, TBT, carbazole, bis(2-ethylhexyl)phthalate, PCP, chlordane, and PCBs were not statistically higher in the GWSA than in the ambient lake. However, the GWSA had statistically higher concentrations than ALU in the case of PAHs. Based on this evaluation, individual HPAHs, HPAH, and TPAH are identified as GWSA COCs.

A further comparison of data distributions was conducted using boxplots for the COCs (Appendix G, Figures G-2 and G-3). Boxplots, or box-and-whisker plots, provide a succinct visual summary of the data distribution by showing where the bulk of the values are concentrated. They also provide an indication of the range of values and distribution of outliers, as demonstrated schematically in Figure G-2. Comparing boxplots for a given COC (e.g., benzo(a)pyrene) between different sample populations can provide a visual overview of similarities or differences in the data distribution. When the visual shape of the boxplots for the data sets being compared strongly overlap, particularly in the vicinity of the median, it is unlikely that a statistically significant difference will be found. By contrast, if the boxes are largely offset from each other (i.e., there is little overlap and/or the medians are far apart), it is more likely that a significant difference will be found. The comparisons of the boxplots (Figure G-3) confirm the conclusions summarized above from the Mann-Whitney statistical tests.

One COC, vanadium, had too few ALU data (only three samples) to conduct a statistical analysis. However, a comparison to Lake Union mean and maximum concentrations revealed that vanadium concentrations are similar between ALU (3 samples; mean of 53 mg/kg) and the GWSA (22 samples, mean of 64 mg/kg). Although the maximum GWSA surface sediment vanadium concentration is higher (132 mg/kg) than the ambient maximum (59 mg/kg), all detected vanadium concentrations are within the range of natural background soil concentrations. Vanadium is a metal present in background soils in the western United States at concentrations ranging up to 500 mg/kg. The mean background soil concentration for the western United States is 88 mg/kg (Shacklette and Boerngen 1984).

Vanadium was not retained as a COC based on the following lines of evidence:

- Concentrations stem from older (1995) data
- A low human health non-carcinogenic HQ exceedance of 4 for only one exposure pathway, and a slight HQ exceedance of 1.4 for ecological risk for only one exposure pathway
- High uncertainty in the effects data (i.e. few toxicity studies)

- Average concentrations are similar between the ALU data set and the GWSA data set
- Observed concentrations in the GWSA and Lake Union are well within the range of naturally occurring background soil concentrations.

5.1.4 GWSA COCs

GWSA COCs are those COCs associated with the study area, and are elevated relative to the ambient lake conditions (i.e., those COCs that occur at significantly higher concentrations in the GWSA relative to the ALU). As demonstrated by the statistical analysis described above and as shown in Table 5-4, the GWSA COCs include: individual HPAHs, HPAH, and TPAH.

5.1.5 ALU COCs

Those COCs where GWSA surface sediment concentrations were found to be statistically equivalent to or lower than ALU concentrations are identified as ALU COCs. The list of ALU COCs is shown in Table 5-4, and includes: metals (antimony, arsenic, chromium, lead), TBT, bis(2-ethylhexyl)phthalate, PCP, chlordane, Aroclors 1254 and 1260, and PCBs. On a lake-wide basis, all ALU COCs occur at concentrations that are similar to or significantly greater than the concentrations present in the GWSA.

Table 5-5 presents a summary of all COCs at the conclusion of this evaluation process and further categorizes each COC depending on whether it was designated as a risk driver or not at the end of Section 4.

5.2 Determination of GWSA Indicator COCs

This section covers the final step in the COC identification process summarized in Section 5.0. The purpose of this step is to determine the GWSA Indicator COCs by combining the subset of COCs that contribute the majority of the overall GWSA RME risk (identified in Section 4.5 and summarized in Section 5.0) with the conclusions from the statistical analysis presented in Section 5.1 regarding GWSA COCs. Those analytes that constitute both risk driver COCs and GWSA COCs are identified as GWSA Indicator COCs.

5.2.1 GWSA Indicator COCs

Table 5-6 summarizes the process of deriving GWSA Indicator COCs. Those COCs that met the following two criteria were identified as GWSA Indicator COCs:

- COCs whose GWSA concentrations are statistically higher than ambient lake concentrations (i.e., GWSA COCs) as detailed in Section 5.2
- COCs whose maximum GWSA concentration comprise the majority of the RME risk (i.e., drive risk) and have the highest RME risk threshold exceedances (as detailed at the end of Section 4).

Based on this analysis, as shown in the last column of Table 5-6, the GWSA Indicator COCs are PAHs including:

- Benzo(a)pyrene
- Total HPAH
- TPAH.

Identification of GWSA Indicator COCs that comprise the bulk of the RME risk and are statistically higher in the GWSA (compared to ALU) will facilitate the remedial analysis in the FS. These GWSA Indicator COCs will be used to help refine the lateral extent of the GWSA remedy.

5.2.2 Risk Driver ALU COCs

ALU COCs that are present at concentrations within the GWSA at statistically lower or equivalent concentrations compared to ALU and were also identified as risk drivers (arsenic, PCBs, and TBT as shown in Table 5-5) will be further evaluated in the FS; this evaluation may include:

- Evaluation of reductions in risk or residual risks from these COCs within the GWSA remedial area
- Inclusion of these COCs as part of the post-cleanup monitoring program.

5.3 Summary

Multiple lines of evidence were evaluated to determine the Indicator COCs that drive risk for the GWSA as detailed in the above sections. Final GWSA Indicator COCs are shown on the last column of Table 5-6 and include: benzo(a)pyrene, HPAH, and TPAH. The selection of GWSA Indicator COCs or risk drivers within the study area, in accordance with Ecology and EPA guidance, focuses the FS by identifying a smaller number of chemicals that have the largest contribution to estimated overall site RME risk. These GWSA Indicator COCs will be the focus of the revised FS analyses.

6.0 Supplemental Conceptual Approach to Remedial Area Identification

In this section, the supplemental evaluation results are reviewed in the context of their application(s) to the RI/FS process. This section describes the parameters for a conceptual evaluation of the extent of cleanup for the GWSA Indicator COCs, including the regulatory framework for the vertical point of compliance and a potential approach for further evaluating the lateral remedial extent during the revision of the draft RI/FS documents. This information augments the cleanup standards previously identified in the *Gas Works Sediment Area Cleanup Standards Determination* (RETEC 2005a), by further evaluating the process by which the extent of remedial action may be refined.

As background to a method for exploring the extent of remedial action, this section revisits the components of the cleanup standard. In accordance with Ecology's MTCA (Ecology 2007), cleanup standards consist of both a cleanup level and a point of compliance where the cleanup level must be met (WAC 173-340-700). The regulation states that "a cleanup level is the concentration of a hazardous substance in soil, water, air, or sediment that is determined to be protective of human health and the environment under specified exposure conditions," and that the point of compliance means "the point or points where cleanup levels established in accordance with WAC 173-340-720 through 173-340-760 shall be attained."

6.1 Vertical Point of Compliance: Surface Sediment

Under MTCA, the vertical point of compliance is surface sediments (WAC 173-204-100, -110, and -200). Under SMS regulations, sediment cleanup levels apply to sediment in the biologically active zone, generally defined as 0–10 cm for sediments.

6.2 GWSA-specific Considerations with Respect to Subsurface Sediment

While this document focuses on surface sediments as the point of compliance per MTCA and the SMS, impacted subsurface sediments will also be evaluated in the revised RI/FS documents. Several evaluations/lines of evidence will be used to evaluate potential impacts associated with subsurface contamination. Groundwater flow and fate and transport modeling will evaluate potential migration to surface sediments. Geotechnical data and ongoing physical processes within the lake environment will be used to evaluate potential disturbances (e.g., from lake uses such as fishing) and erosion that could expose contaminated subsurface sediments, as well as net deposition and natural recovery areas. Post remediation compliance monitoring to ensure that surface sediments are not recontaminated by subsurface sediments will be further addressed in the revised RI/FSs and remediation documents.

6.3 Evaluation of Estimated Lateral Extent of Cleanup

This section explores an approach to evaluate the lateral extent of remedial action. In the Cleanup Standards Determination document, the lateral extent within which remedial actions will be considered was defined as the Area Boundary (AB) based on synoptic chemical and bioassay results in accordance with the SMS. This section describes an alternative or additional approach to identify the lateral extent of remedial action that may be considered in the revised RI/FSs.

The complexity of determining the extent of cleanup in the GWSA is directly related to its urban setting. The GWSA exists within a continuum of impacted sediments with a "working lake" history. This complicates the determination of a cleanup approach that is protective of both human and ecological health, since all of the COCs that drive risk (and nearly all of the COPCs) are ubiquitous

urban pollutants. Many of these ubiquitous urban pollutants are not associated with historical Uplands activities.

Given the urban setting and elevated concentrations of a variety of chemicals of potential concern throughout Lake Union, the GWSA lateral extent will encompass areas where historically elevated GWSA Indicator COCs occur at concentrations above ambient conditions. This remedial goal requires a comparison between the Indicator COC concentrations within the GWSA and their concentrations in the rest of the lake (ALU data set) to determine the appropriate lateral extent of cleanup within the GWSA. Within that lateral extent, both GWSA Indicator COCs and ALU COCs will be further evaluated in the FS process.

6.4 Statistical Approach

Exploration of the estimated lateral extent for the GWSA Indicator COCs was statistically evaluated using the following steps:

1. Five offshore bands of varying widths were identified from the Uplands shoreline outward into the offshore area within the GWSA (see Figure 6-1).
2. Bands are numbered 1 to 5 (Band 1 is located closest to the Uplands shoreline and 5 is located farthest offshore). The statistical iterations to explore lateral extent follow the outer extent of successive bands. Each iteration encompasses the areas of lower-numbered (closer to shore) bands; for instance, Iteration 2 represents the area encompassed by both Band 1 and Band 2. The area between the outer band encompassed by the iteration and the GWSA boundary is conceptually a “no action” area. For Iteration 2, the “no action” area is the area between the outer extent of Band 2 and the GWSA. This approach to identifying the extent of the potential remedial area may be refined as part of the detailed analyses included in the revised RI/FS documents. To assess any given iteration, the GWSA data outside (farther offshore) of the associated band(s) were statistically compared to the ALU data for each individual GWSA Indicator COC.

   Data within bands (i.e., the area of assumed remedial action) being evaluated (e.g., Iteration 1) were excluded from the statistical analysis to provide a more conservative approach than substituting “clean” values for all samples within the band to generate a post-remedial action average of the entire GWSA. Summary statistics and 90^{th} percentiles for all iterations were calculated using the MTCAStat 97 Background Module. Per Ecology guidance, the 90^{th} percentile on the arithmetic mean was used in all cases, except when the 90^{th} percentile was greater than four times the 50^{th} percentile (in those cases, the four times the 50^{th} percentile was used). Two-sample hypothesis tests (e.g., Mann Whitney) were used to statistically compare the potential ”no action” area data set associated with a given iteration to the ambient lake data set for each GWSA Indicator COC.
3. The statistical evaluation process was repeated for each successive band for each GWSA Indicator COC as shown in Tables 6-1 to 6-4. A lake-wide view of the GWSA is shown on Figure 6-1 for reference. The estimated lateral extent for remediation using this approach is identified as the farthest offshore band where the GWSA data was statistically higher than the ALU data for an individual GWSA Indicator COC.

Because this approach simulates a surface weighted average method of evaluating the population of concentrations, it will be adequately protective of human health direct contact scenarios such as Tribal netfishing because that exposure is more accurately represented by an average or percentile (as

compared to the maximum value used in the RME site-specific risk evaluation completed in Section 4). This approach does not apply to the nearshore areas where direct contact beach-play exposure may occur because the most extensive remedial actions will be implemented in those areas and will result in protectiveness of that exposure scenario. This conceptual approach may be further evaluated in the revised RI/FSs.

6.5 Summary of Step-wise Iterative Approach for Lateral Extent Estimation

The results of the step-wise iterative approach to determining the estimated lateral remedial extent for the GWSA Indicator COCs are shown on Table 6-4 and can be summarized as follows:

- Active remediation to the outer edge of Band 2 (Iteration 2) results in cleanup to ambient lake concentrations of HPAH and TPAH
- Active remediation to the outer edge of Band 3 (Iteration 3) results in cleanup to ambient lake concentrations of benzo(a)pyrene
- Thus, extending active remediation into Bands 4 and 5 provides no substantive advantage in terms of risk reduction for GWSA Indicator COCs.

The outcome of a lateral remedial extent defined in this manner will result in an area along the GWSA shoreline (estimated to include Bands 1 through 3) that is, immediately post-remediation, protective of ecological receptors and human health (prior to the reintroduction of sediment from adjacent, less clean areas). The area between the outer edge of Band 3 and the GWSA line will have concentrations of GWSA Indicator COCs that are similar to (i.e., not statistically significantly different than) the rest of Lake Union. This outer area is expected to naturally recover as potential sources of recontamination from the nearshore areas are remediated and as lake-wide sources are reduced or eliminated.

As can be seen on Figure 6-2, the estimated lateral extent shown by the outer edge of Band 3 could be used to augment the previously established bioassay- and chemistry-based cleanup standard (AB shown in blue) from the Cleanup Standard Determination document.

6.6 Summary of Conceptual Potential Approach

Using an iterative statistical approach, an estimate was made of how far offshore remedial actions may need to extend laterally within the GWSA to address the GWSA Indicator COCs. This conceptual approach does not establish a new cleanup standard; rather, it may be used to refine the proposed remedial alternatives in the draft RI/FS documents in conjunction with key elements developed in previous GWSA documents, including the *Gas Works Sediment Area Cleanup Standard Determination* (RETEC 2005a). The Cleanup Standard Determination document is based on the SMS directive regarding the use of biological testing in conjunction with chemistry results to make cleanup decisions. For the GWSA, biological testing results were correlated with chemistry data to define numeric chemical cleanup levels. As part of the Cleanup Standard Determination document, site-specific cleanup levels were established for the GWSA as follows:

- The site-specific cleanup standard for TPAH or SSQL is 170 mg/kg TPAH dry weight was derived using the following parameters (RETEC 2005c):
  - Site-specific synoptic sediment bioassay and chemistry results
  - Spatial distribution of biological responses
  - Determination of TPAH effects concentrations.
- The AB delineated for the draft RI/FSs using a combination of synoptic bioassay results and chemistry data (RETEC 2004b; RETEC 2005c). The AB, wherein

remedial actions will be evaluated, is based on the distribution of bioassay passes and was refined by the extent of surface sediment TPAH concentrations exceeding the SSQL.

In summary, the previously established site-specific cleanup standard (the SSQL and AB) is complimented by the statistical analyses for the GWSA Indicator COCs presented in this section. This conceptual approach (e.g., statistical Iteration 3) is one option that may be used as an additional line of evidence to refine the lateral extent of the remedial alternatives evaluated for the GWSA Indicator COCs in the revised RI/FS documents. Additional evaluation of GWSA Indicator COCs as well as ALU COCs will occur in the RI/FS process.

7.0 Summary and Integration with Revised RI/FSs

As noted in Section 1.0, this document is a companion to the original *Gas Works Sediment Area Cleanup Standard Determination* (RETEC 2005a). Like the original Cleanup Standard Determination document, this Supplement to the Cleanup Standards work will be carried forward into the RI/FS process for the GWSA. Draft RI/FS documents have been submitted for both the Eastern and Western GWSA Study Areas (RETEC 2006; Floyd|Snider 2007). As proposed in the draft RI/FS documents, the remedial action for the entire GWSA will involve capping selected areas and some removal actions in the shoreline area. In this section, the supplemental evaluation results are reviewed in the context of their application(s) to the RI/FS process.

This Supplement to the *Gas Works Sediment Area Cleanup Standards Determination* document was developed to address several objectives including:

- Fulfill agency and stakeholder requests for a more comprehensive site-wide COPC screening process
- Fulfill agency and stakeholder requests for a site-specific quantitative evaluation of risks to human health and ecological receptors
- Revisit the TPAH-based site-specific SSQL in the context of the results of the revised COPC screening process and site-specific risk evaluation
- Revisit the remedial action area and consider an alternative approach to defining the lateral remedial extent so that potential risks outside the remediation area will at a minimum be indistinguishable from those associated with ALU conditions.

The additional site specific quantitative ecological risk evaluation conducted as part of this supplemental work compliments the bioassay work conducted to identify thresholds that are protective of the benthic invertebrate populations per the SMS and as summarized in the Cleanup Standards Determination document.

7.1 GWSA Sediment Cleanup Indicator COCs and Remedial Objectives

As described in Section 5, multiple lines of evidence were evaluated to determine the Indicator COCs that drive risk for the GWSA. TPAH, benzo(a)pyrene, and HPAH collectively comprise the GWSA Indicator COCs because they were identified as both GWSA COPCs (COPCs whose GWSA concentrations are statistically higher than ambient lake concentrations) and risk driver COPCs (COPCs whose maximum GWSA concentration comprise the majority of the RME risk [i.e., drive risk] and have the highest risk threshold exceedances). Potential human health risks were largely associated with the highly conservative RME scenario.

Identification of GWSA Indicator COCs will facilitate the remedial analysis in the FSs by focusing on GWSA risk reduction. Additionally, ALU risk driver COCs (arsenic, PCBs, and TBT) will be further evaluated as part of the FSs and subsequent remedy design.

Based on sediment conditions and current regulations, overall remedial goals applicable to the GWSA include:

- Compliance of bioactive zone (0 to 10 cm) sediments with SMS-guided GWSA cleanup levels within a 10-year restoration time frame
- Compliance with MTCA requirements for remedy selection

- Consistency with ARARs, facility characteristics (e.g., GWSA use), and other factors relevant to remedy implementation.

More specific GWSA remedial objectives that will be incorporated into the FSs include:

- Compliance with the site-specific 170 ppm TPAH SSQL to protect the benthic community against toxicity.
- Address the potential for human direct contact with impacted sediment in the nearshore areas. Post-remedial nearshore areas of the GWSA will have a clean surface that will protect beach users from impacted sediments.
- Address the potential for human direct contact with impacted sediment throughout the GWSA during netfishing activities.
- Address the potential for human consumption of impacted fisheries resources.
- Address the potential for other ecological receptors to contact impacted sediment or food resources.
- Develop cap performance standards that protect surface sediment from recontamination from subsurface sediment impacts. Potential mechanisms for this to occur include: exposure of impacted subsurface sediment by erosion, human activity (e.g., disturbances from lake uses, such as fishing), biological activity, or leaching and migration of subsurface chemicals such as those associated with subsurface dense non-aqueous phase liquid (DNAPL).
- Minimize or avoid habitat impacts and enhance habitat, if possible, within the context of the cleanup

Meeting the combined remedial objectives itemized above will result in a protective GWSA remedy that will address risks within the GWSA lateral extent.

The results of this Supplement will be used to complement the *Gas Works Sediment Area Cleanup Standards Determination* document and will be incorporated into the revised RI/FS documents being prepared for the Eastern and Western Study Areas (by PSE and the City, respectively).

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Table 2-1 Summary of Lake Union Sampling Studies

Year of Study	Agency/Company	Study/Report	Survey Name	Type of Sample	# of Lake Union Samples	Location	Used in Lake Union Data Set?	Notes
1977	Tomlinson/ Municipality of Metropolitan Seattle (Metro)	Tomlinson et al., 1977		SW, US, BI	4		N	No PAH data
1981–1986	King County*		LUUMON86	SS	6	Throughout lake, nearshore	Y	
1984	USEPA*	Hileman et al., 1985	EPAGAS84	SS, SW	33	Throughout lake, concentrated near Gas Works Park	N	Quality of PAH data is questionable
1984	Seattle-King County Health Dept.	F. Frost, 1984; Hansen, 1994		Crayfish	126	Gas Works Park	Y	Tissue data used for human health and ecological risk evaluations
1985	Department of Ecology*	Yake et al., 1986	GWPLKUN	SS	1	Gas Works Park	N	Incomplete suite of PAHs
1986	City of Seattle/Ecology/Solomon*		SLUPLT86	SS, BI, BA	15	South and southeast, nearshore	Y	
1987	Seattle City Light	Trial 1988; Hansen 1994	Lk Union PCB		230	Gas Works Park	Y	Tissue data used for human health and ecological risk evaluations
1989	EcoChem*		SCLITE89	SS	11	East side, nearshore	Y	
1990	Department of Ecology*		LKUNION	SS	14	Throughout lake	Y	
1990	Hart-Crowser*		SLUPRK90	SS	5	Southwest, nearshore	Y	
1991	King County	University Regulator, Pre-Separation Study		Crayfish, Fish	91	GWSA Stn B535, 527	Y	Selected tissue data used for human health and ecological risk evaluations
1991	Landolt Busch & Assoc./Ecology	Ecology 1991		Fish	157	Throughout lake	N	Histopathology only
1991	GeoEngineers*		UNIMAR2	SS	9	Northwest, principally nearshore	Y	Near shipyard docks
1992	Hart-Crowser*		LKUNDRDK	SS	4	East side, nearshore; north of NOAA docks	Y	
1994	NOAA*		NOAPMC94	SS	5	East side	Y	
1994	Department of Ecology*		SEACOM94	SS	4	Southwest, nearshore	Y	
1995	USEPA*		EPAGAS95	SS	29	Near Gas Works Park	Y	
1995	King County*		LUUMON95	SS	5	Ship Canal and mid-lake	Y	
1996	ATC Environmental*		DUNATO96	SS	4	Northeast, nearshore	Y	
1997	King County*		LUUCSO97	SS	6	East Ship Canal	N	Incomplete suite of PAHs; quality of PAH data is questionable
1997	King County	University Regulator, Post-Separation Study		Crayfish, Fish	116	GWSA Stn B535, 527	Y	Selected tissue data used for human health and ecological risk evaluations
1999	King County	University Regulator, Post-Separation Study		Fish	14	GWS-ESA, nearshore	Y	Selected tissue data used for human health and ecological risk evaluations
1999	RETEC Phase 1	RETEC 2002	RETEC99	SS, US	75	North Lake Union	Y	21 cores, 26 surface samples
2000	King County*		LUUCSO00	SS	5	Ship Canal and mid-lake	Y	
2001	King County	R. Jack, pers. comm. 2009		SS	9	Throughout lake	Y	Data supplied by King County
2002	Ecology/TAMU (March)			SS, BA, Fish	11	North Lake Union	Y	RETEC collected split samples
2002	Ecology/TAMU (July)				11	North Lake Union	Y	
2002	RETEC Phase 2	RETEC 2004a		SS, US	92	North Lake Union	Y	36 surface samples, 17 cores
2004–2005	RETEC Phase 3 / Bioassay Data Gap Analysis	RETEC 2005; RETEC 2006		SS, US, BA	163	North Lake Union	Y	59 surface samples, 29 cores
2005	Floyd|Snider	Floyd|Snider 2007		SS, US	95	North Lake Union	Y	16 surface samples, 21 cores
2008	King County	R. Jack, pers. comm. 2009		SS	1	Mid-lake	Y	Data supplied by King County
2009	Northlake Shipyard	Ecology & Environment, Inc. 2009		US	29	Northwest, in vicinity of Northlake Shipyard	Y	Data obtained through Ecology

Notes:

* Studies in Ecology's Sediment Quality Information System database (SEDQUAL), Release 4.4, February 2003. SEDQUAL has since been replaced by Ecology's Environmental Information Management (EIM) System.

BA: Bioassay

BI: Benthic infaunal abundance

PAH: Polycyclic aromatic hydrocarbon

SS: Surface sediment

SW: Surface water

US: Subsurface sediment

Table 2-2 Ambient Lake Union (ALU) Sediment Data Set

Location ID	Sample ID	Study Code	Study Date
513	8611067	LUUMON86	1986
515	8611073	LUUMON86	1986
1-300	SAMP1-1-300	SLUPLT86	1986
13	8242	LKUNION	1990
15	8244	LKUNION	1990
16	8245	LKUNION	1990
17	8246	LKUNION	1990
8	8B	UNIMAR2-Grabs	1991
PMCLU02	110-162	NOAPMC94	1994
PMCLU03	110-163	NOAPMC94	1994
4	94482353	EPAGAS95	1994-1995
8	94482356	EPAGAS95	1994-1995
16	94482364	EPAGAS95	1994-1995
515	L6586-3	LUUMON95	1995
ST-10	ST-10	RETEC99-Grabs	1999
ST-13	ST-13	RETEC99-Grabs	1999
ST-14	ST-14	RETEC99-Grabs	1999
ST-15	ST-15	RETEC99-Grabs	1999
ST-16	ST-16	RETEC99-Grabs	1999
ST-17	ST-17	RETEC99-Grabs	1999
ST-19	ST-19	RETEC99-Grabs	1999
ST-20	ST-20	RETEC99-Grabs	1999
ST-21	ST-21	RETEC99-Grabs	1999
ST-22	ST-22	RETEC99-Grabs	1999
ST-23	ST-23	RETEC99-Grabs	1999
ST-24	ST-24	RETEC99-Grabs	1999
ST-25	ST-25	RETEC99-Grabs	1999
ST-26	ST-26	RETEC99-Grabs	1999
ST-27	ST-27	RETEC99-Grabs	1999
ST-29	ST-29	RETEC99-Grabs	1999
ST-30	ST-30	RETEC99-Grabs	1999
ST-32	ST-32	RETEC99-Grabs	1999
ST-35	ST-35	RETEC99-Grabs	1999
KC 564	L21645-4	KC_LKUN01	2001
KC 565	L21645-5	KC_LKUN01	2001
KC 566	L21645-6	KC_LKUN01	2001
KC 567	L21645-7	KC_LKUN01	2001
KC 568	L21689-1	KC_LKUN01	2001
KC 569	L21689-4	KC_LKUN01	2001
KC 570	L21645-9	KC_LKUN01	2001
KC 575	L21689-5	KC_LKUN01	2001
LU-10	LU-10	TAMU02	2002
LU-11	LU-11	TAMU02	2002
LU-8	LU-8	TAMU02	2002
LU-9	LU-9	TAMU02	2002
NLU102	NLU-102-SS-0010	RETEC02-Grabs	2002
NLU104	NLU-104-SS-0010	RETEC02-Grabs	2002
NLU105	NLU-105-SS-0010	RETEC02-Grabs	2002
NLU106	NLU-106-SS-0010	RETEC02-Grabs	2002
NLU13	NLU13-SS-0010	RETEC02-Grabs	2002
NLU15	NLU15-SS-0010	RETEC02-Grabs	2002
NLU52	NLU52-SS-0010	RIFSE	2004
NLU81	NLU81-SS-0010	RIFSE	2004
NLU13-TX	NLU13-TX-0010	GWSA05	2005
NLU81-TX	NLU81-TX-0010	GWSA05	2005
KC 570	L46506-32	KC_2008ww	2008

Notes:

The ALU data set is comprised of samples located outside the Gas Works Sediment Area and away from nearshore sources.

Table 2-3 Gas Works Sediment Area (GWSA) Sediment Data Set

Location ID	Sample ID	Study Code	Study Date
1	94482350	EPAGAS95	1994-1995
2	94482351	EPAGAS95	1994-1995
3	94482352	EPAGAS95	1994-1995
5	94492359	EPAGAS95	1994-1995
6	94482354	EPAGAS95	1994-1995
7	94482355	EPAGAS95	1994-1995
10	94482358	EPAGAS95	1994-1995
11	94482359	EPAGAS95	1994-1995
12	94482360	EPAGAS95	1994-1995
15	94482363	EPAGAS95	1994-1995
17	94482365	EPAGAS95	1994-1995
18	94482366	EPAGAS95	1994-1995
19	94482367	EPAGAS95	1994-1995
20	94492351	EPAGAS95	1994-1995
21	94492352	EPAGAS95	1994-1995
22	94492353	EPAGAS95	1994-1995
23	94492354	EPAGAS95	1994-1995
24	94492355	EPAGAS95	1994-1995
25	94492356	EPAGAS95	1994-1995
26	94492357	EPAGAS95	1994-1995
27	94492358	EPAGAS95	1994-1995
32	95042153	EPAGAS95	1994-1995
33	95042200	EPAGAS95	1994-1995
527	L6586-9	LUUMON95	1995
ST-03	ST-03	RETEC99-Grabs	1999
ST-04	ST-04	RETEC99-Grabs	1999
ST-05	ST-05	RETEC99-Grabs	1999
ST-06	ST-06	RETEC99-Grabs	1999
ST-07	ST-07	RETEC99-Grabs	1999
ST-08	ST-08	RETEC99-Grabs	1999
ST-09	ST-09	RETEC99-Grabs	1999
ST-11	ST-11	RETEC99-Grabs	1999
ST-12	ST-12	RETEC99-Grabs	1999
ST-18	ST-18	RETEC99-Grabs	1999
ST-28	ST-28	RETEC99-Grabs	1999
ST-42	ST-42	RETEC99-Grabs	1999
527	L17656-18	LUUCSO00	2000
KC 572	L21689-6	KC_LKUN01	2001
LU-1	LU 1	TAMU02	2002
LU-2	LU 2	TAMU02	2002
LU-3	LU 3	TAMU02	2002
LU-4	LU 4	TAMU02	2002
LU-5	LU 5	TAMU02	2002
LU-6	LU 6	TAMU02	2002
LU-7	LU-7	TAMU02	2002
NLU04	NLU04-SS-0010	RETEC02-Grabs	2002
NLU05	NLU05-SS-0010	RETEC02-Grabs	2002
NLU06	NLU06-SS-0010	RETEC02-Grabs	2002
NLU07	NLU07-SS-0010	RETEC02-Grabs	2002
NLU08	NLU08-SS-0010	RETEC02-Grabs	2002
NLU10	NLU10-SS-0010	RETEC02-Grabs	2002
NLU12	NLU12-SS-0010	RETEC02-Grabs	2002
NLU14	NLU14-SS-0010	RETEC02-Grabs	2002
NLU17	NLU17-SS-0010	RETEC02-Grabs	2002
NLU112	NLU-112-SS-0010	RETEC02-Grabs	2002
NLU114	NLU-114-SS-0010	RETEC02-Grabs	2002
NLU120	NLU-120-SS-0010	RETEC02-Grabs	2002
NLU121	NLU-121-SS-0010	RETEC02-Grabs	2002
NLU122	NLU-122-SS-0010	RETEC02-Grabs	2002
NLU130	NLU-130-SS-0010	RETEC02-Grabs	2002
NLU131	NLU-131-SS-0010	RETEC02-Grabs	2002
NLU133	NLU-133-SS-0010	RETEC02-Grabs	2002
NLU134	NLU-134-SS-0010	RETEC02-Grabs	2002
NLU135	NLU-135-SS-0010	RETEC02-Grabs	2002
NLU136	NLU-136-SS-0010	RETEC02-Grabs	2002

Table 2-3 Gas Works Sediment Area (GWSA) Sediment Data Set

Location ID	Sample ID	Study Code	Study Date
NLU40	NLU40-SS-0010	RIFSE	2004
NLU41	NLU41-SS-0010	RIFSE	2004
NLU42	NLU42-SS-0010	RIFSE	2004
NLU43	NLU43-SS-0010	RIFSE	2004
NLU44	NLU44-SS-0010	RIFSE	2004
NLU45	NLU45-SS-0010	RIFSE	2004
NLU46	NLU46-SS-0010	RIFSE	2004
NLU47	NLU47-SS-0010	RIFSE	2004
NLU48	NLU48-SS-0010	RIFSE	2004
NLU49	NLU49-SS-0010	RIFSE	2004
NLU50	NLU50-SS-0010	RIFSE	2004
NLU51	NLU51-SS-0010	RIFSE	2004
NLU53	NLU53-SS-0010	RIFSE	2004
NLU54	NLU54-SS-0010	RIFSE	2004
NLU55	NLU55-SS-0010	RIFSE	2004
NLU56	NLU56-SS-0010	RIFSE	2004
NLU57	NLU57-SS-0010	RIFSE	2004
NLU58	NLU58-SS-0010	RIFSE	2004
NLU59	NLU59-SS-0010	RIFSE	2004
NLU60	NLU60-SS-0010	RIFSE	2005
NLU61	NLU61-SS-0010	RIFSE	2004
NLU62	NLU62-SS-0010	RIFSE	2004
NLU63	NLU63-SS-0010	RIFSE	2004
NLU64	NLU64-SS-0010	RIFSE	2004
NLU65	NLU65-SS-0010	RIFSE	2004
NLU66	NLU66-SS-0010	RIFSE	2004
NLU67	NLU67-SS-0010	RIFSE	2004
NLU68	NLU68-SS-0010	RIFSE	2004
NLU69	NLU69-SS-0010	RIFSE	2004
NLU70	NLU70-SS-0010	RIFSE	2004
NLU71	NLU71-SS-0010	RIFSE	2004
NLU72	NLU72-SS-0010	RIFSE	2004
NLU73	NLU73-SS-0010	RIFSE	2004
NLU74	NLU74-SS-0010	RIFSE	2004
NLU75	NLU75-SS-0010	RIFSE	2004
NLU76	NLU76-SS-0010	RIFSE	2005
NLU77	NLU77-SS-0010	RIFSE	2004
NLU78	NLU78-SS-0010	RIFSE	2004
NLU41-TX	NLU41-TX-0010	GWSA05	2005
NLU51-TX	NLU51TX0010	GWSA05	2005
NLU55-TX	NLU55-TX0010	GWSA05	2005
NLU64-TX	NLU64TX0010	GWSA05	2005
NLU66-TX	NLU66TX0010	GWSA05	2005
NLU69-TX	NLU69TX0010	GWSA05	2005
NLU73-TX	NLU73TX0010	GWSA05	2005
NLU76-TX	NLU76-TX-0010	GWSA05	2005
NLU83-TX	NLU83-TX-0010	GWSA05	2005
NLU84-TX	NLU84TX0010	GWSA05	2005
NLU85-TX	NLU85-TX-0010	GWSA05	2005
NLU117-TX	NLU117TX0010	GWSA05	2005
NLUEPA5-TX	NLUEPA5TX0010	GWSA05	2005
NLUEPA19-TX	NLUEPA19TX0010	GWSA05	2005
GWS-SG01	GWS-SG01	FSnider_05	2005
GWS-SG02	GWS-SG02	FSnider_05	2005
GWS-SG03	GWS-SG03	FSnider_05	2005
GWS-SG04	GWS-SG04	FSnider_05	2005
GWS-SG05	GWS-SG05	FSnider_05	2005
GWS-SG06	GWS-SG06	FSnider_05	2005
GWS-SG07	GWS-SG07	FSnider_05	2005
GWS-SG08	GWS-SG08	FSnider_05	2005
GWS-SG09	GWS-SG09	FSnider_05	2005
GWS-SG10	GWS-SG10	FSnider_05	2005
GWS-SG11	GWS-SG11	FSnider_05	2005
GWS-SG13	GWS-SG13	FSnider_05	2005
GWS-SG16	GWS-SG16	FSnider_05	2005

Notes:

This GWSA data set is comprised of surface sediment only and is used for the risk evaluations. The subsurface sample GWSA data set used in the Chemical of Potential Concern screening process is provided in the draft RI/FSs (RETEC 2006 and Floyd|Snider 2007).

Table 2-4 Summary of Crayfish and Finfish Tissue Data

Lab Sample Number	Sample Collection Date	Sample Collection Method	Tissue Source	Location	Number of Individual Organisms in Composite	Tissue Type	Cooked or Raw	Survey/ Study Info	Incorporated into Human Health/ Ecological Risk Evaluation?	Rationale
840912	Summer 1984	Crayfish/crab pots deployed near docks, piers	Crayfish	GWS-ESA Station 527	126	Whole	Raw	King County Health Department, F. Frost 1984; Hansen, 1993	Y	Receptor of interest in GWSA. Sample size greater than 3.
870812	Summer 1987	Crayfish/crab pots deployed near docks, piers	Crayfish	GWS-ESA Station 527	Approx. 230	Whole	Raw	Seattle City Light, W. Trial, 1987; Hansen 1993	Y	Receptor of interest in GWSA. Sample size greater than three.
9101514	7/31/1991	Crayfish/crab pots deployed near docks, piers	Crayfish	Canal between Lake Union and Portage Bay near Ivar's restaurant, collected over five days; Station B535	4	Tails	Raw	University Regulator, Pre-separation Study	Y	Receptor of interest in reasonably close proximity to GWSA. Sample size greater than three.
9101820	10/16/1991	Hand-deployed fishnet	Perch	GWS-ESA Station 527	29	Fillet	Raw	University Regulator, Pre-separation Study	Y	Receptor of interest in GWSA. Sample size greater than three.
9101821	10/16/1991	Hand-deployed fishnet	Sculpin	GWS-ESA Station 527	56	Whole and Fillet	Raw	University Regulator, Pre-separation Study	Y	Though not previously recommended as a receptor of interest in GWSA, sculpin is occasionally caught by fisherman. Sample size greater than three.
9114538	10/17/1991	Hand-deployed fishnet	Bullhead	GWS-ESA Station 527	1	Fillet	Raw	University Regulator, Pre-separation Study	N	Insufficient sample size (less than three).
L12005-1	8/15/1997	Hand-deployed fishnet	Sucker	GWS-ESA Station 527	2	Fillet	Raw	University Regulator, Post-separation Study	N	Insufficient sample size (less than three).
L12005-2	8/15/1997	Hand-deployed fishnet	Largemouth Bass	GWS-ESA Station 527	5	Fillet	Raw	University Regulator, Post-separation Study	Y	Receptor of interest in GWSA. Sample size greater than three.
L12005-3	8/15/1997	Hand-deployed fishnet	Catfish	GWS-ESA Station 527	4	Fillet	Raw	University Regulator, Post-separation Study	Y	Though not previously recommended as a receptor of interest in GWSA, catfish is known to be a game fish. Sample size greater than three.
L12005-4	8/15/1997	Crayfish/crab pots deployed near docks, piers	Crayfish	GWS-ESA Station 527	45	Tails, cleaned	Raw	University Regulator, Post-separation Study	Y	Receptor of interest in GWSA. Sample size greater than three.
L12005-5	8/15/1997	Crayfish/crab pots deployed near docks, piers	Crayfish	Mercer Island, east side 1/2 mile south of I-90 Bridge	60	Tails, cleaned	Raw	University Regulator, Post-separation Study	N	Not in vicinity of GWSA, sample size greater than three.
L17433-1	7/13/1999	Hand-deployed fishnet	Sucker	North Portage Bay	1	Fillet, edible tissue only	Raw	University Regulator, Post-separation Study	N	Not in vicinity of GWSA, sample size greater than three.
L17433-2	7/13/1999	Hand-deployed fishnet	Pike minnow	Ship Canal	2	Fillet, edible tissue only	Raw	University Regulator, Post-separation Study	N	Not in vicinity of GWSA, sample size greater than three.
L17433-3	7/13/1999	Hand-deployed fishnet	Smallmouth Bass	Aurora Bridge	1	Fillet, edible tissue only	Raw	University Regulator, Post-separation Study	N	Insufficient sample size (less than three).
L17433-4	7/22/1999	Hand-deployed fishnet	Crappie	GWS-ESA, Nearshore	6	Fillet, edible tissue only	Raw	University Regulator, Post-separation Study	Y	Though not previously recommended as a Receptor of interest in vicinity of GWSA, crappie is known to be a game fish. Sample size greater than three.
L17433-5	7/22/1999	Hand-deployed fishnet	Yellow Perch	GWS-ESA, Nearshore	4	Fillet, edible tissue only	Raw	University Regulator, Post-separation Study	Y	Receptor of interest in vicinity of GWSA. Sample size greater than three.

Notes:
GWSA: Gas Works Sediment Area.

Table 2-5 Crayfish Tissue Concentrations

Chemical of Potential Concern	Sample Name and Date (mg/kg ww)				Summary[4]	
	870812 1987	9101514 7/31/1991	840912 1984	L12005-4 8/15/1997	Minimum (mg/kg ww)	Maximum (mg/kg ww)
Conventionals/Misc.						
Total Cyanide	na	na	na	na	na	na
Metals						
Antimony	na	0.6[1]	na	0.02[1]	0.01	0.3
Arsenic	na	0.9[1]	0.57	0.179	0.179	0.57
Cadmium	na	0.02	0.37	0.008[1]	0.004	0.37
Chromium	na	0.02	na	0.09	0.02	0.09
Cobalt	na	na	na	na	na	na
Copper	na	14	0.10[1]	9.38	0.05	14
Lead	na	0.2	3.16	0.074	0.074	3.16
Mercury	na	0.15	0.05	0.091	0.05	0.15
Nickel	na	0.2[1]	na	0.042	0.042	0.042
Selenium	na	0.9[1]	0.18	0.15	0.15	0.18
Silver	na	0.009	na	na	0.009	0.009
Zinc	na	14	na	12.2	12.2	14
Butyltins						
Tributyltin	na	na	na	0.003	0.003	0.003
LPAH						
Acenaphthene	na	0.004[1]	na	0.011[1]	0.002	0.0055
Acenaphthylene	na	0.006[1]	na	0.016[1]	0.003	0.008
Anthracene	na	0.006[1]	0.003	0.016[1]	0.003	0.003
Fluorene	na	0.006[1]	na	0.016[1]	0.003	0.008
2-Methylnaphthalene	na	0.017[1]	na	0.043[1]	0.0085	0.0215
Naphthalene	na	0.017[1]	na	0.043[1]	0.0085	0.0215
Phenanthrene	na	0.006[1]	0.028	0.016[1]	0.003	0.028
Total LPAH	na	0.017[2]	0.031	0.043[2]	0.0085	0.031
HPAH						
Benzo(a)anthracene	na	0.006[1]	0.019	0.016[1]	0.003	0.019
Benzo(a)pyrene	na	0.011[1]	0.017	0.027[1]	0.0055	0.017
Benzo(b)fluoranthene	na	0.017[1]	0.011	0.043[1]	0.0085	0.011
Benzo(k)fluoranthene	na	0.017[1]	0.015	0.043[1]	0.0085	0.015
Benzo(g,h,i)perylene	na	0.011[1]	na	0.027[1]	0.0055	0.0135
Chrysene	na	0.006[1]	0.033	0.016[1]	0.003	0.033
Dibenzo(a,h)anthracene	na	0.017[1]	na	0.043[1]	0.0085	0.0215
Fluoranthene	na	0.007[1]	0.01	0.016[1]	0.0035	0.01
Indeno(1,2,3-cd)pyrene	na	0.011[1]	na	0.027[1]	0.0055	0.0135
Pyrene	na	0.006[1]	0.111	0.016[1]	0.003	0.111
Total HPAH	na	0.017[2]	0.216	0.043[2]	0.0085	0.216
Total PAHs	na	0.017[2]	0.247	0.043[2]	0.0085	0.247
Phthalates						
Bis(2-Ethylhexyl)phthalate	na	0.006[1]	na	0.022	0.003	0.022
Butylbenzyl phthalate	na	0.006[1]	na	0.016[1]	0.003	0.008
Di-n-butylphthalate	na	0.011[1]	na	0.027[1]	0.0055	0.0135
Diethylphthalate	na	0.011[1]	na	0.027[1]	0.0055	0.0135
Dimethylphthalate	na	0.003[1]	na	0.011[1]	0.0015	0.0055
Di-n-octylphthalate	na	0.006[1]	na	0.016[1]	0.003	0.008

Table 2-5 Crayfish Tissue Concentrations

Chemical of Potential Concern	Sample Name and Date (mg/kg ww)				Summary[4]	
	870812 1987	9101514 7/31/1991	840912 1984	L12005-4 8/15/1997	Minimum (mg/kg ww)	Maximum (mg/kg ww)
Phenols						
2,4-Dimethylphenol	na	0.011[1]	na	0.027[1]	0.0055	0.0135
4-Methylphenol	na	0.011[1]	na	0.027[1]	0.0055	0.0135
Pentachlorophenol	na	0.011[1]	na	0.027[1]	0.0055	0.0135
Phenol	na	0.033[1]	na	7.88	0.0165	7.88
Misc. Extractables						
Benzoic Acid	na	0.3	na	0.11[1]	0.055	0.3
Carbazole	na	0.011[1]	na	0.027[1]	0.0055	0.0135
Dibenzofuran	na	0.011[1]	na	0.027[1]	0.0055	0.0135
Retene	na	na	na	na	na	na
Volatile Organic Compounds						
Benzene	na	na	na	na	na	na
Ethylbenzene	na	na	na	na	na	na
Toluene	na	na	na	na	na	na
Total Xylenes	na	na	na	na	na	na
1,2,4-Trimethylbenzene	na	na	na	na	na	na
1,3,5-Trimethylbenzene	na	na	na	na	na	na
Pesticides/PCBs						
Chlordane	na	0.002[1]	na	0.007[1]	0.001	0.0035
DDD	na	0.0004[1]	na	0.001[1]	0.0002	0.0005
DDT	na	0.0004[1]	na	0.001[1]	0.0002	0.0005
Aroclor 1254	na	0.004[1]	0.110	0.013[1]	0.002	0.11
Aroclor 1260	na	0.004[1]	0.118	0.013[1]	0.002	0.118
Total PCBs	0.012	0.0004[2]	0.262[3]	0.013[2]	0.0002	0.262

Notes:

[1] No reported results; the maximum method detection limit (MDL) is presented here.

[2] Total reported as highest MDL value.

[3] Total includes values for Aroclor 1242 and Aroclor 1248 as reported in King County, 2009.

[4] Maximum defers to detected concentrations, unless all values are non-detect. Non-detects are set to one-half the MDL.

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

na: Not analyzed

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

Table 2-6 Finfish Tissue Concentrations

Chemical of Potential Concern	Sample Name and Date (mg/kg ww)						Summary[3]	
	9101820 10/16/1991	9101821 10/16/1991	L12005-2 8/15/1997	L12005-3 8/15/1997	L17433-4 7/22/1999	L17433-5 7/22/1999	Minimum (mg/kg ww)	Maximum (mg/kg ww)
Conventionals/Misc.								
Total Cyanide	na	na	na	na	na	na	na	na
Metals								
Antimony	0.3[1]	0.3[1]	0.02[1]	na	na	na	0.01	0.15
Arsenic	0.5[1]	0.5[1]	0.11	na	na	0.033	0.033	0.11
Cadmium	0.005[1]	0.005[1]	0.008[1]	na	na	0.004[1]	0.002	0.004
Chromium	0.08	0.2	0.054	na	na	0.337	0.054	0.337
Cobalt	na	na	na	na	na	na	na	na
Copper	0.31	0.39	0.343	na	na	0.255	0.255	0.39
Lead	0.03[1]	0.1	0.02[1]	na	na	0.008[1]	0.004	0.1
Mercury	0.16	0.12	0.104	0.0384	na	0.177	0.0384	0.177
Nickel	0.1[1]	0.1[1]	0.02[1]	na	na	na	0.01	0.05
Selenium	0.5[1]	0.6	0.18	na	na	0.2	0.18	0.6
Silver	0.003[1]	0.003[1]	na	na	na	0.008[1]	0.0015	0.004
Zinc	5.9	9.9	4.4	na	na	6.2	4.4	9.9
Butyltins								
Tributyltin	na	na	0.093	na	na	na	0.093	0.093
LPAH								
Acenaphthene	0.006[1]	0.003[1]	0.011[1]	na	na	na	0.0015	0.0055
Acenaphthylene	0.007[1]	0.004[1]	0.016[1]	na	na	na	0.002	0.008
Anthracene	0.007[1]	0.004[1]	0.016[1]	na	na	na	0.002	0.008
Fluorene	0.007[1]	0.004[1]	0.016[1]	na	na	na	0.002	0.008
2-Methylnaphthalene	0.022[1]	0.011[1]	0.043[1]	na	na	na	0.0055	0.0215
Naphthalene	0.022[1]	0.011[1]	0.043[1]	na	na	na	0.0055	0.0215
Phenanthrene	0.007[1]	0.004[1]	0.016[1]	na	na	na	0.002	0.008
Total LPAH	0.022[2]	0.011[2]	0.043[2]	na	na	na	0.0055	0.0215
HPAH								
Benzo(a)anthracene	0.007[1]	0.004[1]	0.016[1]	na	na	na	0.002	0.008
Benzo(a)pyrene	0.015[1]	0.007[1]	0.027[1]	na	na	na	0.0035	0.0135
Benzo(b)fluoranthene	0.022[1]	0.011[1]	0.043[1]	na	na	na	0.0055	0.0215
Benzo(k)fluoranthene	0.022[1]	0.011[1]	0.043[1]	na	na	na	0.0055	0.0215
Benzo(g,h,i)perylene	0.015[1]	0.007[1]	0.027[1]	na	na	na	0.0035	0.0135
Chrysene	0.007[1]	0.004[1]	0.016[1]	na	na	na	0.002	0.008
Dibenzo(a,h)anthracene	0.022[1]	0.011[1]	0.043[1]	na	na	na	0.0055	0.0215
Fluoranthene	0.009[1]	0.004[1]	0.016[1]	na	na	na	0.002	0.008
Indeno(1,2,3-cd)pyrene	0.015[1]	0.007[1]	0.027[1]	na	na	na	0.0035	0.0135
Pyrene	0.007[1]	0.004[1]	0.016[1]	na	na	na	0.002	0.008
Total HPAH	0.022[2]	0.011[2]	0.043[2]	na	na	na	0.0055	0.0215
Total PAHs	0.022[2]	0.011[2]	0.043[2]	na	na	na	0.0055	0.0215
Phthalates								
Bis(2-Ethylhexylphthalate)	0.007[1]	0.004[1]	0.016[1]	na	na	na	0.002	0.008
Butylbenzylphthalate	0.007[1]	0.004[1]	0.016[1]	na	na	na	0.002	0.008
Di-n-butylphthalate	0.015[1]	0.007[1]	0.027[1]	na	na	na	0.0035	0.0135
Diethylphthalate	0.015[1]	0.007[1]	0.027[1]	na	na	na	0.0035	0.0135
Dimethylphthalate	0.004[1]	0.002[1]	0.011[1]	na	na	na	0.001	0.0055
Di-n-octylphthalate	0.007[1]	0.004[1]	0.016[1]	na	na	na	0.002	0.008
Phenols								
2,4-Dimethylphenol	0.015[1]	0.007[1]	0.027[1]	na	na	na	0.0035	0.0135
4-Methylphenol	0.015[1]	0.007[1]	0.027[1]	na	na	na	0.0035	0.0135
Pentachlorophenol	0.015[1]	0.007[1]	0.027[1]	na	na	na	0.0035	0.0135
Phenol	0.043[1]	0.021[1]	0.110[1]	na	na	na	0.0105	0.055
Misc. Extractables								
Benzoic Acid	0.14	0.07	0.110[1]	na	na	na	0.055	0.14
Carbazole	0.015[1]	0.007[1]	0.027[1]	na	na	na	0.0035	0.0135
Dibenzofuran	0.015[1]	0.007[1]	0.027[1]	na	na	na	0.0035	0.0135
Retene	na	na	na	na	na	na	na	na

Table 2-6 Finfish Tissue Concentrations

Chemical of Potential Concern	Sample Name and Date (mg/kg ww)						Summary[3]	
	9101820 10/16/1991	9101821 10/16/1991	L12005-2 8/15/1997	L12005-3 8/15/1997	L17433-4 7/22/1999	L17433-5 7/22/1999	Minimum (mg/kg ww)	Maximum (mg/kg ww)
Volatile Organic Compounds								
Benzene	na	na	na	na	na	na	na	na
Ethylbenzene	na	na	na	na	na	na	na	na
Toluene	na	na	na	na	na	na	na	na
Total Xylenes	na	na	na	na	na	na	na	na
1,2,4-Trimethylbenzene	na	na	na	na	na	na	na	na
Pesticides/PCBs								
Chlordane	na	na	0.007[1]	0.006[1]	na	na	0.003	0.0035
DDD	na	na	0.001[1]	0.001[1]	na	na	0.0005	0.0005
DDT	na	na	0.001[1]	0.001[1]	na	na	0.0005	0.0005
Aroclor 1254	na	na	0.013[1]	0.012[1]	0.007	0.009	0.006	0.009
Aroclor 1260	na	na	0.013[1]	0.012[1]	0.005[1]	0.005[1]	0.0025	0.0065
Total PCBs	na	na	0.013[2]	0.012[2]	0.007	0.009	0.006	0.009

Notes:

[1] No reported results; the maximum method detection limit (MDL) is presented here.

[2] Total reported as highest MDL value.

[3] Maximum defers to detected concentrations, unless all values are non-detect. Non-detects are set to one-half the MDL.

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

na: Not analyzed

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

Table 3-1 Comparison of Draft RI/FS GWS-ESA and GWS-WSA Documents COPC Lists

GWS-ESA List	GWS-WSA List
SVOCs – PAHs	
16 PAHs for TPAH	16 PAHs for TPAH
SVOC – Other	
Carbazole	Carbazole
Dibenzofuran	
Phenols *	Phenols
Phthalates *	Phthalates, limited set
VOCs	
Benzene	Benzene
Ethylbenzene	Ethylbenzene
Toluene	Toluene
Xylenes	
Metals	
Antimony *	Antimony
Arsenic	Arsenic
Cadmium *	Cadmium
Chromium *	
Copper *	Copper
Lead *	Lead
Mercury *	Mercury
Nickel *	Nickel
Silver *	Silver
Zinc *	Zinc
Conventionals	
Sulfides	Sulfides
Total Solids	
Total Organic Carbon	Total Organic Carbon
Dissolved Organic Carbon	
Ammonia	Ammonia
Other	
Pesticides *	
Cyanide	
Total PCBs *	Total PCBs
Tributyltin *	Tributyltin

Notes:

* Indicates Supplemental List

COPC: Chemical of potential concern

GWS-ESA: Gas Works Sediment - Eastern Study Area

GWS-WSA: Gas Works Sediment - Western Study Area

PAH: Polycyclic aromatic hydrocarbon

RI/FS: Remedial investigation/feasibility study

PCB: Polychlorinated biphenyl

SVOC: Semivolatile organic compound

TPAH: Total polycyclic aromatic hydrocarbons

VOC: Volatile organic compound

Table 3-2 Statistical Summary of Sediment Data (1995–2009 GWSA)

Parameter	CAS Number	No. of Samples	No. of Detects	% Detects	No. of Non-Detects	% Non-Detects	All Data			Detects Only		
							Mean (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)
Conventionals/Misc.												
Total Cyanide	CN	168	82	49	86	51	16	0.13	780	32	0.30	780
Metals												
Aluminum	7429-90-5	24	24	100	0	0	16400	5690	121000	16400	5690	121000
Antimony	7440-36-0	130	23	18	107	82	6.1	0.10	20	4.2	0.30	19
Arsenic	7440-38-2	351	179	51	172	49	45	1.5	2400	75	3.0	2400
Barium	7440-39-3	29	29	100	0	0	100	64	470	100	64	470
Beryllium	7440-41-7	25	23	92	2	8	0.34	0.17	0.46	0.35	0.17	0.46
Cadmium	7440-43-9	259	130	50	129	50	1.0	0.050	4.0	1.5	0.10	4.0
Calcium	7440-70-2	24	24	100	0	0	6200	3300	8000	6200	3300	8000
Chromium	7440-47-3	177	177	100	0	0	49	13	250	49	13	250
Cobalt	7440-48-4	22	22	100	0	0	54	7.4	240	54	7.4	240
Copper	7440-50-8	259	259	100	0	0	140	6.40	1050	140	6.40	1050
Iron	7439-89-6	38	38	100	0	0	24400	10600	33600	24400	10600	33600
Lead	7439-92-1	259	187	72	72	28	150	0.50	1100	210	1.0	1100
Magnesium	7439-95-4	24	24	100	0	0	5200	2600	7600	5200	2600	7600
Manganese	7439-96-5	24	24	100	0	0	260	120	390	260	120	390
Mercury	7439-97-6	261	149	57	112	43	0.52	0.0050	3.3	0.84	0.010	3.3
Methylmercury	22967-92-6	1	1	100	0	0	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012
Nickel	7440-02-0	190	190	100	0	0	64	10	630	64	10	630
Potassium	9/7/7440	24	23	96	1	4	710	300	1200	700	300	1200
Selenium	7782-49-2	31	24	77	7	23	0.98	0.21	2.3	0.82	0.21	2.3
Silver	7440-22-4	200	55	28	145	73	1.0	0.10	9.0	1.8	0.20	9.0
Sodium	7440-23-5	23	23	100	0	0	540	220	980	540	220	980
Thallium	7440-28-0	24	1	4	23	96	0.14	0.13	0.55	0.14	0.14	0.14
Tin	7440-31-5	1	1	100	0	0	6.8	6.8	6.8	6.8	6.8	6.8
Vanadium	7440-62-2	22	22	100	0	0	64	43	130	64	43	130
Zinc	7440-66-6	259	259	100	0	0	230	16.1	1360	230	16.1	1360
Butyltins												
Tributyltin	688-73-3	53	37	70	16	30	0.36	0.0018	7.0	0.52	0.0043	7.0
LPAH												
Naphthalene	91-20-3	366	293	80	73	20	210	0.0085	20000	260	0.010	20000
Acenaphthylene	208-96-8	366	267	73	99	27	12	0.0048	1100	16	0.014	1100
Acenaphthene	83-32-9	367	287	78	80	22	46	0.0085	4100	58	0.011	4100
Fluorene	86-73-7	367	271	74	96	26	27	0.0085	2100	36	0.022	2100
Phenanthrene	85-01-8	361	310	86	51	14	130	0.0095	9900	150	0.020	9900
Anthracene	120-12-7	367	294	80	73	20	32	0.0090	2500	40	0.0094	2500
2-methlynaphthalene	91-57-6	367	255	69	112	31	68	0.0085	5000	97	0.021	5000
Total LPAH		367	328	89	39	11	450	0.0095	40000	500	0.015	40000
HPAH												
Fluoranthene	206-44-0	361	305	84	56	16	110	0.0090	5600	120	0.016	5600
Pyrene	129-00-0	361	303	84	58	16	110	0.0090	5700	130	0.016	5700
Benzo(a)anthracene	56-55-3	367	288	78	79	22	33	0.0085	2100	43	0.018	2100
Chrysene	218-01-9	366	288	79	78	21	37	0.0085	2400	47	0.019	2400
Benzo(b)fluoranthene	205-99-2	366	284	78	82	22	31	0.0085	2100	40	0.017	2100
Benzo(k)fluoranthene	207-08-9	366	285	78	81	22	23	0.0085	1400	29	0.018	1400
Benzo(b,k)fluoranthenes (Total)		366	286	78	80	22	53	0.0085	3500	68	0.028	3500
Benzo(a)pyrene	50-32-8	367	287	78	80	22	43	0.0085	2200	55	0.0099	2200
Indeno(1,2,3-cd)pyrene	193-39-5	367	279	76	88	24	25	0.0048	1100	33	0.014	1100
Dibenzo(a,h)anthracene	53-70-3	367	238	65	129	35	4.7	0.0048	220	7.2	0.023	220
Benzo(g,h,i)perylene	191-24-2	367	279	76	88	24	28	0.0048	1100	36	0.015	1100
Total HPAH		366	312	85	54	15	440	0.0090	24000	510	0.016	24000
Total PAH		367	331	90	36	10	880	0.0095	64000	980	0.015	64000

Table 3-2 Statistical Summary of Sediment Data (1995–2009 GWSA)

Parameter	CAS Number	No. of Samples	No. of Detects	% Detects	No. of Non-Detects	% Non-Detects	All Data			Detects Only		
							Mean (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)
Phthalates												
Dimethylphthalate	131-11-3	265	29	11	236	89	0.37	0.0048	16	0.19	0.062	0.42
Diethylphthalate	84-66-2	244	21	9	223	91	0.37	0.0085	16	0.37	0.012	4.5
Di-n-butylphthalate	84-74-2	267	41	15	226	85	0.73	0.0065	37	1.5	0.014	37
Butylbenzylphthalate	85-68-7	265	27	10	238	90	0.48	0.0048	16	0.30	0.036	0.66
bis(2-Ethylhexyl)phthalate	117-81-7	265	100	38	165	62	0.85	0.0090	16	1.2	0.011	6.5
Di-n-octyl Phthalate	117-84-0	244	3	1	241	99	0.53	0.0085	56	19	0.13	56
Phenols												
Phenol	108-95-2	339	20	6	319	94	0.43	0.0090	22	0.91	0.020	12
2-Chlorophenol	95-57-8	104	0	0	104	100	0.40	0.0095	22	NA	NA	NA
2,4-Dichlorophenol	120-83-2	104	0	0	104	100	2.0	0.048	110	NA	NA	NA
2,4,5-Trichlorophenol	95-95-4	104	0	0	104	100	2.0	0.048	110	NA	NA	NA
2,4,6-Trichlorophenol	88-06-2	104	0	0	104	100	2.0	0.048	110	NA	NA	NA
4-Chloro-3-methylphenol	59-50-7	103	0	0	103	100	2.0	0.048	110	NA	NA	NA
2-Methylphenol	95-48-7	267	8	3	259	97	0.50	0.0085	27	4.7	0.043	27
4-Methylphenol	106-44-5	267	59	22	208	78	0.76	0.0085	69	1.9	0.010	69
2,4-Dimethylphenol	105-67-9	339	38	11	301	89	0.54	0.0085	30	2.1	0.012	30
2-Nitrophenol	88-75-5	125	0	0	125	100	1.7	0.048	110	NA	NA	NA
4-Nitrophenol	100-02-7	103	1	1	102	99	2.0	0.048	110	0.75	0.75	0.75
2,4-Dinitrophenol	51-28-5	103	0	0	103	100	4.0	0.095	220	NA	NA	NA
4,6-Dinitro-2-methylphenol	534-52-1	103	0	0	103	100	4.0	0.095	220	NA	NA	NA
Pentachlorophenol	87-86-5	246	8	3	238	97	2.2	0.043	110	0.21	0.059	0.46
Misc. Extractables												
Benzidine	92-87-5	2	0	0	2	100	2.8	2.5	3.0	NA	NA	NA
Benzoic Acid	65-85-0	267	33	12	234	88	3.6	0.031	160	1.7	0.031	4.0
Benzyl Alcohol	100-51-6	244	8	3	236	97	0.37	0.0085	16	0.35	0.088	0.92
Caffeine	58-08-2	2	0	0	2	100	0.04	0.020	0.062	NA	NA	NA
Carbazole	86-74-8	246	130	53	116	47	4.6	0.0095	150	8.6	0.024	150
B-Coprostanol	360-68-9	3	0	0	3	100	0.61	0.14	1.2	NA	NA	NA
Dibenzofuran	132-64-9	367	204	56	163	44	8.9	0.0048	830	16	0.012	830
Hexachlorobenzene	118-74-1	286	2	1	284	99	0.31	0.00048	16	2.3	0.0022	4.5
Hexachlorobutadiene	87-68-3	286	0	0	286	100	0.30	0.00047	16	NA	NA	NA
Hexachlorocyclopentadiene	77-47-4	103	0	0	103	100	0.90	0.048	11	NA	NA	NA
Hexachloroethane	67-72-1	104	0	0	104	100	0.18	0.0095	2.2	NA	NA	NA
Isophorone	78-59-1	125	13	10	112	90	0.19	0.0095	2.2	0.091	0.019	0.21
Nitrobenzene	98-95-3	104	0	0	104	100	0.18	0.0095	2.2	NA	NA	NA
N-Nitrosodimethylamine	62-75-9	3	0	0	3	100	0.38	0.21	0.48	NA	NA	NA
N-Nitrosodiphenylamine	86-30-6	244	8	3	236	97	0.36	0.0048	16	0.43	0.015	2.4
N-Nitroso-di-N-propylamine	621-64-7	104	0	0	104	100	0.90	0.048	11	NA	NA	NA
Retene	483-65-8	64	38	59	26	41	1.5	0.0095	12	2.4	0.042	12
4-Chloroaniline	106-47-8	122	0	0	122	100	0.83	0.048	11	NA	NA	NA
2-Nitroaniline	88-74-4	103	0	0	103	100	0.91	0.048	11	NA	NA	NA
3-Nitroaniline	99-09-2	103	0	0	103	100	0.91	0.048	11	NA	NA	NA
P-Nitroaniline	100-01-6	103	0	0	103	100	0.91	0.048	11	NA	NA	NA
1,2-Dichlorobenzene	95-50-1	253	0	0	253	100	0.33	0.0028	16	NA	NA	NA
1,3-Dichlorobenzene	541-73-1	183	0	0	183	100	1.1	0.0028	31	NA	NA	NA
1,4-Dichlorobenzene	106-46-7	253	0	0	253	100	0.33	0.0014	16	NA	NA	NA
1,2,3-Trichlorobenzene	87-61-6	9	0	0	9	100	77	29	160	NA	NA	NA
1,2,4-Trichlorobenzene	120-82-1	253	0	0	253	100	0.34	0.0028	16	NA	NA	NA
3,3'-Dichlorobenzidine	91-94-1	103	0	0	103	100	0.90	0.048	11	NA	NA	NA
bis-(2-Chloroethyl) ether	111-44-4	104	0	0	104	100	0.18	0.0095	2.2	NA	NA	NA
bis(2-Chloroisopropyl)ether	39638-32-9	76	0	0	76	100	0.19	0.0095	1.8	NA	NA	NA
bis(2-Chloroethoxy) methane	111-91-1	104	0	0	104	100	0.18	0.0095	2.2	NA	NA	NA
2-Chloronaphthalene	91-58-7	104	0	0	104	100	0.18	0.0095	2.2	NA	NA	NA
4-Bromophenyl-phenylether	101-55-3	104	0	0	104	100	0.18	0.0095	2.2	NA	NA	NA
4-Chlorophenyl-phenylether	7005-72-3	104	0	0	104	100	0.18	0.0095	2.2	NA	NA	NA
2,2'-Oxybis(1-chloropropane)	108-60-1	28	0	0	28	100	0.18	0.0095	2.2	NA	NA	NA
2,4-Dinitrotoluene	121-14-2	104	0	0	104	100	0.89	0.031	11	NA	NA	NA
2,6-Dinitrotoluene	606-20-2	104	0	0	104	100	0.89	0.045	11	NA	NA	NA

Table 3-2 Statistical Summary of Sediment Data (1995–2009 GWSA)

Parameter	CAS Number	No. of Samples	No. of Detects	% Detects	No. of Non-Detects	% Non-Detects	All Data			Detects Only		
							Mean (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)
Volatile Organic Compounds												
Acetone	67-64-1	31	2	6	29	94	22	0.048	160	0.26	0.054	0.47
Acrolein	107-02-8	10	0	0	10	100	690	0.15	1600	NA	NA	NA
Acrylonitrile	107-13-1	10	0	0	10	100	69	0.12	160	NA	NA	NA
Aniline	62-53-3	3	0	0	3	100	0.23	0.19	0.25	NA	NA	NA
Benzene	71-43-2	233	63	27	170	73	27	0.00045	3500	97	0.0012	3500
n-Butylbenzene	104-51-8	9	0	0	9	100	30	12	60	NA	NA	NA
sec-Butylbenzene	135-98-8	30	2	7	28	93	4.6	0.0029	31	0.0044	0.0037	0.0050
tert-Butylbenzene	98-06-6	9	0	0	9	100	15	6.0	31	NA	NA	NA
1,2,4-Trimethylbenzene	95-63-6	9	3	33	6	67	35	6.0	130	78	14	130
1,3,5-Trimethylbenzene	108-67-8	30	4	13	26	87	4.9	0.0029	31	3.8	0.0063	15
n-Propylbenzene	103-65-1	30	6	20	24	80	4.6	0.0029	31	0.011	0.0044	0.025
Bromobenzene	108-86-1	9	0	0	9	100	15	6.0	31	NA	NA	NA
Chlorobenzene	108-90-7	10	0	0	10	100	14	0.020	31	NA	NA	NA
Ethylbenzene	100-41-4	233	73	31	160	69	8.7	0.00045	730	27	0.00089	730
Isopropylbenzene	98-82-8	31	9	29	22	71	4.4	0.0023	31	0.030	0.0023	0.071
Bromoform	75-25-2	10	0	0	10	100	14	0.020	31	NA	NA	NA
trans-1,4-Dichloro-2-butene	110-57-6	9	0	0	9	100	77	29	160	NA	NA	NA
Carbon disulfide	75-15-0	10	0	0	10	100	14	0.020	31	NA	NA	NA
Carbon yetrachloride	56-23-5	10	0	0	10	100	14	0.020	31	NA	NA	NA
Chloroform	67-66-3	32	3	9	29	91	4.3	0.0023	31	0.020	0.0023	0.056
Bromoethane	74-96-4	9	0	0	9	100	30	12	60	NA	NA	NA
1,2-Dibromoethane	106-93-4	9	0	0	9	100	15	6.0	31	NA	NA	NA
Chloroethane	75-00-3	10	0	0	10	100	14	0.020	31	NA	NA	NA
1,1-Dichloroethane	75-34-3	10	0	0	10	100	14	0.020	31	NA	NA	NA
1,2-Dichloroethane	107-06-2	31	1	3	30	97	4.4	0.0025	31	0.0074	0.0074	0.0074
1,1,1-Trichloroethane	71-55-6	11	1	9	10	91	12	0.0072	31	0.0072	0.0072	0.0072
1,1,2-Trichloroethane	79-00-5	10	0	0	10	100	14	0.020	31	NA	NA	NA
1,1,1,2-Tetrachloroethane	630-20-6	9	0	0	9	100	15	6.0	31	NA	NA	NA
1,1,2,2-Tetrachloroethane	79-34-5	10	0	0	10	100	14	0.020	31	NA	NA	NA
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	9	0	0	9	100	15	6.0	31	NA	NA	NA
1,1-Dichloroethene	75-35-4	10	0	0	10	100	14	0.020	31	NA	NA	NA
cis-1,2-Dichloroethene	156-59-2	9	0	0	9	100	15	6.0	31	NA	NA	NA
trans-1,2-Dichloroethene	156-60-5	10	0	0	10	100	14	0.020	31	NA	NA	NA
Trichloroethene	79-01-6	10	0	0	10	100	14	0.020	31	NA	NA	NA
Tetrachloroethene	127-18-4	10	0	0	10	100	14	0.020	31	NA	NA	NA
1,2-Diphenylhydrazine	122-66-7	3	0	0	3	100	0.19	0.10	0.24	NA	NA	NA
Bromomethane	74-83-9	10	0	0	10	100	14	0.020	31	NA	NA	NA
Dibromomethane	74-95-3	9	0	0	9	100	15	6.0	31	NA	NA	NA
Chloromethane	74-87-3	10	0	0	10	100	14	0.020	31	NA	NA	NA
Bromochloromethane	74-97-5	9	0	0	9	100	15	6.0	31	NA	NA	NA
Bromodichloromethane	75-27-4	10	0	0	10	100	14	0.020	31	NA	NA	NA
Dibromochloromethane	124-48-1	10	0	0	10	100	14	0.020	31	NA	NA	NA
Trichlorofluoromethane	75-69-4	10	0	0	10	100	14	0.020	31	NA	NA	NA
Methyl iodide	74-88-4	9	0	0	9	100	15	6.0	31	NA	NA	NA
Methylene chloride	75-09-2	32	1	3	31	97	8.5	0.0050	60	0.020	0.020	0.020
2-Butanone	78-93-3	31	9	29	22	71	22	0.022	160	0.21	0.029	0.37
2-Hexanone	591-78-6	31	3	10	28	90	22	0.0074	160	0.035	0.014	0.067
4-Methyl-2-pentanone (MIBK)	108-10-1	31	3	10	28	90	22	0.0025	160	0.0062	0.0046	0.0078
1,2-Dichloropropane	78-87-5	10	0	0	10	100	14	0.020	31	NA	NA	NA
1,3-Dichloropropane	142-28-9	9	0	0	9	100	15	6.0	31	NA	NA	NA
2,2-Dichloropropane	594-20-7	9	0	0	9	100	15	6.0	31	NA	NA	NA
1,2,3-Trichloropropane	96-18-4	9	0	0	9	100	30	12	60	NA	NA	NA
1,2-Dibromo-3-chloropropane	96-12-8	9	0	0	9	100	77	29	160	NA	NA	NA
1,1-Dichloropropene	563-58-6	9	0	0	9	100	15	6.0	31	NA	NA	NA
cis-1,3-Dichloropropene	10061-01-5	10	0	0	10	100	14	0.020	31	NA	NA	NA
trans-1,3-Dichloropropene	10061-02-6	10	0	0	10	100	14	0.020	31	NA	NA	NA
Styrene	100-42-5	31	1	3	30	97	4.4	0.0025	31	0.0058	0.0058	0.0058
Toluene	108-88-3	233	52	22	181	78	2.5	0.00040	180	9.0	0.00092	180
2-Chlorotoluene	95-49-8	9	0	0	9	100	15	6.0	31	NA	NA	NA
4-Chlorotoluene	106-43-4	9	0	0	9	100	15	6.0	31	NA	NA	NA
4-Isopropyltoluene	99-87-6	30	4	13	26	87	4.6	0.0027	31	0.017	0.0027	0.045
Total Xylenes	CALC-TX	156	52	33	104	67	8.0	0.00045	480	23	0.0013	480
Vinyl Acetate	108-05-4	10	0	0	10	100	69	0.15	160	NA	NA	NA
Vinyl Chloride	75-01-4	10	0	0	10	100	14	0.020	31	NA	NA	NA
2-Chloroethylvinylether	110-75-8	10	0	0	10	100	69	0.020	160	NA	NA	NA

Table 3-2 Statistical Summary of Sediment Data (1995–2009 GWSA)

Parameter	CAS Number	No. of Samples	No. of Detects	% Detects	No. of Non-Detects	% Non-Detects	All Data			Detects Only		
							Mean (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)
Pesticides/PCBs												
2,4,5-T	93-76-5	2	0	0	2	100	58	0.0036	120	NA	NA	NA
2,4,5-TP (Silvex)	93-72-1	2	0	0	2	100	70	0.0054	140	NA	NA	NA
2,4-D	94-75-7	2	0	0	2	100	45	0.0014	90	NA	NA	NA
2,4-DB	94-82-6	2	0	0	2	100	63	0.0023	130	NA	NA	NA
Aldrin	309-00-2	3	0	0	3	100	0.0042	0.0026	0.0050	NA	NA	NA
alpha-BHC	319-84-6	3	0	0	3	100	0.0038	0.0013	0.0050	NA	NA	NA
beta-BHC	319-85-7	3	0	0	3	100	0.0038	0.0013	0.0050	NA	NA	NA
delta-BHC	319-86-8	3	0	0	3	100	0.0038	0.0013	0.0050	NA	NA	NA
gamma-BHC (Lindane)	58-89-9	3	0	0	3	100	0.0038	0.0013	0.0050	NA	NA	NA
beta-Chlordane	5103-74-2	42	11	26	31	74	0.020	0.00048	0.28	0.068	0.0011	0.28
Chlordane	12789-03-6	44	2	5	42	95	0.0066	0.00047	0.12	0.11	0.090	0.12
DDD	72-54-8	45	24	53	21	47	0.011	0.00095	0.089	0.017	0.0018	0.089
DDE	72-55-9	45	2	4	43	96	0.0040	0.00095	0.035	0.023	0.010	0.035
DDT	50-29-3	45	2	4	43	96	0.0085	0.00095	0.13	0.11	0.084	0.13
Dicamba	1918-00-9	2	0	0	2	100	35	0.0041	70	NA	NA	NA
Dieldrin	60-57-1	3	0	0	3	100	0.0042	0.0026	0.0050	NA	NA	NA
Dinoseb	88-85-7	2	0	0	2	100	75	0.0014	150	NA	NA	NA
Endosulfan	115-29-7	3	0	0	3	100	0.0042	0.0026	0.0050	NA	NA	NA
Endosulfan Sulfate	1031-07-8	3	0	0	3	100	0.0068	0.0050	0.010	NA	NA	NA
Endrin	72-20-8	3	0	0	3	100	0.0042	0.0026	0.0050	NA	NA	NA
Endrin Aldehyde	7421-93-4	3	0	0	3	100	0.0050	0.0050	0.0051	NA	NA	NA
Heptachlor	76-44-8	3	0	0	3	100	0.0038	0.0013	0.0050	NA	NA	NA
Heptachlor Epoxide	1024-57-3	3	0	0	3	100	0.0059	0.0050	0.0077	NA	NA	NA
MCPA	94-74-6	2	0	0	2	100	78	0.0025	160	NA	NA	NA
MCPP	93-65-2	2	0	0	2	100	70	0.0046	140	NA	NA	NA
Methoxychlor	72-43-5	3	0	0	3	100	0.023	0.013	0.030	NA	NA	NA
Toxaphene	8001-35-2	3	0	0	3	100	0.047	0.026	0.060	NA	NA	NA
Aroclor 1016	12674-11-2	128	0	0	128	100	0.015	0.0033	0.10	NA	NA	NA
Aroclor 1221	11104-28-2	128	0	0	128	100	0.017	0.0064	0.10	NA	NA	NA
Aroclor 1232	11141-16-5	128	0	0	128	100	0.017	0.0064	0.15	NA	NA	NA
Aroclor 1242	53469-21-9	128	0	0	128	100	0.017	0.0033	0.20	NA	NA	NA
Aroclor 1248	12672-29-6	128	2	2	126	98	0.018	0.0033	0.12	0.019	0.018	0.020
Aroclor 1254	11097-69-1	128	23	18	105	82	0.041	0.0095	0.40	0.11	0.019	0.40
Aroclor 1260	11096-82-5	128	26	20	102	80	0.037	0.0095	0.30	0.077	0.014	0.30
Total PCBs		128	28	22	100	78	0.059	0.0095	0.70	0.16	0.020	0.70

Notes:

Data parameters for revised COPC screening: 1995 to 2009, samples within the GWSA (except those in the Northlake Shipyard vicinity), surface and subsurface samples.

Non-detects were set to one-half the reporting limit.

DDD: Dichlorodiphenyldichloroethane

DDE: Dichlorodiphenyldichloroethylene

DDT: Dichlorodiphenyltrichloroethane

GWSA: Gas Works Sediment Area

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

NA: Not applicable

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

Table 3-3 Revised COPC Sediment Screening Criteria Values

Parameter[1]	CAS Number	SMS	Ecological Risk: Ecology 2003 Freshwater SQVs[2] LAET (SQS)	Ecological Risk: Ecology 2003 Freshwater SQVs[2] 2LAET (CSL)	Ecological Risk: RSET September 2006 Interim Freshwater Sediment Quality Guidelines[3] (mg/kg) SL1	Ecological Risk: RSET September 2006 Interim Freshwater Sediment Quality Guidelines[3] (mg/kg) SL2	Ecological Risk: USEPA Region 3 BTAG 2006 Freshwater Sediment Screening Benchmarks[4] (mg/kg)	Human Health Risk: Direct Contact: MTCA Method A Soil, Unrestricted Land Use[5] (mg/kg) Total	Human Health Risk: Direct Contact: MTCA Method B Soil Direct Contact (Ingestion Only), Unrestricted Land Use[6] (mg/kg) Carcinogen	Human Health Risk: Direct Contact: MTCA Method B Soil Direct Contact (Ingestion Only), Unrestricted Land Use[6] (mg/kg) Non-Carcinogen	Human Health Risk: Direct Contact: USEPA Regional Screening Levels, Total Risk, Residential Soil[7] – Dec 2009 (mg/kg) Carcinogen (TR = 1E-6)	Human Health Risk: Direct Contact: USEPA Regional Screening Levels, Total Risk, Residential Soil[7] – Dec 2009 (mg/kg) Non-Carcinogen (HI = 1)	Human Health Risk: Direct Contact: USEPA Regional Screening Levels, Total Risk, Residential Soil[7] – Dec 2009 (mg/kg) Non-Carcinogen (HI = 0.1)+	Bioaccumulative Risk: Oregon DEQ 2007 Sediment Bioaccumulation Screening Level Values[8] (mg/kg dw) Fish (Freshwater)	Bioaccumulative Risk: Oregon DEQ 2007 Sediment Bioaccumulation Screening Level Values[8] (mg/kg dw) Humans (Subsistence)	Bioaccumulative Risk: Oregon DEQ 2007 Sediment Bioaccumulation Screening Level Values[8] (mg/kg dw) Inorganic Background ^
Conventionals/Misc.			***mg/kg dw***													
Total Cyanide	CN		—	—	—	—	—	—	—	1600	—	1560	156	—	—	—
Metals			***mg/kg dw***													
Aluminum	7429-90-5		—	—	—	—	—	—	—	—	—	77400	7740	—	—	—
Antimony	7440-36-0		0.6	1.9	—	—	2	—	—	32	—	31.3	3.13	—	—	—
Arsenic	7440-38-2	X	31.4	50.9	20	51	9.8	20	0.667	24	0.389	21.6	2.16	—	—	7.3
Barium	7440-39-3		—	—	—	—	—	—	—	16000	—	15300	1530	—	—	—
Beryllium	7440-41-7		0.46	—	—	—	—	—	—	160	1380	156	15.6	—	—	—
Cadmium	7440-43-9	X	2.39	2.9	1.1	1.5	0.99	2	—	80	1840	70	7	—	—	0.77
Calcium	7440-70-2		—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chromium	7440-47-3	X	95	133	95	100	43.4	—	—	—	—	—	—	—	—	—
Cobalt	7440-48-4		—	—	—	—	50	—	—	—	368	23.4	2.34	—	—	—
Copper	7440-50-8	X	619	829	80	830	31.6	—	—	2960	—	3130	313	—	—	—
Iron	7439-89-6		—	—	—	—	20000	—	—	—	—	54800	5480	—	—	—
Lead	7439-92-1	X	335	431	340	430	35.8	250	—	—	—	400	40	—	—	16.83
Magnesium	7439-95-4		—	—	—	—	—	—	—	—	—	—	—	—	—	—
Manganese	7439-96-5		—	—	—	—	460	—	—	11200	—	—	—	—	—	—
Mercury	7439-97-6	X	0.8	3.04	0.28	0.75	0.18	2	—	24	—	5.6	0.56	—	—	0.07
Methylmercury	22967-92-6		—	—	—	—	—	—	—	8	—	7.82	0.782	—	—	—
Nickel	7440-02-0		53.1	113	60	70	22.7	—	—	1600	12700	1550	155	—	—	—
Potassium	9/7/7440		—	—	—	—	—	—	—	—	—	—	—	—	—	—
Selenium	7782-49-2		—	—	—	—	2	—	—	400	—	391	39.1	—	—	—
Silver	7440-22-4	X	0.545	3.5	2	2.5	1	—	—	400	—	391	39.1	—	—	—
Sodium	7440-23-5		—	—	—	—	—	—	—	—	—	—	—	—	—	—
Thallium	7440-28-0		—	—	—	—	—	—	—	5.6	—	—	—	—	—	—
Tin	7440-31-5		—	—	—	—	—	—	—	48000	—	46900	4690	—	—	—
Vanadium	7440-62-2		—	—	—	—	—	—	—	560	—	394	39.4	—	—	—
Zinc	7440-66-6	X	683	1080	130	400	121	—	—	24000	—	23500	2350	—	—	—
Butyltins			***mg/kg ion***													
Tributyltin	688-73-3		0.26	6.65	0.075	0.075	—	—	—	—	—	18.3	1.83	0.0023	0.01	—
LPAH			***mg/kg dw***													
Naphthalene	91-20-3	X	0.529	1.31	0.5	1.3	0.176	5	—	1600	3.57	137	13.7	—	—	—
Acenaphthylene	208-96-8	X	0.470	0.640	0.47	0.64	0.0059	—	—	—	—	—	—	—	—	—
Acenaphthene	83-32-9	X	1.06	1.32	1.1	1.3	0.0067	—	—	4800	—	3440	344	—	—	—
Fluorene	86-73-7	X	1.07	3.85	1	3	0.0774	—	—	3200	—	2290	229	—	—	—
Phenanthrene	85-01-8	X	6.10	7.57	6.1	7.6	0.204	—	—	—	—	—	—	—	—	—
Anthracene	120-12-7	X	1.23	1.58	1.2	1.6	0.0572	—	—	24000	—	17200	1720	—	—	—
2-methlynaphthalene	91-57-6	X	0.469	0.555	0.47	0.56	0.0202	—	—	320	—	313	31.3	—	—	—
Total LPAH		X	6.59	9.20	6.6	9.2	0.076	—	—	—	—	—	—	—	—	—
HPAH			***mg/kg dw***													
Fluoranthene	206-44-0	X	11.1	15.0	11	15	0.423	—	—	3200	—	2290	229	37	62	—
Pyrene	129-00-0	X	8.79	16.0	8.8	16	0.195	—	—	2400	—	1720	172	1.9	47	—
Benzo(a)anthracene	56-55-3	X	4.26	5.80	4.3	5.8	0.108	—	0.014 *	—	0.148	—	—	—	—	—
Chrysene	218-01-9	X	5.94	6.40	5.9	6.4	0.166	—	0.0014 *	—	14.8	—	—	—	—	—
Benzo(b)fluoranthene	205-99-2		—	—	—	—	—	—	0.014 *	—	0.148	—	—	—	—	—
Benzo(k)fluoranthene	207-08-9		—	—	—	—	0.24	—	0.014 *	—	1.48	—	—	—	—	—
Benzo(b,k)fluoranthenes (Total)		X	11.0	13.8	0.6	4	0.0272	—	—	—	—	—	—	—	—	—
Benzo(a)pyrene	50-32-8	X	3.30	4.81	3.3	4.8	0.15	0.10	0.14	—	0.0148	—	—	—	—	—
Indeno(1,2,3-cd)pyrene	193-39-5	X	4.12	5.30	4.1	5.3	0.017	—	0.014 *	—	0.148	—	—	—	—	—
Dibenzo(a,h)anthracene	53-70-3	X	0.800	0.839	0.8	0.84	0.033	—	0.014 *	—	0.0148	—	—	—	—	—
Benzo(g,h,i)perylene	191-24-2	X	4.02	5.20	4	5.2	0.17	—	—	—	—	—	—	—	—	—
Total HPAH		X	31.64	54.8	31	55	0.19	—	—	—	—	—	—	—	—	—
Total PAH			—	—	—	—	1.61	—	—	—	—	—	—	—	—	—
Phthalates			***mg/kg dw***													
Dimethylphthalate	131-11-3	X	0.311	0.436	0.046	0.44	—	—	—	80000	—	—	—	—	—	—
Diethylphthalate	84-66-2	X	—	—	—	—	0.603	—	—	64000	—	48900	4890	—	—	—
Di-n-butylphthalate	84-74-2	X	0.103	—	—	—	6.47	—	—	8000	—	6110	611	—	—	—
Butylbenzylphthalate	85-68-7	X	0.260	0.366	0.26	0.37	10.9	—	—	16000	256	12200	1220	—	—	—
Bis(2-Ethylhexyl)phthalate	117-81-7	X	2.52	6.38	0.22	0.32	0.18	—	71.4	1600	34.7	1220	122	—	—	—
Di-n-octyl Phthalate	117-84-0	X	0.011	0.201	0.026	0.045	—	—	—	1600	—	—	—	—	—	—

Table 3-3 Revised COPC Sediment Screening Criteria Values

Parameter[1]	CAS Number	SMS	Ecological Risk: Ecology 2003 Freshwater SQVs[2] LAET (SQS)	Ecological Risk: Ecology 2003 Freshwater SQVs[2] 2LAET (CSL)	Ecological Risk: RSET September 2006 Interim Freshwater Sediment Quality Guidelines[3] (mg/kg) SL1	Ecological Risk: RSET September 2006 Interim Freshwater Sediment Quality Guidelines[3] (mg/kg) SL2	Ecological Risk: USEPA Region 3 BTAG 2006 Freshwater Sediment Screening Benchmarks[4] (mg/kg)	Human Health Risk: Direct Contact: MTCA Method A Soil, Unrestricted Land Use[5] (mg/kg) Total	Human Health Risk: Direct Contact: MTCA Method B Soil Direct Contact (Ingestion Only), Unrestricted Land Use[6] (mg/kg) Carcinogen	Human Health Risk: Direct Contact: MTCA Method B Soil Direct Contact (Ingestion Only), Unrestricted Land Use[6] (mg/kg) Non-Carcinogen	Human Health Risk: Direct Contact: USEPA Regional Screening Levels, Total Risk, Residential Soil[7] – Dec 2009 (mg/kg) Carcinogen (TR = 1E-6)	Human Health Risk: Direct Contact: USEPA Regional Screening Levels, Total Risk, Residential Soil[7] – Dec 2009 (mg/kg) Non-Carcinogen (HI = 1)	Human Health Risk: Direct Contact: USEPA Regional Screening Levels, Total Risk, Residential Soil[7] – Dec 2009 (mg/kg) Non-Carcinogen (HI = 0.1)+	Bioaccumulative Risk: Oregon DEQ 2007 Sediment Bioaccumulation Screening Level Values[8] (mg/kg dw) Fish (Freshwater)	Bioaccumulative Risk: Oregon DEQ 2007 Sediment Bioaccumulation Screening Level Values[8] (mg/kg dw) Humans (Subsistence)	Bioaccumulative Risk: Oregon DEQ 2007 Sediment Bioaccumulation Screening Level Values[8] (mg/kg dw) Inorganic Background ^
Phenols			***mg/kg dw***													
Phenol	108-95-2	X	—	—	—	—	0.42	—	—	48000	—	18300	1830	—	—	—
2-Chlorophenol	95-57-8		—	—	—	—	0.0312	—	—	400	—	391	39.1	—	—	—
2,4-Dichlorophenol	120-83-2		—	—	—	—	0.117	—	—	240	—	183	18.3	—	—	—
2,4,5-Trichlorophenol	95-95-4		—	—	—	—	—	—	—	8000	—	6110	611	—	—	—
2,4,6-Trichlorophenol	88-06-2		—	—	—	—	0.213	—	90.9	—	44.1	61.1	6.11	—	—	—
4-Chloro-3-methylphenol	59-50-7		—	—	—	—	—	—	—	—	—	6110	611	—	—	—
2-Methylphenol	95-48-7	X	—	—	—	—	—	—	—	4000	—	3060	306	—	—	—
4-Methylphenol	106-44-5	X	0.760	2.36	—	—	0.67	—	—	400	—	306	30.6	—	—	—
2,4-Dimethylphenol	105-67-9	X	—	—	—	—	0.029	—	—	1600	—	1220	122	—	—	—
2-Nitrophenol	88-75-5		—	—	—	—	—	—	—	—	—	—	—	—	—	—
4-Nitrophenol	100-02-7		—	—	—	—	—	—	—	—	—	—	—	—	—	—
2,4-Dinitrophenol	51-28-5		—	—	—	—	—	—	—	160	—	122	12.2	—	—	—
4,6-Dinitro-2-Methylphenol	534-52-1		—	—	—	—	—	—	—	—	—	6.11	0.611	—	—	—
Pentachlorophenol	87-86-5	X	—	—	—	—	0.504	—	8.33	2400	2.97	1380	138	0.31	0.03	—
Misc. Extractables			***mg/kg dw***													
Benzidine	92-87-5		—	—	—	—	—	—	0.0043	240	0.000501	183	18.3	—	—	—
Benzoic Acid	65-85-0	X	2.91	3.79	—	—	0.65	—	—	320000	—	244000	24400	—	—	—
Benzyl Alcohol	100-51-6	X	—	—	—	—	—	—	—	24000	—	6110	611	—	—	—
Caffeine	58-08-2		—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carbazole	86-74-8		0.923	—	—	—	—	—	50	—	—	—	—	—	—	—
B-Coprostanol	360-68-9		—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dibenzofuran	132-64-9	X	0.399	0.443	0.4	0.44	0.415	—	—	160	—	78.2	7.82	—	—	—
Hexachlorobenzene	118-74-1	X	—	—	—	—	0.02	—	0.625	64	0.303	48.9	4.89	61	0.0023	—
Hexachlorobutadiene	87-68-3	X	—	—	—	—	—	—	12.8	16	6.22	61.1	6.11	—	—	—
Hexachlorocyclopentadiene	77-47-4		—	—	—	—	—	—	—	480	—	366	36.6	—	—	—
Hexachloroethane	67-72-1		—	—	—	—	1.027	—	71.4	80	34.7	61.1	6.11	—	—	—
Isophorone	78-59-1		—	—	—	—	—	—	1052.6	16000	511	12200	1220	—	—	—
Nitrobenzene	98-95-3		—	—	—	—	—	—	—	40	4.79	129	12.9	—	—	—
N-Nitrosodimethylamine	62-75-9		—	—	—	—	—	—	0.0196	—	0.00226	0.489	0.0489	—	—	—
N-Nitrosodiphenylamine	86-30-6	X	—	—	—	—	2.68	—	204	—	99.1	—	—	—	—	—
N-Nitroso-Di-N-Propylamine	621-64-7		—	—	—	—	—	—	0.143	—	0.0694	—	—	—	—	—
Retene	483-65-8		6.02	—	—	—	—	—	—	—	—	—	—	—	—	—
4-Chloroaniline	106-47-8		—	—	—	—	—	—	—	320	2.43	244	24.4	—	—	—
2-Nitroaniline	88-74-4		—	—	—	—	—	—	—	—	—	606	60.6	—	—	—
3-Nitroaniline	99-09-2		—	—	—	—	—	—	—	—	—	—	—	—	—	—
P-Nitroaniline	100-01-6		—	—	—	—	—	—	—	—	24.3	244	24.4	—	—	—
1,2-Dichlorobenzene	95-50-1	X	—	—	—	—	0.0165	—	—	7200	—	1910	191	—	—	—
1,3-Dichlorobenzene	541-73-1		—	—	—	—	4.43	—	—	—	—	—	—	—	—	—
1,4-Dichlorobenzene	106-46-7	X	—	—	—	—	0.599	—	41.7	—	2.44	3460	346	—	—	—
1,2,3-Trichlorobenzene	87-61-6		—	—	—	—	0.858	—	—	—	—	48.9	4.89	—	—	—
1,2,4-Trichlorobenzene	120-82-1	X	—	—	—	—	2.1	—	—	800	22	61.9	6.19	—	—	—
3,3'-Dichlorobenzidine	91-94-1		—	—	—	—	0.127	—	2.22	—	1.08	—	—	—	—	—
Bis-(2-Chloroethyl) Ether	111-44-4		—	—	—	—	—	—	0.909	—	0.214	—	—	—	—	—
Bis(2-chloroisopropyl)ether	39638-32-9		—	—	—	—	—	—	—	3200	—	—	—	—	—	—
bis(2-Chloroethoxy) Methane	111-91-1		—	—	—	—	—	—	—	—	—	183	18.3	—	—	—
2-Chloronaphthalene	91-58-7		—	—	—	—	—	—	—	6400	—	6260	626	—	—	—
4-Bromophenyl-phenylether	101-55-3		—	—	—	—	1.23	—	—	—	—	—	—	—	—	—
4-Chlorophenyl-phenylether	7005-72-3		—	—	—	—	—	—	—	—	—	—	—	—	—	—
2,2'-Oxybis(1-Chloropropane)	108-60-1		—	—	—	—	—	—	14.3	—	4.57	3130	313	—	—	—
2,4-Dinitrotoluene	121-14-2		—	—	—	—	0.0416	—	—	160	1.56	122	12.2	—	—	—
2,6-Dinitrotoluene	606-20-2		—	—	—	—	—	—	—	80	—	61.2	6.12	—	—	—

Table 3-3 Revised COPC Sediment Screening Criteria Values

Parameter[1]	CAS Number	SMS	Ecological Risk: Ecology 2003 Freshwater SQVs[2] LAET (SQS)	Ecological Risk: Ecology 2003 Freshwater SQVs[2] 2LAET (CSL)	Ecological Risk: RSET September 2006 Interim Freshwater Sediment Quality Guidelines[3] (mg/kg) SL1	Ecological Risk: RSET September 2006 Interim Freshwater Sediment Quality Guidelines[3] (mg/kg) SL2	Ecological Risk: USEPA Region 3 BTAG 2006 Freshwater Sediment Screening Benchmarks[4] (mg/kg)	Human Health Risk: Direct Contact: MTCA Method A Soil, Unrestricted Land Use[5] (mg/kg) Total	Human Health Risk: Direct Contact: MTCA Method B Soil Direct Contact (Ingestion Only), Unrestricted Land Use[6] (mg/kg) Carcinogen	Human Health Risk: Direct Contact: MTCA Method B Soil Direct Contact (Ingestion Only), Unrestricted Land Use[6] (mg/kg) Non-Carcinogen	Human Health Risk: Direct Contact: USEPA Regional Screening Levels, Total Risk, Residential Soil[7] – Dec 2009 (mg/kg) Carcinogen (TR = 1E-6)	Human Health Risk: Direct Contact: USEPA Regional Screening Levels, Total Risk, Residential Soil[7] – Dec 2009 (mg/kg) Non-Carcinogen (HI = 1)	Human Health Risk: Direct Contact: USEPA Regional Screening Levels, Total Risk, Residential Soil[7] – Dec 2009 (mg/kg) Non-Carcinogen (HI = 0.1)+	Bioaccumulative Risk: Oregon DEQ 2007 Sediment Bioaccumulation Screening Level Values[8] (mg/kg dw) Fish (Freshwater)	Bioaccumulative Risk: Oregon DEQ 2007 Sediment Bioaccumulation Screening Level Values[8] (mg/kg dw) Humans (Subsistence)	Bioaccumulative Risk: Oregon DEQ 2007 Sediment Bioaccumulation Screening Level Values[8] (mg/kg dw) Inorganic Background ^
Volatile Organic Compounds			***mg/kg dw***													
Acetone	67-64-1		—	—	—	—	—	—	—	8000	—	61300	6130	—	—	—
Acrolein	107-02-8		—	—	—	—	—	—	—	1600	—	0.155	0.0155	—	—	—
Acrylonitrile	107-13-1		—	—	—	—	—	—	1.9	80	0.237	17.2	1.72	—	—	—
Aniline	62-53-3		—	—	—	—	—	—	175.4	—	85.2	428	42.8	—	—	—
Benzene	71-43-2		—	—	—	—	—	0.03	18.2	320	1.08	86.2	8.62	—	—	—
n-Butylbenzene	104-51-8		—	—	—	—	—	—	—	—	—	—	—	—	—	—
sec-Butylbenzene	135-98-8		—	—	—	—	—	—	—	—	—	—	—	—	—	—
tert-Butylbenzene	98-06-6		—	—	—	—	—	—	—	—	—	—	—	—	—	—
1,2,4-Trimethylbenzene	95-63-6		—	—	—	—	—	—	—	4000	—	62.2	6.22	—	—	—
1,3,5-Trimethylbenzene	108-67-8		—	—	—	—	—	—	—	4000	—	782	78.2	—	—	—
n-Propylbenzene	103-65-1		—	—	—	—	—	—	—	—	—	3440	344	—	—	—
Bromobenzene	108-86-1		—	—	—	—	—	—	—	—	—	297	29.7	—	—	—
Chlorobenzene	108-90-7		—	—	—	—	0.00842	—	—	1600	—	294	29.4	—	—	—
Ethylbenzene	100-41-4		—	—	—	—	1.1	6	—	8000	5.39	3510	351	—	—	—
Isopropylbenzene	98-82-8		—	—	—	—	0.086	—	—	8000	—	2050	205	—	—	—
Bromoform	75-25-2		—	—	—	—	0.654	—	126.6	1600	61.5	1220	122	—	—	—
trans-1,4-Dichloro-2-butene	110-57-6		—	—	—	—	—	—	—	—	0.00694	—	—	—	—	—
Carbon Disulfide	75-15-0		—	—	—	—	0.000851	—	—	8000	—	821	82.1	—	—	—
Carbon Tetrachloride	56-23-5		—	—	—	—	0.0642	—	7.7	56	0.248	46.7	4.67	—	—	—
Chloroform	67-66-3		—	—	—	—	—	—	163.9	800	0.295	211	21.1	—	—	—
Bromoethane	74-96-4		—	—	—	—	—	—	—	—	—	—	—	—	—	—
1,2-Dibromoethane	106-93-4		—	—	—	—	—	0.005	0.0118	—	0.0337	77.7	7.77	—	—	—
Chloroethane	75-00-3		—	—	—	—	—	—	345	32000	—	14500	1450	—	—	—
1,1-Dichloroethane	75-34-3		—	—	—	—	—	—	—	16000	3.31	15600	1560	—	—	—
1,2-Dichloroethane	107-06-2		—	—	—	—	—	—	11.0	1600	0.432	1390	139	—	—	—
1,1,1-Trichloroethane	71-55-6		—	—	—	—	0.0302	2.0	—	72000	—	8740	874	—	—	—
1,1,2-Trichloroethane	79-00-5		—	—	—	—	1.24	—	17.5	320	1.07	313	31.3	—	—	—
1,1,1,2-Tetrachloroethane	630-20-6		—	—	—	—	—	—	38.5	2400	1.86	2350	235	—	—	—
1,1,2,2-Tetrachloroethane	79-34-5		—	—	—	—	1.36	—	5.0	—	0.562	313	31.3	—	—	—
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1		—	—	—	—	—	—	—	2400000	—	42500	4250	—	—	—
1,1-Dichloroethene	75-35-4		—	—	—	—	0.031	—	—	4000	—	243	24.3	—	—	—
cis-1,2-Dichloroethene	156-59-2		—	—	—	—	—	—	—	800	—	782	78.2	—	—	—
trans-1,2-Dichloroethene	156-60-5		—	—	—	—	1.05	—	—	1600	—	153	15.3	—	—	—
Trichloroethene	79-01-6		—	—	—	—	0.0969	0.03	11	24	2.82	—	—	—	—	—
Tetrachloroethene	127-18-4		—	—	—	—	0.468	0.05	1.85	800	0.554	374	37.4	—	—	—
1,2-Diphenylhydrazine	122-66-7		—	—	—	—	—	—	1.25	—	0.607	—	—	—	—	—
Bromomethane	74-83-9		—	—	—	—	—	—	—	112	—	7.32	0.732	—	—	—
Dibromomethane	74-95-3		—	—	—	—	—	—	—	800	—	24.6	2.46	—	—	—
Chloromethane	74-87-3		—	—	—	—	—	—	76.9	—	—	119	11.9	—	—	—
Bromochloromethane	74-97-5		—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bromodichloromethane	75-27-4		—	—	—	—	—	—	16.1	1600	0.273	1560	156	—	—	—
Dibromochloromethane	124-48-1		—	—	—	—	—	—	11.9	1600	0.68	1220	122	—	—	—
Trichlorofluoromethane	75-69-4		—	—	—	—	—	—	—	24000	—	787	78.7	—	—	—
Methyl Iodide	74-88-4		—	—	—	—	—	—	—	—	—	—	—	—	—	—
Methylene Chloride	75-09-2		—	—	—	—	—	0.02	133	4800	10.7	1660	166	—	—	—
2-Butanone	78-93-3		—	—	—	—	—	—	—	48000	—	27800	2780	—	—	—
2-Hexanone	591-78-6		—	—	—	—	—	—	—	—	—	209	20.9	—	—	—
4-Methyl-2-Pentanone (MIBK)	108-10-1		—	—	—	—	—	—	—	6400	—	5320	532	—	—	—
1,2-Dichloropropane	78-87-5		—	—	—	—	—	—	14.7	—	0.895	16.1	1.61	—	—	—
1,3-Dichloropropane	142-28-9		—	—	—	—	—	—	—	—	—	1560	156	—	—	—
2,2-Dichloropropane	594-20-7		—	—	—	—	—	—	—	—	—	—	—	—	—	—
1,2,3-Trichloropropane	96-18-4		—	—	—	—	—	—	0.143	480	0.00497	5.2	0.52	—	—	—
1,2-Dibromo-3-chloropropane	96-12-8		—	—	—	—	—	—	0.714	—	0.00535	4.92	0.492	—	—	—
1,1-Dichloropropene	563-58-6		—	—	—	—	—	—	—	—	—	—	—	—	—	—
cis-1,3-Dichloropropene	10061-01-5		—	—	—	—	—	—	—	—	—	—	—	—	—	—
trans-1,3-Dichloropropene	10061-02-6		—	—	—	—	—	—	—	—	—	—	—	—	—	—
Styrene	100-42-5		—	—	—	—	0.559	—	33.3	16000	—	6280	628	—	—	—
Toluene	108-88-3		—	—	—	—	—	7	—	6400	—	4970	497	—	—	—
2-Chlorotoluene	95-49-8		—	—	—	—	—	—	—	1600	—	1560	156	—	—	—
4-Chlorotoluene	106-43-4		—	—	—	—	—	—	—	—	—	5480	548	—	—	—
4-Isopropyltoluene	99-87-6		—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total Xylenes	CALC-TX		—	—	—	—	—	9	—	16000	—	627	62.7	—	—	—
Vinyl Acetate	108-05-4		—	—	—	—	—	—	—	80000	—	975	97.5	—	—	—
Vinyl Chloride	75-01-4		—	—	—	—	—	—	0.667	240	0.0597	73.6	7.36	—	—	—
2-Chloroethylvinylether	110-75-8		—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table 3-3 Revised COPC Sediment Screening Criteria Values

Parameter[1]	CAS Number	SMS	Ecological Risk: Ecology 2003 Freshwater SQVs[2] LAET (SQS)	Ecology 2003 Freshwater SQVs[2] 2LAET (CSL)	RSET September 2006 Interim Freshwater Sediment Quality Guidelines[3] (mg/kg) SL1	RSET September 2006 Interim Freshwater Sediment Quality Guidelines[3] (mg/kg) SL2	USEPA Region 3 BTAG 2006 Freshwater Sediment Screening Benchmarks[4] (mg/kg)	Human Health Risk: Direct Contact: MTCA Method A Soil, Unrestricted Land Use[5] (mg/kg) Total	MTCA Method B Soil Direct Contact (Ingestion Only), Unrestricted Land Use[6] (mg/kg) Carcinogen	MTCA Method B Soil Direct Contact (Ingestion Only), Unrestricted Land Use[6] (mg/kg) Non-Carcinogen	USEPA Regional Screening Levels, Total Risk, Residential Soil[7] – Dec 2009 (mg/kg) Carcinogen (TR = 1E-6)	USEPA Regional Screening Levels, Total Risk, Residential Soil[7] – Dec 2009 (mg/kg) Non-Carcinogen (HI = 1)	USEPA Regional Screening Levels, Total Risk, Residential Soil[7] – Dec 2009 (mg/kg) Non-Carcinogen (HI = 0.1)[+]	Bioaccumulative Risk: Oregon DEQ 2007 Sediment Bioaccumulation Screening Level Values[8] (mg/kg dw) Fish (Freshwater)	Oregon DEQ 2007 Sediment Bioaccumulation Screening Level Values[8] (mg/kg dw) Humans (Subsistence)	Oregon DEQ 2007 Sediment Bioaccumulation Screening Level Values[8] (mg/kg dw) Inorganic Background ^
Pesticides/PCBs			***mg/kg dw***													
2,4,5-T	93-76-5		—	—	—	—	12.3	—	—	800	—	611	61.1	—	—	—
2,4,5-TP (Silvex)	93-72-1		—	—	—	—	0.675	—	—	640	—	489	48.9	—	—	—
2,4-D	94-75-7		—	—	—	—	—	—	—	800	—	686	68.6	—	—	—
2,4-DB	94-82-6		—	—	—	—	—	—	—	640	—	489	48.9	—	—	—
Aldrin	309-00-2		—	—	—	—	0.002	—	0.06	2.4	0.0286	1.83	0.183	—	—	—
alpha-BHC	319-84-6		—	—	—	—	0.006	—	0.16	—	0.0771	489	48.9	—	—	—
beta-BHC	319-85-7		—	—	—	—	0.005	—	0.56	—	0.27	—	—	—	—	—
delta-BHC	319-86-8		—	—	—	—	6.4	—	—	—	—	—	—	—	—	—
gamma-BHC (Lindane)	58-89-9		—	—	—	—	0.00237	0.01	0.77	24	0.516	21.1	2.11	—	—	—
beta-Chlordane	5103-74-2		—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chlordane	12789-03-6		—	—	—	—	0.00324	—	2.86	40	1.62	35.2	3.52	0.0005	0.000046	—
DDD	72-54-8		0.096	—	—	—	0.00488	—	4.17	—	2.02	—	—	—	—	—
DDE	72-55-9		0.021	—	—	—	0.00316	—	2.94	—	1.43	—	—	—	—	—
DDT	50-29-3		0.019	—	—	—	0.00416	3	2.94	40	1.72	36.1	3.61	0.00039	0.00004	—
Dicamba	1918-00-9		—	—	—	—	—	—	—	2400	—	1830	183	—	—	—
Dieldrin	60-57-1		—	—	—	—	0.0019	—	0.0625	4	0.0303	3.06	0.306	0.0022	0.000001	—
Dinoseb	88-85-7		—	—	—	—	0.000611	—	—	80	—	61.1	6.11	—	—	—
Endosulfan	115-29-7		—	—	—	—	0.00214	—	—	480	—	367	36.7	—	—	—
Endosulfan Sulfate	1031-07-8		—	—	—	—	0.0054	—	—	—	—	—	—	—	—	—
Endrin	72-20-8		—	—	—	—	0.00222	—	—	24	—	18.3	1.83	—	—	—
Endrin Aldehyde	7421-93-4		—	—	—	—	—	—	—	—	—	—	—	—	—	—
Heptachlor	76-44-8		—	—	—	—	0.068	—	0.22	40	0.108	30.6	3.06	—	—	—
Heptachlor Epoxide	1024-57-3		—	—	—	—	0.00247	—	0.11	1.04	0.0533	0.794	0.0794	—	—	—
MCPA	94-74-6		—	—	—	—	—	—	—	40	—	30.6	3.06	—	—	—
MCPP	93-65-2		—	—	—	—	—	—	—	80	—	61.1	6.11	—	—	—
Methoxychlor	72-43-5		—	—	—	—	0.0187	—	—	400	—	306	30.6	—	—	—
Toxaphene	8001-35-2		—	—	—	—	0.0001	—	0.91	—	0.441	—	—	—	—	—
Aroclor 1016	12674-11-2		—	—	—	—	—	—	—	5.6	6.33	3.93	0.393	—	—	—
Aroclor 1221	11104-28-2		—	—	—	—	—	—	—	—	0.141	—	—	—	—	—
Aroclor 1232	11141-16-5		—	—	—	—	—	—	—	—	0.141	—	—	—	—	—
Aroclor 1242	53469-21-9		—	—	—	—	—	—	—	—	0.221	—	—	—	—	—
Aroclor 1248	12672-29-6		—	—	—	—	—	—	—	—	0.221	—	—	—	—	—
Aroclor 1254	11097-69-1		0.230	0.294	—	—	—	—	—	1.6	0.221	1.12	0.112	—	—	—
Aroclor 1260	11096-82-5		0.138	0.140	—	—	—	—	—	—	0.221	—	—	—	—	—
Total PCBs		X	0.062	0.354	0.06	0.12	0.0598	1	0.50	—	0.221	—	—	0.022	0.000048	—

Notes:

— Indicates no criterion

[1] Parameter list generated from GWSA database; all available parameters are included.

[2] Ecology Freshwater Sediment LAET (lowest Apparent Effects Threshold) and 2LAET (second lowest Apparent Effects Threshold) from *H. azteca* (10-day mortality), *C. dilutus* (10-day mortality and growth), and Microtox (Ecology September 2003 Phase II Report).

[3] Northwest Regional Sediment Evaluation Framework Interim Freshwater Sediment Quality Guidelines (RSET September 2006).

[4] USEPA Region 3 Biological Technical Assistance Group (BTAG) Freshwater Sediment Screening Benchmarks, as queried (3/18/10) from http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fwsed/screenbench.htm.

[5] MTCA Method A values, as queried from the CLARC database (1/21/10): https://fortress.wa.gov/ecy/clarc/CLARCHome.aspx.

[6] MTCA Method B values, as queried from the CLARC database (7/13/09): https://fortress.wa.gov/ecy/clarc/CLARCHome.aspx.

* CLARC no longer contains Method B soil cleanup levels for these individual chemicals and requires the application of the TEF methodology. For these purposes, the cPAHs were weighted relative to the BaP Method B criterion based on the TEFs in MTCA.

[7] December 2009 USEPA RSL values, as queried from http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm.

[+] Per 1993 USEPA Regional Guidance (EPA/903/R-93-001), the non-carcinogen Hazard Index (HI) should be adjusted to 0.1 to account for possible additive effects. The adjusted RSLs are therefore shown for comparison.

[8] Oregon DEQ SLVs from *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment* (Pub. No. 07-LQ-023A; Oregon DEQ April 2007).

BTAG: Biological Technical Assistance Group
CSL: Cleanup screening level
COPC: Chemical of potential concern
DDD: Dichlorodiphenyldichloroethane
DDE: Dichlorodiphenyldichloroethylene
DDT: Dichlorodiphenyltrichloroethane
Ecology: Washington State Department of Ecology
GWSA: Gas Works Sediment Area
HI: Hazard Index
HPAH: High-molecular weight polycyclic aromatic hydrocarbon
LAET: Lowest Apparent Effects Theshold
2LAET: Second lowest Apparent Effects Theshold
LPAH: Low-molecular weight polycyclic aromatic hydrocarbon
MTCA: Washington State Model Toxics Control Act
Oregon DEQ: Oregon Department of Environmental Quality
PAH: Polycyclic aromatic hydrocarbon
PCB: Polychlorinated biphenyl
RSET: Regional Sediment Evaluation Team
RSL: Regional screening level
SLV: Screening level value
SMS: Sediment Management Standards
SQS: Sediment Quality Standards
TEF: Toxicity Equivalence Factor
TR: Threshold risk level
USEPA: U.S. Environmental Protection Agency

Table 3-4 Revised COPC Sediment Screening Exceedances of Selected Criteria

Parameter[1]	CAS Number	No. of Samples	SMS	Ecological Risk: Ecology 2003 Freshwater SQVs[2] LAET (SQS) No. of Exceed (Detects)	LAET (SQS) No. of Exceed (Non-Detects)	LAET (SQS) % Exceed/ All #	2LAET (CSL) No. of Exceed (Detects)	2LAET (CSL) No. of Exceed (Non-Detects)	2LAET (CSL) % Exceed/ All #	RSET September 2006 Interim Freshwater Sediment Quality Guidelines[3] SL1 No. of Exceed (Detects)	SL1 No. of Exceed (Non-Detects)	SL1 % Exceed/ All #	SL2 No. of Exceed (Detects)	SL2 No. of Exceed (Non-Detects)	SL2 % Exceed/ All #	USEPA Region 3 BTAG 2006 Freshwater Sediment Screening Guidelines[4] No. of Exceed (Detects)	USEPA Region 3 BTAG 2006 Freshwater Sediment Screening Guidelines[4] No. of Exceed (Non-Detects)	USEPA Region 3 BTAG 2006 Freshwater Sediment Screening Guidelines[4] % Exceed/ All #	Human Health Risk: Direct Contact: MTCA Method A Soil, Unrestricted Land Use[5] Total No. of Exceed (Detects)	Total No. of Exceed (Non-Detects)	Total % Exceed/ All #	MTCA Method B Soil Direct Contact (Ingestion Only), Unrestricted Land Use[6] Carcinogen No. of Exceed (Detects)	Carcinogen No. of Exceed (Non-Detects)	Carcinogen % Exceed/ All #	Non-Carcinogen No. of Exceed (Detects)	Non-Carcinogen No. of Exceed (Non-Detects)	Non-Carcinogen % Exceed/ All #
Conventionals/Misc.																													
Total Cyanide	CN	168		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0.0
Metals																													
Aluminum	7429-90-5	24		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Antimony	7440-36-0	130		20	86	81.5	15	79	72.3	—	—	—	—	—	—	15	56	54.6	—	—	—	—	—	—	—	—	0	0	0.0
Arsenic	7440-38-2	351	X	85	0	24.1	44	0	12.5	104	19	35.0	44	0	12.5	149	127	78.6	105	19	35.3	177	176	100.0	103	19	34.6
Barium	7440-39-3	29		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0.0
Beryllium	7440-41-7	25		0	0	0.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0.0
Cadmium	7440-43-9	259	X	18	0	6.9	9	0	3.4	83	0	32.0	69	0	26.6	94	42	52.5	35	0	13.5	—	—	—	0	0	0.0
Calcium	7440-70-2	24		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chromium	7440-47-3	177	X	8	0	4.5	5	0	2.8	8	0	4.5	8	0	4.5	96	0	54.2	—	—	—	—	—	—	—	—	—	—	—
Cobalt	7440-48-4	22		—	—	—	—	—	—	—	—	—	—	—	—	6	0	27.3	—	—	—	—	—	—	—	—	—	—	—
Copper	7440-50-8	259	X	5	0	1.9	2	0	0.8	116	0	44.8	2	0	0.8	144	0	55.6	—	—	—	—	—	—	0	0	0.0
Iron	7439-89-6	38		—	—	—	—	—	—	—	—	—	—	—	—	31	0	81.6	—	—	—	—	—	—	—	—	—	—	—
Lead	7439-92-1	259	X	35	0	13.4	22	0	8.4	34	0	13.1	22	0	8.5	136	0	52.5	67	0	25.9	—	—	—	—	—	—	—	—
Magnesium	7439-95-4	24		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Manganese	7439-96-5	24		—	—	—	—	—	—	—	—	—	—	—	—	0	0	0.0	—	—	—	—	—	—	0	0	0.0		
Mercury	7439-97-6	261	X	60	0	23.0	1	0	0.4	120	0	46.0	70	0	26.8	123	23	55.9	7	0	2.7	—	—	—	0	0	0.0		
Methylmercury	22967-92-6	1		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0.0		
Nickel	7440-02-0	190		66	0	34.7	12	0	6.3	48	0	25.3	31	0	16.3	186	0	97.9	—	—	—	—	—	—	0	0	0.0		
Potassium	9/7/7440	24		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
Selenium	7782-49-2	31		—	—	—	—	—	—	—	—	—	—	—	—	1	0	3.2	—	—	—	—	—	—	0	0	0.0		
Silver	7440-22-4	200	X	47	78	61.6	5	0	2.5	15	0	7.5	12	0	6.0	38	18	28.0	—	—	—	—	—	—	0	0	0.0		
Sodium	7440-23-5	23		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
Thallium	7440-28-0	24		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA		
Tin	7440-31-5	1		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0.0		
Vanadium	7440-62-2	22		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0.0		
Zinc	7440-66-6	259	X	14	0	5.3	1	0	0.4	127	0	49.0	60	0	23.2	127	0	49.0	—	—	—	—	—	—	0	0	0.0		
Butyltins																													
Tributyltin	688-73-3	53		18	0	34.0	1	0	1.9	28	0	52.8	28	0	52.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—
LPAH																													
Naphthalene	91-20-3	366	X	210	0	57.4	181	0	49.5	213	0	58.2	182	0	49.7	251	4	69.7	131	0	35.8	—	—	—	10	0	2.7		
Acenaphthylene	208-96-8	366	X	184	4	51.4	172	2	47.5	185	4	51.6	173	2	47.8	264	103	100.3	—	—	—	—	—	—	—	—	—		
Acenaphthene	83-32-9	367	X	177	0	48.2	166	0	45.2	174	0	47.4	167	0	45.5	283	86	100.5	—	—	—	—	—	—	0	0	0.0		
Fluorene	86-73-7	367	X	164	0	44.7	115	0	31.3	165	0	45.0	122	0	33.2	250	22	74.1	—	—	—	—	—	—	0	0	0.0		
Phenanthrene	85-01-8	361	X	152	0	42.1	144	0	39.9	153	0	42.4	143	0	39.6	280	0	77.6	—	—	—	—	—	—	—	—	—		
Anthracene	120-12-7	367	X	179	0	48.8	169	0	46.0	180	0	49.0	167	0	45.5	280	28	83.9	—	—	—	—	—	—	0	0	0.0		
2-methlynaphthalene	91-57-6	367	X	179	0	48.8	172	0	46.9	178	0	48.5	173	0	47.1	251	84	91.3	—	—	—	—	—	—	13	0	3.5		
Total LPAH		367	X	200	0	54.5	182	0	49.6	200	0	54.5	183	0	49.9	310	7	86.4	—	—	—	—	—	—	—	—	—		
HPAH																													
Fluoranthene	206-44-0	361	X	151	0	41.8	135	0	37.4	152	0	42.1	136	0	37.7	267	0	74.0	—	—	—	—	—	—	2	0	0.6		
Pyrene	129-00-0	361	X	164	0	45.4	136	0	37.7	165	0	45.7	137	0	38.0	272	3	76.2	—	—	—	—	—	—	2	0	0.6		
Benzo(a)anthracene	56-55-3	367	X	158	0	43.1	137	0	37.3	157	0	42.8	138	0	37.6	270	11	76.6	—	—	—	283	60	93.5	—	—	—		
Chrysene	218-01-9	366	X	146	0	39.9	138	0	37.7	147	0	40.2	139	0	38.0	268	7	75.1	—	—	—	283	84	100.3	—	—	—		
Benzo(b)fluoranthene	205-99-2	366		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	280	61	93.2	—	—	—		
Benzo(k)fluoranthene	207-08-9	366		—	—	—	—	—	—	—	—	—	—	—	—	260	2	71.6	—	—	—	281	61	93.4	—	—	—		
Benzo(b,k)fluoranthenes (Total)		366	X	142	0	38.8	124	0	33.9	254	1	69.7	184	0	50.3	282	50	90.7	—	—	—	—	—	—	—	—	—		
Benzo(a)pyrene	50-32-8	367	X	179	0	48.8	167	0	45.5	180	0	49.0	168	0	45.8	268	8	75.2	274	11	77.7	268	11	76.0	—	—	—		
Indeno(1,2,3-cd)pyrene	193-39-5	367	X	141	0	38.4	128	0	34.9	142	0	38.7	129	0	35.1	275	63	92.1	—	—	—	275	66	92.9	—	—	—		
Dibenzo(a,h)anthracene	53-70-3	367	X	142	7	40.6	141	7	40.3	143	7	40.9	142	7	40.6	229	77	83.4	—	—	—	235	98	90.7	—	—	—		
Benzo(g,h,i)perylene	191-24-2	367	X	146	0	39.8	129	0	35.1	147	0	40.1	130	0	35.4	257	11	73.0	—	—	—	—	—	—	—	—	—		
Total HPAH		366	X	178	0	48.6	156	0	42.6	181	0	49.5	157	0	42.9	294	0	80.3	—	—	—	—	—	—	—	—	—		
Total PAH		367		—	—	—	—	—	—	—	—	—	—	—	—	289	0	78.7	—	—	—	—	—	—	—	—	—		
Phthalates																													
Dimethylphthalate	131-11-3	265	X	6	48	20.4	0	40	15.1	29	168	74.3	0	39	14.7	—	—	—	—	—	—	—	—	—	0	0	0.0		
Diethylphthalate	84-66-2	244	X	—	—	—	—	—	—	—	—	—	—	—	—	1	24	10.2	—	—	—	—	—	—	0	0	0.0		
Di-n-butylphthalate	84-74-2	267	X	31	113	53.9	—	—	—	—	—	—	—	—	—	2	4	2.2	—	—	—	—	—	—	0	0	0.0		
Butylbenzylphthalate	85-68-7	265	X	16	58	27.9	12	51	23.8	16	58	27.9	10	51	23.0	0	2	0.8	—	—	—	—	—	—	0	0	0.0		
Bis(2-Ethylhexyl)phthalate	117-81-7	265	X	18	4	8.3	1	2	1.1	78	59	51.7	70	55	47.2	81	69	56.6	—	—	—	0	0	0.0	0	0	0.0		
Di-n-octyl Phthalate	117-84-0	244	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—	NA	NA	NA		
Phenols																													
Phenol	108-95-2	339	X	—	—	—	—	—	—	—	—	—	—	—	—	5	44	14.5	—	—	—	—	—	—	0	0	0.0		
2-Chlorophenol	95-57-8	104		—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	NA	NA	NA		
2,4-Dichlorophenol	120-83-2	104		—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	NA	NA	NA		
2,4,5-Trichlorophenol	95-95-4	104		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA		
2,4,6-Trichlorophenol	88-06-2	104		—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	—	—	—		
4-Chloro-3-methylphenol	59-50-7	103		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
2-Methylphenol	95-48-7	267	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA		
4-Methylphenol	106-44-5	267	X	8	21	10.9	2	4	2.2	—	—	—	—	—	—	9	24	12.4	—	—	—	—	—	—	0	0	0.0		
2,4-Dimethylphenol	105-67-9	339	X	—	—	—	—	—	—	—	—	—	—	—	—	38	228	78.5	—	—	—	—	—	—	0	0	0.0		
2-Nitrophenol	88-75-5	125		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
4-Nitrophenol	100-02-7	103		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
2,4-Dinitrophenol	51-28-5	103		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA		
4,6-Dinitro-2-Methylphenol	534-52-1	103		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
Pentachlorophenol	87-86-5	246	X	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	NA	NA	NA		

Table 3-4 Revised COPC Sediment Screening Exceedances of Selected Criteria

Parameter[1]	CAS Number	No. of Samples	SMS	Ecological Risk: Ecology 2003 Freshwater SQVs[2] — LAET (SQS): No. of Exceed (Detects)	LAET (SQS): No. of Exceed (Non-Detects)	LAET (SQS): % Exceed/ All #	2LAET (CSL): No. of Exceed (Detects)	2LAET (CSL): No. of Exceed (Non-Detects)	2LAET (CSL): % Exceed/ All #	Ecological Risk: RSET September 2006 Interim Freshwater Sediment Quality Guidelines[3] — SL1: No. of Exceed (Detects)	SL1: No. of Exceed (Non-Detects)	SL1: % Exceed/ All #	SL2: No. of Exceed (Detects)	SL2: No. of Exceed (Non-Detects)	SL2: % Exceed/ All #	Ecological Risk: USEPA Region 3 BTAG 2006 Freshwater Sediment Screening Guidelines[4]: No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #	Human Health Risk: Direct Contact: MTCA Method A Soil, Unrestricted Land Use[5] — Total: No. of Exceed (Detects)	Total: No. of Exceed (Non-Detects)	Total: % Exceed/ All #	MTCA Method B Soil Direct Contact (Ingestion Only), Unrestricted Land Use[6] — Carcinogen: No. of Exceed (Detects)	Carcinogen: No. of Exceed (Non-Detects)	Carcinogen: % Exceed/ All #	Non-Carcinogen: No. of Exceed (Detects)	Non-Carcinogen: No. of Exceed (Non-Detects)	Non-Carcinogen: % Exceed/ All #
Misc. Extractables																													
Benzidine	92-87-5	2		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	NA	NA	NA
Benzoic Acid	65-85-0	267	X	3	49	19.5	1	43	16.5	—	—	—	—	—	—	29	144	64.8	—	—	—	—	—	—	0	0	0.0
Benzyl Alcohol	100-51-6	244	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
Caffeine	58-08-2	2		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carbazole	86-74-8	246		58	0	23.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	0	2.4	—	—	—
B-Coprostanol	360-68-9	3		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dibenzofuran	132-64-9	367	X	135	3	37.6	134	2	37.1	136	3	37.9	135	2	37.3	136	3	37.9	—	—	—	—	—	—	4	0	1.1
Hexachlorobenzene	118-74-1	286	X	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	NA	NA	NA
Hexachlorobutadiene	87-68-3	286	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	NA	NA	NA
Hexachlorocyclopentadiene	77-47-4	103		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
Hexachloroethane	67-72-1	104		—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	NA	NA	NA
Isophorone	78-59-1	125		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0.0	0	0	0.0
Nitrobenzene	98-95-3	104		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
N-Nitrosodimethylamine	62-75-9	3		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—
N-Nitrosodiphenylamine	86-30-6	244	X	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	—	—	—
N-Nitroso-Di-N-Propylamine	621-64-7	104		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—
Retene	483-65-8	64		4	0	6.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4-Chloroaniline	106-47-8	122		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
2-Nitroaniline	88-74-4	103		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3-Nitroaniline	99-09-2	103		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
P-Nitroaniline	100-01-6	103		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1,2-Dichlorobenzene	95-50-1	253	X	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	NA	NA	NA
1,3-Dichlorobenzene	541-73-1	183		—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	—	—	—
1,4-Dichlorobenzene	106-46-7	253	X	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	—	—	—
1,2,3-Trichlorobenzene	87-61-6	9		—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	—	—	—
1,2,4-Trichlorobenzene	120-82-1	253	X	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	NA	NA	NA
3,3'-Dichlorobenzidine	91-94-1	103		—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	—	—	—
Bis-(2-Chloroethyl) Ether	111-44-4	104		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—
Bis(2-chloroisopropyl)ether	39638-32-9	76		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
bis(2-Chloroethoxy) Methane	111-91-1	104		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2-Chloronaphthalene	91-58-7	104		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
4-Bromophenyl-phenylether	101-55-3	104		—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	—	—	—
4-Chlorophenyl-phenylether	7005-72-3	104		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2,2'-Oxybis(1-Chloropropane)	108-60-1	28		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—
2,4-Dinitrotoluene	121-14-2	104		—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	NA	NA	NA
2,6-Dinitrotoluene	606-20-2	104		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
Volatile Organic Compounds																													
Acetone	67-64-1	31		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0.0
Acrolein	107-02-8	10		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
Acrylonitrile	107-13-1	10		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	NA	NA	NA
Aniline	62-53-3	3		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—
Benzene	71-43-2	233		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	47	13	25.8	12	2	6.0	2	0	0.9
n-Butylbenzene	104-51-8	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
sec-Butylbenzene	135-98-8	30		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
tert-Butylbenzene	98-06-6	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1,2,4-Trimethylbenzene	95-63-6	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0.0
1,3,5-Trimethylbenzene	108-67-8	30		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0.0
n-Propylbenzene	103-65-1	30		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bromobenzene	108-86-1	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chlorobenzene	108-90-7	10		—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	NA	NA	NA
Ethylbenzene	100-41-4	233		—	—	—	—	—	—	—	—	—	—	—	—	41	5	19.7	29	4	14.2	—	—	—	0	0	0.0
Isopropylbenzene	98-82-8	31		—	—	—	—	—	—	—	—	—	—	—	—	0	10	32.3	—	—	—	—	—	—	0	0	0.0
Bromoform	75-25-2	10		—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	NA	NA	NA
trans-1,4-Dichloro-2-butene	110-57-6	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carbon Disulfide	75-15-0	10		—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	NA	NA	NA
Carbon Tetrachloride	56-23-5	10		—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	NA	NA	NA
Chloroform	67-66-3	32		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0.0	0	0	0.0
Bromoethane	74-96-4	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1,2-Dibromoethane	106-93-4	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	NA	NA	NA	—	—	—
Chloroethane	75-00-3	10		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	NA	NA	NA
1,1-Dichloroethane	75-34-3	10		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
1,2-Dichloroethane	107-06-2	31		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	71-55-6	11		—	—	—	—	—	—	—	—	—	—	—	—	0	9	81.8	0	9	81.8	—	—	—	0	0	0.0
1,1,2-Trichloroethane	79-00-5	10		—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	NA	NA	NA
1,1,1,2-Tetrachloroethane	630-20-6	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane	79-34-5	10		—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	—	—	—
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
1,1-Dichloroethene	75-35-4	10		—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	NA	NA	NA
cis-1,2-Dichloroethene	156-59-2	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
trans-1,2-Dichloroethene	156-60-5	10		—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	NA	NA	NA
Trichloroethene	79-01-6	10		—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tetrachloroethene	127-18-4	10		—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Diphenylhydrazine	122-66-7	3		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—
Bromomethane	74-83-9	10		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
Dibromomethane	74-95-3	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
Chloromethane	74-87-3	10		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—
Bromochloromethane	74-97-5	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bromodichloromethane	75-27-4	10		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	NA	NA	NA
Dibromochloromethane	124-48-1	10		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	NA	NA	NA
Trichlorofluoromethane	75-69-4	10		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
Methyl Iodide	74-88-4	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table 3-4 Revised COPC Sediment Screening Exceedances of Selected Criteria

Parameter[1]	CAS Number	No. of Samples	SMS	Ecological Risk: Ecology 2003 Freshwater SQVs[2] — LAET (SQS): No. of Exceed (Detects)	LAET (SQS): No. of Exceed (Non-Detects)	LAET (SQS): % Exceed/ All #	2LAET (CSL): No. of Exceed (Detects)	2LAET (CSL): No. of Exceed (Non-Detects)	2LAET (CSL): % Exceed/ All #	Ecological Risk: RSET September 2006 Interim Freshwater Sediment Quality Guidelines[3] — SL1: No. of Exceed (Detects)	SL1: No. of Exceed (Non-Detects)	SL1: % Exceed/ All #	SL2: No. of Exceed (Detects)	SL2: No. of Exceed (Non-Detects)	SL2: % Exceed/ All #	Ecological Risk: USEPA Region 3 BTAG 2006 Freshwater Sediment Screening Guidelines[4]: No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #	Human Health Risk: Direct Contact: MTCA Method A Soil, Unrestricted Land Use[5] — Total: No. of Exceed (Detects)	Total: No. of Exceed (Non-Detects)	Total: % Exceed/ All #	MTCA Method B Soil Direct Contact (Ingestion Only), Unrestricted Land Use[6] — Carcinogen: No. of Exceed (Detects)	Carcinogen: No. of Exceed (Non-Detects)	Carcinogen: % Exceed/ All #	Non-Carcinogen: No. of Exceed (Detects)	Non-Carcinogen: No. of Exceed (Non-Detects)	Non-Carcinogen: % Exceed/ All #
Volatile Organics (cont'd)																													
Methylene Chloride	75-09-2	32		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Butanone	78-93-3	31		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0.0
2-Hexanone	591-78-6	31		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4-Methyl-2-Pentanone (MIBK)	108-10-1	31		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0.0
1,2-Dichloropropane	78-87-5	10		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—
1,3-Dichloropropane	142-28-9	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2,2-Dichloropropane	594-20-7	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1,2,3-Trichloropropane	96-18-4	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	NA	NA	NA
1,2-Dibromo-3-chloropropane	96-12-8	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—
1,1-Dichloropropene	563-58-6	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
cis-1,3-Dichloropropene	10061-01-5	10		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
trans-1,3-Dichloropropene	10061-02-6	10		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Styrene	100-42-5	31		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA
Toluene	108-88-3	233		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	5	4.7	—	—	—	0	0	0.0
2-Chlorotoluene	95-49-8	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
4-Chlorotoluene	106-43-4	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4-Isopropyltoluene	99-87-6	30		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total Xylenes	CALC-TX	156		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	13	2	9.6	—	—	—	0	0	0.0
Vinyl Acetate	108-05-4	10		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
Vinyl Chloride	75-01-4	10		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	NA	NA	NA
2-Chloroethylvinylether	110-75-8	10		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pesticides/PCBs																													
2,4,5-T	93-76-5	2		—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	NA	NA	NA
2,4,5-TP (Silvex)	93-72-1	2		—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	NA	NA	NA
2,4-D	94-75-7	2		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
2,4-DB	94-82-6	2		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
Aldrin	309-00-2	3		—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	NA	NA	NA
alpha-BHC	319-84-6	3		—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	—	—	—
beta-BHC	319-85-7	3		—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	—	—	—
delta-BHC	319-86-8	3		—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	—	—	—
gamma-BHC (Lindane)	58-89-9	3		—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
beta-Chlordane	5103-74-2	42		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chlordane	12789-03-6	44		—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	NA	NA	NA
DDD	72-54-8	45		0	0	0.0	—	—	—	—	—	—	—	—	—	15	5	44.4	—	—	—	0	0	0.0	—	—	—
DDE	72-55-9	45		NA	NA	NA	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	—	—	—
DDT	50-29-3	45		NA	NA	NA	—	—	—	—	—	—	—	—	—	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dicamba	1918-00-9	2		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
Dieldrin	60-57-1	3		—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	NA	NA	NA
Dinoseb	88-85-7	2		—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	NA	NA	NA
Endosulfan	115-29-7	3		—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	NA	NA	NA
Endosulfan Sulfate	1031-07-8	3		—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	—	—	—
Endrin	72-20-8	3		—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	NA	NA	NA
Endrin Aldehyde	7421-93-4	3		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Heptachlor	76-44-8	3		—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	NA	NA	NA
Heptachlor Epoxide	1024-57-3	3		—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	NA	NA	NA
MCPA	94-74-6	2		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
MCPP	93-65-2	2		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
Methoxychlor	72-43-5	3		—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	—	—	—	NA	NA	NA
Toxaphene	8001-35-2	3		—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA	—	—	—	NA	NA	NA	—	—	—
Aroclor 1016	12674-11-2	128		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NA	NA	NA
Aroclor 1221	11104-28-2	128		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aroclor 1232	11141-16-5	128		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aroclor 1242	53469-21-9	128		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aroclor 1248	12672-29-6	128		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aroclor 1254	11097-69-1	128		3	0	2.3	2	0	1.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0.0
Aroclor 1260	11096-82-5	128		4	4	6.3	3	4	5.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total PCBs		128	X	18	13	24.2	4	0	3.1	19	13	25.0	11	6	13.3	19	16	27.3	0	0	0.0	1	0	0.8	—	—	—

Table 3-4 Revised COPC Sediment Screening Exceedances of Selected Criteria

Parameter[1]	CAS Number	No. of Samples	MTCA Ecology SMS	Human Health Risk: Direct Contact (cont'd) — USEPA Regional Screening Levels, Total Risk, Residential Soil - December 2009[7] — Carcinogen (TR = 1E-6)			Non-Carcinogen (HI = 1)			Non-Carcinogen (HI = 0.1)+			Bioaccumulative Risk — Oregon DEQ 2007 Sediment Bioaccumulation Screening Level Values[8] — Fish (Freshwater)			Humans (Subsistence)			Inorganic Background ^		
				No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #	No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #	No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #	No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #	No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #	No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #
Conventionals/Misc.																					
Total Cyanide	CN	168		—	—	—	0	0	0.0	4	0	2.5	—	—	—	—	—	—	—	—	—
Metals																					
Aluminum	7429-90-5	24		—	—	—	1	0	4.2	23	0	95.8	—	—	—	—	—	—	—	—	—
Antimony	7440-36-0	130		—	—	—	0	0	0.0	9	47	43.1	—	—	—	—	—	—	—	—	—
Arsenic	7440-38-2	351	X	177	176	100.0	103	19	34.8	177	164	96.6	—	—	—	—	—	—	158	127	81.2
Barium	7440-39-3	29		—	—	—	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
Beryllium	7440-41-7	25		0	0	0.0	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
Cadmium	7440-43-9	259	X	0	0	0.0	0	0	0.0	0	0	0.0	—	—	—	—	—	—	98	42	54.1
Calcium	7440-70-2	24		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chromium	7440-47-3	177	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cobalt	7440-48-4	22		0	0	0.0	8	0	36.4	22	0	100.0	—	—	—	—	—	—	—	—	—
Copper	7440-50-8	259	X	—	—	—	0	0	0.0	35	0	13.4	—	—	—	—	—	—	—	—	—
Iron	7439-89-6	38		—	—	—	0	0	0.0	37	0	100.0	—	—	—	—	—	—	—	—	—
Lead	7439-92-1	259	X	—	—	—	26	0	10.0	135	0	51.5	—	—	—	—	—	—	147	0	56.8
Magnesium	7439-95-4	24		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Manganese	7439-96-5	24		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mercury	7439-97-6	261	X	—	—	—	0	0	0.0	95	0	41.8	—	—	—	—	—	—	132	65	75.5
Methylmercury	22967-92-6	1		—	—	—	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
Nickel	7440-02-0	190		0	0	0.0	0	0	0.0	9	0	4.7	—	—	—	—	—	—	—	—	—
Potassium	9/7/7440	24		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Selenium	7782-49-2	31		—	—	—	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
Silver	7440-22-4	200	X	—	—	—	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
Sodium	7440-23-5	23		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Thallium	7440-28-0	24		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tin	7440-31-5	1		—	—	—	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
Vanadium	7440-62-2	22		—	—	—	0	0	0.0	22	0	100.0	—	—	—	—	—	—	—	—	—
Zinc	7440-66-6	259	X	—	—	—	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
Butyltins																					
Tributyltin	688-73-3	53		—	—	—	0	0	0.0	1	0	1.9	35	2	69.8	33	1	64.2	—	—	—
LPAH																					
Naphthalene	91-20-3	366	X	140	0	38.3	44	0	12.0	92	0	25.1	—	—	—	—	—	—	—	—	—
Acenaphthylene	208-96-8	366	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Acenaphthene	83-32-9	367	X	—	—	—	1	0	0.3	8	0	2.2	—	—	—	—	—	—	—	—	—
Fluorene	86-73-7	367	X	—	—	—	0	0	0.0	10	0	2.7	—	—	—	—	—	—	—	—	—
Phenanthrene	85-01-8	361	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Anthracene	120-12-7	367	X	—	—	—	0	0	0.0	1	0	0.3	—	—	—	—	—	—	—	—	—
2-methlynaphthalene	91-57-6	367	X	—	—	—	13	0	3.5	55	0	15.0	—	—	—	—	—	—	—	—	—
Total LPAH		367	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
HPAH																					
Fluoranthene	206-44-0	361	X	—	—	—	2	0	0.6	34	0	9.4	102	0	28.3	80	0	22.2	—	—	—
Pyrene	129-00-0	361	X	—	—	—	3	0	0.8	41	0	11.4	230	0	63.7	94	0	26.0	—	—	—
Benzo(a)anthracene	56-55-3	367	X	268	11	76.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chrysene	218-01-9	366	X	104	0	28.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Benzo(b)fluoranthene	205-99-2	366		264	12	75.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Benzo(k)fluoranthene	207-08-9	366		193	0	52.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Benzo(b,k)fluoranthenes (Total)		366	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Benzo(a)pyrene	50-32-8	367	X	283	58	92.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Indeno(1,2,3-cd)pyrene	193-39-5	367	X	259	15	74.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dibenzo(a,h)anthracene	53-70-3	367	X	236	96	90.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Benzo(g,h,i)perylene	191-24-2	367	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total HPAH		366	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total PAH		367		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Phthalates																					
Dimethylphthalate	131-11-3	265	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Diethylphthalate	84-66-2	244	X	—	—	—	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
Di-n-butylphthalate	84-74-2	267	X	—	—	—	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
Butylbenzylphthalate	85-68-7	265	X	0	0	0.0	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
Bis(2-Ethylhexyl)phthalate	117-81-7	265	X	0	0	0.0	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
Di-n-octyl Phthalate	117-84-0	244	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Phenols																					
Phenol	108-95-2	339	X	—	—	—	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
2-Chlorophenol	95-57-8	104		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
2,4-Dichlorophenol	120-83-2	104		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
2,4,5-Trichlorophenol	95-95-4	104		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
2,4,6-Trichlorophenol	88-06-2	104		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
4-Chloro-3-methylphenol	59-50-7	103		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
2-Methylphenol	95-48-7	267	X	—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
4-Methylphenol	106-44-5	267	X	—	—	—	0	0	0.0	1	0	0.4	—	—	—	—	—	—	—	—	—
2,4-Dimethylphenol	105-67-9	339	X	—	—	—	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
2-Nitrophenol	88-75-5	125		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4-Nitrophenol	100-02-7	103		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2,4-Dinitrophenol	51-28-5	103		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
4,6-Dinitro-2-Methylphenol	534-52-1	103		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Pentachlorophenol	87-86-5	246	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—

Table 3-4 Revised COPC Sediment Screening Exceedances of Selected Criteria

Parameter[1]	CAS Number	No. of Samples	MTCA Ecology SMS	Human Health Risk: Direct Contact (cont'd) — USEPA Regional Screening Levels, Total Risk, Residential Soil - December 2009[7] — Carcinogen (TR = 1E-6)			Non-Carcinogen (HI = 1)			Non-Carcinogen (HI = 0.1)+			Bioaccumulative Risk — Oregon DEQ 2007 Sediment Bioaccumulation Screening Level Values[8] — Fish (Freshwater)			Humans (Subsistence)			Inorganic Background ^		
				No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #	No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #	No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #	No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #	No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #	No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #
Misc. Extractables																					
Benzidine	92-87-5	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Benzoic Acid	65-85-0	267	X	—	—	—	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
Benzyl Alcohol	100-51-6	244	X	—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Caffeine	58-08-2	2		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carbazole	86-74-8	246		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B-Coprostanol	360-68-9	3		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dibenzofuran	132-64-9	367	X	—	—	—	9	0	2.5	40	0	10.9	—	—	—	—	—	—	—	—	—
Hexachlorobenzene	118-74-1	286	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—
Hexachlorobutadiene	87-68-3	286	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Hexachlorocyclopentadiene	77-47-4	103		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Hexachloroethane	67-72-1	104		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Isophorone	78-59-1	125		0	0	0.0	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
Nitrobenzene	98-95-3	104		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
N-Nitrosodimethylamine	62-75-9	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
N-Nitrosodiphenylamine	86-30-6	244	X	NA	NA	NA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
N-Nitroso-Di-N-Propylamine	621-64-7	104		NA	NA	NA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Retene	483-65-8	64		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4-Chloroaniline	106-47-8	122		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
2-Nitroaniline	88-74-4	103		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
3-Nitroaniline	99-09-2	103		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
P-Nitroaniline	100-01-6	103		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
1,2-Dichlorobenzene	95-50-1	253	X	—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
1,3-Dichlorobenzene	541-73-1	183		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1,4-Dichlorobenzene	106-46-7	253	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
1,2,3-Trichlorobenzene	87-61-6	9		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
1,2,4-Trichlorobenzene	120-82-1	253	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
3,3'-Dichlorobenzidine	91-94-1	103		NA	NA	NA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bis-(2-Chloroethyl) Ether	111-44-4	104		NA	NA	NA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bis(2-chloroisopropyl)ether	39638-32-9	76		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
bis(2-Chloroethoxy) Methane	111-91-1	104		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
2-Chloronaphthalene	91-58-7	104		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
4-Bromophenyl-phenylether	101-55-3	104		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4-Chlorophenyl-phenylether	7005-72-3	104		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2,2'-Oxybis(1-Chloropropane)	108-60-1	28		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
2,4-Dinitrotoluene	121-14-2	104		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
2,6-Dinitrotoluene	606-20-2	104		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Volatile Organic Compounds																					
Acetone	67-64-1	31		—	—	—	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
Acrolein	107-02-8	10		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Acrylonitrile	107-13-1	10		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Aniline	62-53-3	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Benzene	71-43-2	233		36	9	19.3	6	0	2.6	18	4	9.4	—	—	—	—	—	—	—	—	—
n-Butylbenzene	104-51-8	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
sec-Butylbenzene	135-98-8	30		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
tert-Butylbenzene	98-06-6	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1,2,4-Trimethylbenzene	95-63-6	9		—	—	—	2	0	22.2	3	5	88.9	—	—	—	—	—	—	—	—	—
1,3,5-Trimethylbenzene	108-67-8	30		—	—	—	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
n-Propylbenzene	103-65-1	30		—	—	—	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
Bromobenzene	108-86-1	9		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Chlorobenzene	108-90-7	10		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Ethylbenzene	100-41-4	233		31	5	15.5	0	0	0.0	1	0	0.4	—	—	—	—	—	—	—	—	—
Isopropylbenzene	98-82-8	31		—	—	—	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
Bromoform	75-25-2	10		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
trans-1,4-Dichloro-2-butene	110-57-6	9		NA	NA	NA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carbon Disulfide	75-15-0	10		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Carbon Tetrachloride	56-23-5	10		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Chloroform	67-66-3	32		0	9	28.1	0	0	0.0	0	2	6.3	—	—	—	—	—	—	—	—	—
Bromoethane	74-96-4	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1,2-Dibromoethane	106-93-4	9		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Chloroethane	75-00-3	10		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
1,1-Dichloroethane	75-34-3	10		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
1,2-Dichloroethane	107-06-2	31		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
1,1,1-Trichloroethane	71-55-6	11		—	—	—	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
1,1,2-Trichloroethane	79-00-5	10		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
1,1,1,2-Tetrachloroethane	630-20-6	9		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
1,1,2,2-Tetrachloroethane	79-34-5	10		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	9		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
1,1-Dichloroethene	75-35-4	10		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
cis-1,2-Dichloroethene	156-59-2	9		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
trans-1,2-Dichloroethene	156-60-5	10		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Trichloroethene	79-01-6	10		—	NA	NA	NA	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tetrachloroethene	127-18-4	10		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
1,2-Diphenylhydrazine	122-66-7	3		NA	NA	NA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bromomethane	74-83-9	10		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Dibromomethane	74-95-3	9		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Chloromethane	74-87-3	10		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Bromochloromethane	74-97-5	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bromodichloromethane	75-27-4	10		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Dibromochloromethane	124-48-1	10		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Trichlorofluoromethane	75-69-4	10		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Methyl Iodide	74-88-4	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table 3-4 Revised COPC Sediment Screening Exceedances of Selected Criteria

Parameter[1]	CAS Number	No. of Samples	MTCA Ecology SMS	Human Health Risk: Direct Contact (cont'd) — USEPA Regional Screening Levels, Total Risk, Residential Soil - December 2009[7] — Carcinogen (TR = 1E-6)			Non-Carcinogen (HI = 1)			Non-Carcinogen (HI = 0.1)+			Bioaccumulative Risk — Oregon DEQ 2007 Sediment Bioaccumulation Screening Level Values[8] — Fish (Freshwater)			Humans (Subsistence)			Inorganic Background ^		
				No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #	No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #	No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #	No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #	No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #	No. of Exceed (Detects)	No. of Exceed (Non-Detects)	% Exceed/ All #
Volatile Organics (cont'd)																					
Methylene Chloride	75-09-2	32		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
2-Butanone	78-93-3	31		—	—	—	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
2-Hexanone	591-78-6	31		—	—	—	0	0	0.0	0	9	29.0	—	—	—	—	—	—	—	—	—
4-Methyl-2-Pentanone (MIBK)	108-10-1	31		—	—	—	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
1,2-Dichloropropane	78-87-5	10		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
1,3-Dichloropropane	142-28-9	9		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
2,2-Dichloropropane	594-20-7	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1,2,3-Trichloropropane	96-18-4	9		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
1,2-Dibromo-3-chloropropane	96-12-8	9		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
1,1-Dichloropropene	563-58-6	9		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
cis-1,3-Dichloropropene	10061-01-5	10		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
trans-1,3-Dichloropropene	10061-02-6	10		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Styrene	100-42-5	31		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Toluene	108-88-3	233		—	—	—	0	0	0.0	0	0	0.0	—	—	—	—	—	—	—	—	—
2-Chlorotoluene	95-49-8	9		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
4-Chlorotoluene	106-43-4	9		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
4-Isopropyltoluene	99-87-6	30		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total Xylenes	CALC-TX	156		—	—	—	0	0	0.0	6	0	4.0	—	—	—	—	—	—	—	—	—
Vinyl Acetate	108-05-4	10		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Vinyl Chloride	75-01-4	10		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
2-Chloroethylvinylether	110-75-8	10		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pesticides/PCBs																					
2,4,5-T	93-76-5	2		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
2,4,5-TP (Silvex)	93-72-1	2		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
2,4-D	94-75-7	2		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
2,4-DB	94-82-6	2		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Aldrin	309-00-2	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
alpha-BHC	319-84-6	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
beta-BHC	319-85-7	3		NA	NA	NA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
delta-BHC	319-86-8	3		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
gamma-BHC (Lindane)	58-89-9	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
beta-Chlordane	5103-74-2	42		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chlordane	12789-03-6	44		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—
DDD	72-54-8	45		0	0	0.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DDE	72-55-9	45		NA	NA	NA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DDT	50-29-3	45		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—
Dicamba	1918-00-9	2		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Dieldrin	60-57-1	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—
Dinoseb	88-85-7	2		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Endosulfan	115-29-7	3		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Endosulfan Sulfate	1031-07-8	3		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Endrin	72-20-8	3		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Endrin Aldehyde	7421-93-4	3		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Heptachlor	76-44-8	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Heptachlor Epoxide	1024-57-3	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
MCPA	94-74-6	2		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
MCPP	93-65-2	2		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Methoxychlor	72-43-5	3		—	—	—	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Toxaphene	8001-35-2	3		NA	NA	NA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aroclor 1016	12674-11-2	128		NA	NA	NA	NA	NA	NA	NA	NA	NA	—	—	—	—	—	—	—	—	—
Aroclor 1221	11104-28-2	128		NA	NA	NA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aroclor 1232	11141-16-5	128		NA	NA	NA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aroclor 1242	53469-21-9	128		NA	NA	NA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aroclor 1248	12672-29-6	128		NA	NA	NA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aroclor 1254	11097-69-1	128		5	0	3.9	0	0	0.0	6	5	8.6	—	—	—	—	—	—	—	—	—
Aroclor 1260	11096-82-5	128		2	0	1.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total PCBs		128	X	6	0	4.7	—	—	—	—	—	—	27	23	39.1	28	100	100.0	—	—	—

Notes:

Number of exceedances (detects and non-detects), as a percentage of all samples.

^ Background values applicable to Washington have been included in place of those applicable to Oreong (Ecology 1994 background values: http://www.ecy.wa.gov/pubs/94115.pdf).

— Indicates no criterion.

Orange highlight = % Exceed is greater than 0 percent. If % Exceed is greater than 0 because of non-detects, the non-detect column is also highlighted.

Non-detects were set to one-half the reporting limit.

NA = Detection frequency was less than 5%.

[1] Data parameters for revised COPC screening: 1995 to 2009, samples within the GWSA (except those in the Northlake Shipyard vicinity), surface, and subsurface samples.
Parameter list generated from GWSA database; all available parameters encompassed by the specified area and date range are included.

[2] Ecology Freshwater Sediment LAET (lowest Apparent Effects Threshold) and 2LAET (second lowest Apparent Effects Threshold) from *H. azteca* (10-day mortality), *C. dilutus* (10-day mortality and growth), and Microtox (Ecology September 2003 Phase II Report).

[3] Northwest Regional Sediment Evaluation Framework Interim Freshwater Sediment Quality Guidelines (RSET September 2006).

[4] USEPA Region 3 Biological Technical Assistance Group (BTAG) Freshwater Sediment Screening Benchmarks, as queried (3/18/10) from http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fwsed/screenbench.htm.

[5] MTCA Method A values, as queried from the CLARC database (1/21/10): https://fortress.wa.gov/ecy/clarc/CLARCHome.aspx.

[6] MTCA Method B values, as queried from the CLARC database (7/13/09): https://fortress.wa.gov/ecy/clarc/CLARCHome.aspx.
* CLARC no longer contains Method B soil cleanup levels for these individual chemicals and requires the application of the TEF methodology. For these purposes, the cPAHs were weighted relative to the BaP Method B criterion based on the TEFs in MTCA.

[7] December 2009 USEPA RSL values, as queried from http://www.epa.gov/reg3hwmd/risk/human/rb-concentration table/Generic Tables/index.htm.
+ Per 1993 USEPA Regional Guidance (EPA/903/R-93-001), the non-carcinogen Hazard Index (HI) should be adjusted to 0.1 to account for possible additive effects. The adjusted RSLs are therefore shown for comparison.

[8] Oregon DEQ SLVs from *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment* (Pub. No. 07-LQ-023A; Oregon DEQ April 2007).
Bird, mammal, and human (general) SLVs were reviewed. These SLVs are encompassed by the range of other criteria used for screening, so are not incorporated here.
^ Background values applicable to Washington have been included in place of those applicable to Oregon (Ecology 1994 background values: http://www.ecy.wa.gov/pubs/94115.pdf).

BTAG: Biological Technical Assistance Group
COPC: Chemical of potential concern
CSL: Cleanup screening level
DDD: Dichlorodiphenyldichloroethane
DDE: Dichlorodiphenyldichloroethylene
DDT: Dichlorodiphenyltrichloroethane
Ecology: Washington State Department of Ecology
Exceed: Exceedance
HI: Hazard Index
HPAH: High-molecular weight polycyclic aromatic hydrocarbon
LAET: Lowest Apparent Effects Theshold
2LAET: Second lowest Apparent Effects Theshold
LPAH: Low-molecular weight polycyclic aromatic hydrocarbon
MTCA: Washington State Model Toxics Control Act
Oregon DEQ: Oregon Department of Environmental Quality
PAH: Polycyclic aromatic hydrocarbon
PCB: Polychlorinated biphenyl
RSET: Regional Sediment Evaluation Team
RSL: Regional screening level
SLV: Screening level value
SMS: Sediment Management Standards
SQS: Sediment Quality Standards
SQV: Sediment Quality Value
TEF: Toxicity Equivalence Factor
TR: Threshold risk level
USEPA: U.S. Environmental Protection Agency

Table 3-5 Summary of Revised COPC Sediment Screening Exceedances

				Ecological Risk										Human Health Risk: Direct Contact												Bioaccumulative Risk					
				Ecology 2003 Freshwater SQVs[2]				RSET September 2006 Interim Freshwater Sediment Quality Guidelines[3]				USEPA Region 3 BTAG 2006 Freshwater Sediment Screening Guidelines[4]		MTCA Method A Soil, Unrestricted Land Use[5]		MTCA Method B Soil Direct Contact (Ingestion Only), Unrestricted Land Use[6]				USEPA Regional Screening Levels, Total Risk, Residential Soil[7]						Oregon DEQ 2007 Sediment Bioaccumulation Screening Level Values[8]					
				LAET (SQS)		2LAET (CSL)		SL1		SL2				Total		Carcinogen		Non-Carcinogen		Carcinogen (TR = 1E-6)		Non-Carcinogen (HI = 1)		Non-Carcinogen (HI = 0.1)*		Fish (FreshH2O)		Humans (Subsistence)		Inorganic Background ^	
Parameter[1]	CAS Number	No. of Samples	SMS	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?
Conventionals/Misc.																															
Total Cyanide	CN	168																						Y							
Metals																															
Aluminum	7429-90-5	24																				Y		Y							
Antimony	7440-36-0	130		Y		Y						Y												Y							
Arsenic	7440-38-2	351	X	Y		Y		Y		Y		Y		Y		Y		Y		Y		Y		Y						Y	
Cadmium	7440-43-9	259	X	Y		Y		Y		Y		Y		Y																Y	
Chromium	7440-47-3	177	X	Y		Y		Y		Y		Y																			
Cobalt	7440-48-4	22										Y										Y		Y							
Copper	7440-50-8	259	X	Y		Y		Y		Y		Y												Y							
Iron	7439-89-6	38										Y												Y							
Lead	7439-92-1	259	X	Y		Y		Y		Y		Y		Y								Y		Y						Y	
Mercury	7439-97-6	261	X	Y		Y		Y		Y		Y		Y										Y						Y	
Nickel	7440-02-0	190		Y		Y		Y		Y		Y												Y							
Selenium	7782-49-2	31										Y																			
Silver	7440-22-4	200	X	Y		Y		Y		Y		Y																			
Vanadium	7440-62-2	22																						Y							
Zinc	7440-66-6	259	X	Y		Y		Y		Y		Y																			
Butyltins																															
Tributyltin	688-73-3	53		Y		Y		Y		Y														Y		Y					
LPAH																															
Naphthalene	91-20-3	366	X	Y		Y		Y		Y		Y		Y				Y		Y		Y		Y							
Acenaphthylene	208-96-8	366	X	Y		Y		Y		Y		Y																			
Acenaphthene	83-32-9	367	X	Y		Y		Y		Y		Y										Y		Y							
Fluorene	86-73-7	367	X	Y		Y		Y		Y		Y												Y							
Phenanthrene	85-01-8	361	X	Y		Y		Y		Y		Y																			
Anthracene	120-12-7	367	X	Y		Y		Y		Y		Y												Y							
2-methlynaphthalene	91-57-6	367	X	Y		Y		Y		Y		Y						Y				Y		Y							
Total LPAH		367	X	Y		Y		Y		Y		Y																			
HPAH																															
Fluoranthene	206-44-0	361	X	Y		Y		Y		Y		Y						Y				Y		Y		Y		Y			
Pyrene	129-00-0	361	X	Y		Y		Y		Y		Y						Y				Y		Y		Y		Y			
Benzo(a)anthracene	56-55-3	367	X	Y		Y		Y		Y		Y				Y				Y											
Chrysene	218-01-9	366	X	Y		Y		Y		Y		Y				Y				Y											
Benzo(b)fluoranthene	205-99-2	366														Y				Y											
Benzo(k)fluoranthene	207-08-9	366										Y				Y				Y											
Benzo(b,k)fluoranthenes (Total)		366	X	Y		Y		Y		Y		Y																			
Benzo(a)pyrene	50-32-8	367	X	Y		Y		Y		Y		Y		Y		Y				Y											
Indeno(1,2,3-cd)pyrene	193-39-5	367	X	Y		Y		Y		Y		Y				Y				Y											
Dibenzo(a,h)anthracene	53-70-3	367	X	Y		Y		Y		Y		Y				Y				Y											
Benzo(g,h,i)perylene	191-24-2	367	X	Y		Y		Y		Y		Y																			
Total HPAH		366	X	Y		Y		Y		Y		Y																			
Total PAH		367										Y																			
Phthalates																															
Dimethylphthalate	131-11-3	265	X	Y		Y	Y	Y		Y	Y																				
Diethylphthalate	84-66-2	244	X									Y																			
Di-n-butylphthalate	84-74-2	267	X	Y								Y																			
Butylbenzylphthalate	85-68-7	265	X	Y		Y		Y		Y		Y	Y																		
Bis(2-Ethylhexyl)phthalate	117-81-7	265	X	Y		Y		Y		Y		Y																			
Phenols																															
Phenol	108-95-2	339	X									Y																			
4-Methylphenol	106-44-5	267	X	Y		Y						Y												Y							
2,4-Dimethylphenol	105-67-9	339	X									Y																			

Table 3-5 Summary of Revised COPC Sediment Screening Exceedances

				Ecological Risk										Human Health Risk: Direct Contact												Bioaccumulative Risk					
				Ecology 2003 Freshwater SQVs[2]				RSET September 2006 Interim Freshwater Sediment Quality Guidelines[3]				USEPA Region 3 BTAG 2006 Freshwater Sediment Screening Guidelines[4]		MTCA Method A Soil, Unrestricted Land Use[5]		MTCA Method B Soil Direct Contact (Ingestion Only), Unrestricted Land Use[6]				USEPA Regional Screening Levels, Total Risk, Residential Soil[7]						Oregon DEQ 2007 Sediment Bioaccumulation Screening Level Values[8]					
				LAET (SQS)		2LAET (CSL)		SL1		SL2				Total		Carcinogen		Non-Carcinogen		Carcinogen (TR = 1E-6)		Non-Carcinogen (HI = 1)		Non-Carcinogen (HI = 0.1)*		Fish (FreshH2O)		Humans (Subsistence)		Inorganic Background ^	
Parameter[1]	CAS Number	No. of Samples	SMS	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?	Exceed?	Due to ND?
Misc. Extractables																															
Benzoic Acid	65-85-0	267	X	Y		Y						Y																			
Carbazole	86-74-8	246		Y												Y															
Dibenzofuran	132-64-9	367	X	Y		Y		Y		Y		Y						Y				Y		Y							
Retene	483-65-8	64		Y																											
Volatile Organics																															
Benzene	71-43-2	233												Y		Y		Y		Y		Y		Y							
1,2,4-Trimethylbenzene	95-63-6	9																				Y		Y							
Ethylbenzene	100-41-4	233										Y		Y						Y				Y							
Isopropylbenzene	98-82-8	31										Y	Y																		
Chloroform	67-66-3	32																		Y	Y			Y	Y						
1,1,1-Trichloroethane	71-55-6	11										Y	Y	Y	Y																
2-Hexanone	591-78-6	31																						Y	Y						
Toluene	108-88-3	233												Y																	
Total Xylenes	CALC-TX	156												Y										Y							
Pesticides/PCBs																															
DDD	72-54-8	45										Y																			
Aroclor 1254	11097-69-	128		Y		Y														Y				Y							
Aroclor 1260	11096-82-	128		Y		Y														Y											
Total PCBs		128	X	Y		Y		Y		Y		Y				Y				Y						Y		Y			

Notes:

ND = Non-detect

Non-detects were set to one-half the reporting limit.

[1] Data parameters for revised COPC screening: 1995 to 2009, samples within the GWSA (except those in the Northlake Shipyard vicinity), surface, and subsurface samples.
Parameter list generated from GWSA database; all available parameters encompassed by the specified area and date range are included.

[2] Ecology Freshwater Sediment LAET (lowest Apparent Effects Threshold) and 2LAET (second lowest Apparent Effects Threshold) from *H. azteca* (10-day mortality), *C. dilutus* (10-day mortality and growth), and Microtox (Ecology September 2003 Phase II Report).

[3] Northwest Regional Sediment Evaluation Framework Interim Freshwater Sediment Quality Guidelines (RSET September 2006).

[4] USEPA Region 3 Biological Technical Assistance Group (BTAG) Freshwater Sediment Screening Benchmarks, as queried (3/18/10) from http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fwsed/screenbench.htm.

[5] MTCA Method A values, as queried from the CLARC database (1/21/10): https://fortress.wa.gov/ecy/clarc/CLARCHome.aspx.

[6] MTCA Method B values, as queried from the CLARC database (7/13/09): https://fortress.wa.gov/ecy/clarc/CLARCHome.aspx.
* CLARC no longer contains Method B soil cleanup levels for these individual chemicals and requires the application of the TEF methodology. For these purposes, the cPAHs were weighted relative to the BaP Method B criterion based on the TEFs in MTCA.

[7] December 2009 USEPA RSL values, as queried from http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm.
[+] Per 1993 USEPA Regional Guidance (EPA/903/R-93-001), the non-carcinogen Hazard Index (HI) should be adjusted to 0.1 to account for possible additive effects. The adjusted RSLs are therefore shown for comparison.

[8] Oregon DEQ SLVs from *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment* (Pub. No. 07-LQ-023A; Oregon DEQ April 2007).
Bird, mammal, and human (general) SLVs were reviewed. These SLVs are encompassed by the range of other criteria used for screening, so are not incorporated here.
^ Background values applicable to Washington have been included in place of those applicable to Oregon (Ecology 1994 background values: http://www.ecy.wa.gov/pubs/94115.pdf).

BTAG: Biological Technical Assistance Group
COPC: Chemical of potential concern
CSL: Chemical screening level
DDD: Dichlorodiphenyldichloroethane
Ecology: Washington State Department of Ecology
Exceed: Exceedance
HI: Hazard Index
HPAH: High-molecular weight polycyclic aromatic hydrocarbon
LAET: Lowest Apparent Effects Theshold
2LAET: Second lowest Apparent Effects Theshold
LPAH: Low-molecular weight polycyclic aromatic hydrocarbon
MTCA: Washington State Model Toxics Control Act
Oregon DEQ: Oregon Department of Environmental Quality
PAH: Polycyclic aromatic hydrocarbon
PCB: Polychlorinated biphenyl
RSET: Regional Sediment Evaluation Team
RSL: Regional screening level
SLV: Screening Level Value
SMS: Sediment Management Standards
SQS: Sediment Quality Standards
SQV: Sediment Quality Value
TEF: Toxicity Equivalence Factor
TR: Threshold risk level
USEPA: U.S. Environmental Protection Agency

Table 3-6a Crayfish Tissue Screening

Chemical of Potential Concern	Maximum Tissue Concentration[1] (mg/kg)	Oregon DEQ 2007[3] Acceptable Tissue Levels (mg/kg ww) Consumption by Bird Populations	Consumption by Wildlife Populations	Carcinogens - Consumption by Humans - Recreational	Carcinogens - Consumption by Humans - Tribal	Non-Carcinogens - Consumption by Humans - Recreational	Non-Carcinogens - Consumption by Humans - Tribal	Critical Tissue Levels (mg/kg ww) Freshwater Organism	USEPA Region 3 Fish Tissue Consumption RSL[4] (mg/kg)	RSET SEF Bioaccumulative Chemicals of Concern[5] (mg/kg ww) Human Health TTL1	Human Health TTL2	Human Health TTL3
Conventionals/Misc.												
Total Cyanide	na	—	—	—	—	—	—	—	27	—	—	—
Metals												
Antimony[2]	0.3	—	—	—	—	—	—	—	0.541	—	—	—
Arsenic	0.57	64	38	**0.0062**	**0.000076**	1.2	**0.15**	6.6	**0.0021**	**0.002**	**0.00027**	**0.00008**
Cadmium	0.37	42	28	—	—	4	0.49	**0.15**	1.35	—	—	—
Chromium	0.09	—	—	—	—	—	—	—	**0.00631**	—	—	—
Cobalt	na	—	—	—	—	—	—	—	0.406	—	—	—
Copper	14	—	—	—	—	—	—	—	54.1	—	—	—
Lead	3.16	46	170	—	—	**0.5**	**0.5**	**0.12**	—	—	—	—
Mercury	0.15	0.15	0.2	—	—	0.4	**0.049**	**0.088**	0.406	**0.13**	**0.04**	**0.012**
Nickel	0.042	—	—	—	—	—	—	—	27	—	—	—
Selenium	0.18	0.46	0.88	—	—	20	2.5	**0.024**	6.76	6.5	2	0.6
Silver	0.009	—	—	—	—	—	—	—	6.76	—	—	—
Zinc	14	—	—	—	—	—	—	—	406	—	—	—
Butyltins												
Tributyltin	0.003	96	26	—	—	1.2	0.015	0.055	0.406	0.39	0.12	0.036
LPAH												
Acenaphthene[2]	0.006	—	—	—	—	—	—	—	81.1	—	—	—
Acenaphthylene[2]	0.008	—	—	—	—	—	—	—	—	—	—	—
Anthracene	0.003	—	—	—	—	—	—	—	406	—	—	—
Fluorene[2]	0.008	—	—	—	—	—	—	—	54.1	52	16	4.8
2-Methylnaphthalene[2]	0.022	—	—	—	—	—	—	—	5.41	—	—	—
Naphthalene[2]	0.022	—	—	—	—	—	—	—	27	—	—	—
Phenanthrene	0.028	—	—	—	—	—	—	—	—	—	—	—
Total LPAH	0.031	—	—	—	—	—	—	—	—	—	—	—
HPAH												
Benzo(a)anthracene	0.019	—	—	—	—	—	—	—	**0.00432**	—	—	—
Benzo(a)pyrene	0.017	—	—	—	—	—	—	—	**0.000432**	—	—	—
Benzo(b)fluoranthene	0.011	—	—	—	—	—	—	—	**0.00432**	—	—	—
Benzo(k)fluoranthene	0.015	—	—	—	—	—	—	—	0.0432	—	—	—
Benzo(g,h,i)perylene[2]	0.014	—	—	—	—	—	—	—	—	—	—	—
Chrysene	0.033	—	—	—	—	—	—	—	0.432	—	—	—
Dibenzo(a,h)anthracene[2]	0.022	—	—	—	—	—	—	—	**0.000432**	—	—	—
Fluoranthene	0.01	—	950	—	—	160	20	19	54.1	52	16	4.8
Indeno(1,2,3-cd)pyrene[2]	0.014	—	—	—	—	—	—	—	**0.00432**	—	—	—
Pyrene	0.111	—	47000	—	—	120	15	1	40.6	39	12	3.6
Total HPAH	0.244	—	—	—	—	—	—	—	—	—	—	—
Total PAH	0.275	—	—	—	—	—	—	—	—	—	—	—
Phthalates												
Bis(2-Ethylhexy)lphthalate	0.022	—	—	—	—	—	—	—	0.225	—	—	—
Butylbenzyl phthalate[2]	0.008	—	—	—	—	—	—	—	1.66	—	—	—
Di-n-butylphthalate[2]	0.014	—	—	—	—	—	—	—	135	—	—	—
Diethylphthalate[2]	0.014	—	—	—	—	—	—	—	1080	—	—	—
Dimethylphthalate[2]	0.006	—	—	—	—	—	—	—	—	—	—	—
Di-n-octylphthalate[2]	0.008	—	—	—	—	—	—	—	—	—	—	—
Phenols												
2,4-Dimethylphenol[2]	0.014	—	—	—	—	—	—	—	27	—	—	—
4-Methylphenol[2]	0.014	—	—	—	—	—	—	—	—	—	—	—
Pentachlorophenol[2]	0.014	—	1.8	0.078	**0.0096**	120	15	0.17	0.0263	0.025	**0.0033**	**0.000075**
Phenol	7.88	—	—	—	—	—	—	—	406	—	—	—
Misc. Extractables												
Benzoic Acid	0.3	—	—	—	—	—	—	—	5410	—	—	—
Carbazole[2]	0.014	—	—	—	—	—	—	—	—	—	—	—
Dibenzofuran[2]	0.014	—	—	—	—	—	—	—	1.35	—	—	—
Retene	na	—	—	—	—	—	—	—	—	—	—	—
Volatile Organic Compounds												
Benzene	na	—	—	—	—	—	—	—	0.0574	—	—	—
1,2,4-Trimethylbenzene	na	—	—	—	—	—	—	—	—	—	—	—
Ethylbenzene	na	—	—	—	—	—	—	—	0.287	—	—	—
Isopropylbenzene	na	—	—	—	—	—	—	—	—	—	—	—
Chloroform	na	—	—	—	—	—	—	—	0.102	—	—	—
1,1,1-Trichloroethane	na	—	—	—	—	—	—	—	2700	—	—	—
2-Hexanone	na	—	—	—	—	—	—	—	6.76	—	—	—
Toluene	na	—	—	—	—	—	—	—	108	—	—	—
Total Xylenes	na	—	—	—	—	—	—	—	270	—	—	—
Pesticides/PCBs												
Chlordane[2]	0.004	6.1	6.7	0.027	**0.0033**	2	0.25	0.06	0.00901	0.0086	**0.0011**	**0.00034**
DDD[2]	0.0005	—	—	—	—	—	—	0.054	0.0131	—	—	—
DDT[2]	0.0005	0.15	2.9	0.027	0.0034	2	0.25	0.054	0.00928	0.0089	0.0012	**0.00035**
Aroclor 1254	0.11	—	—	—	—	—	—	—	**0.00158**	—	—	—
Aroclor 1260	0.118	—	—	—	—	—	—	—	**0.00158**	—	—	—
Total PCBs	0.262	3.4	1.7	**0.0047**	**0.00057**	**0.08**	**0.0098**	0.43	—	**0.0015**	**0.0002**	**0.00006**

Notes:

Bold represents an exceedance (maximum tissue concentration exceeds screening criteria).

— Indicates no criterion.

[1] Maximum concentration from crayfish tissue samples 870812 , 840912 (raw,whole), 9101514, and L12005-4 (tails, cleaned).

[2] Value is one-half of the maximum method detection limit.

[3] Oregon DEQ ATLs and CTLs from Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment (Pub. No. 07-LQ-023A; ODEQ April 2007).

[4] USEPA Region 3 RSL Fish Ingestion Supporting Table, as queried from http://www.epa.gov/reg3hwmd/risk/human/pdf/MAY_2010_FISH.pdf.

[5] Northwest Regional Sediment Evaluation Framework Final Sediment Quality Guidelines BCOCs (RSET May 2009).

ATL: Acceptable tissue level
BCOC: Bioaccumulative chemical of concern
CTL: Critical tissue level
DDD: Dichlorodiphenyldichloroethane
DDT: Dichlorodiphenyltrichloroethane
HPAH: High-molecular weight polycyclic aromatic hydrocarbon
LPAH: Low-molecular weight polycyclic aromatic hydrocarbon
na: Not applicable
Oregon: Oregon Department of Environmental Quality
PAH: Polycyclic aromatic hydrocarbon
PCB: Polychlorinated biphenyl
RSL: Regional screening level
RSET: Northwest Regional Sediment Evaluation Framework
SEF: Sediment Evaluation Framework
TTL: Target tissue level
USEPA: U.S. Environmental Protection Agency

Table 3-6b Finfish Tissue Screening

Chemical of Potential Concern	Maximum Tissue Concentration[1] (mg/kg)	Oregon DEQ 2007[3] Acceptable Tissue Levels (mg/kg ww) Consumption by Bird Populations	Consumption by Wildlife Populations	Carcinogens - Consumption by Humans - Recreational	Carcinogens - Consumption by Humans - Tribal	Non-Carcinogens - Consumption by Humans - Recreational	Non-Carcinogens - Consumption by Humans - Tribal	Critical Tissue Levels (mg/kg ww) Freshwater Organism	USEPA Region 3 Fish Tissue Consumption RSL[4] (mg/kg)	SEF Bioaccumulative Chemicals of Concern[5] (mg/kg ww) Human Health TTL1	Human Health TTL2	Human Health TTL3
Conventionals/Misc												
Total Cyanide	na	—	—	—	—	—	—	—	27	—	—	—
Metals												
Antimony[2]	0.15	—	—	—	—	—	—	—	0.541	—	—	—
Arsenic	0.11	64	38	**0.0062**	**0.000076**	1.2	0.15	6.6	**0.0021**	**0.002**	**0.00027**	**0.00008**
Cadmium[2]	0.004	42	28	—	—	4	0.49	0.15	1.35	—	—	—
Chromium	0.337	—	—	—	—	—	—	—	**0.00631**	—	—	—
Cobalt	na	—	—	—	—	—	—	—	0.406	—	—	—
Copper	0.39	—	—	—	—	—	—	—	54.1	—	—	—
Lead	0.1	46	170	—	—	0.5	0.5	0.12	—	—	—	—
Mercury	0.18	**0.15**	0.2	—	—	0.4	**0.049**	**0.088**	0.406	**0.13**	**0.04**	**0.012**
Nickel[2]	0.05	—	—	—	—	—	—	—	27	—	—	—
Selenium	0.18	0.46	0.88	—	—	20	2.5	**0.024**	6.76	6.5	2	0.6
Silver[2]	0.004	—	—	—	—	—	—	—	6.76	—	—	—
Zinc	9.9	—	—	—	—	—	—	—	406	—	—	—
Butyltins												
Tributyltin	0.093	96	26	—	—	1.2	**0.015**	**0.055**	0.406	0.39	0.12	**0.036**
LPAH												
Acenaphthene[2]	0.006	—	—	—	—	—	—	—	81.1	—	—	—
Acenaphthylene[2]	0.008	—	—	—	—	—	—	—	—	—	—	—
Anthracene[2]	0.008	—	—	—	—	—	—	—	406	—	—	—
Fluorene[2]	0.008	—	—	—	—	—	—	—	54.1	52	16	4.8
2-Methylnaphthalene[2]	0.022	—	—	—	—	—	—	—	5.41	—	—	—
Naphthalene[2]	0.022	—	—	—	—	—	—	—	27	—	—	—
Phenanthrene[2]	0.008	—	—	—	—	—	—	—	—	—	—	—
Total LPAH	0.022	—	—	—	—	—	—	—	—	—	—	—
HPAH												
Benzo(a)anthracene[2]	0.008	—	—	—	—	—	—	—	**0.00432**	—	—	—
Benzo(a)pyrene[2]	0.014	—	—	—	—	—	—	—	**0.000432**	—	—	—
Benzo(b)fluoranthene[2]	0.022	—	—	—	—	—	—	—	**0.00432**	—	—	—
Benzo(k)fluoranthene[2]	0.022	—	—	—	—	—	—	—	0.0432	—	—	—
Benzo(g,h,i)perylene[2]	0.014	—	—	—	—	—	—	—	—	—	—	—
Chrysene[2]	0.008	—	—	—	—	—	—	—	0.432	—	—	—
Dibenzo(a,h)anthracene[2]	0.022	—	—	—	—	—	—	—	**0.000432**	—	—	—
Fluoranthene[2]	0.008	—	950	—	—	160	20	19	54.1	52	16	4.8
Indeno(1,2,3-cd)pyrene[2]	0.014	—	—	—	—	—	—	—	**0.00432**	—	—	—
Pyrene[2]	0.008	—	47000	—	—	120	15	1	40.6	39	12	3.6
Total HPAH	0.022	—	—	—	—	—	—	—	—	—	—	—
Total PAHs	0.022	—	—	—	—	—	—	—	—	—	—	—
Phthalates												
Bis(2-Ethylhexylphthalate)	0.008	—	—	—	—	—	—	—	0.225	—	—	—
Butylbenzylphthalate[2]	0.008	—	—	—	—	—	—	—	1.66	—	—	—
Di-n-butylphthalate[2]	0.014	—	—	—	—	—	—	—	135	—	—	—
Diethylphthalate[2]	0.014	—	—	—	—	—	—	—	1080	—	—	—
Dimethylphthalate[2]	0.006	—	—	—	—	—	—	—	—	—	—	—
Di-n-octylphthalate[2]	0.008	—	—	—	—	—	—	—	—	—	—	—
Phenols												
2,4-Dimethylphenol[2]	0.014	—	—	—	—	—	—	—	27	—	—	—
4-Methylphenol[2]	0.014	—	—	—	—	—	—	—	—	—	—	—
Pentachlorophenol	0.014	—	1.8	0.078	**0.0096**	120	15	0.17	0.0263	0.025	**0.0033**	**0.000075**
Phenol[2]	0.055	—	—	—	—	—	—	—	406	—	—	—
Misc. Extractables												
Benzoic Acid	0.14	—	—	—	—	—	—	—	5410	—	—	—
Carbazole[2]	0.014	—	—	—	—	—	—	—	—	—	—	—
Dibenzofuran[2]	0.014	—	—	—	—	—	—	—	1.35	—	—	—
Retene	na	—	—	—	—	—	—	—	—	—	—	—
Volatile Organic Compounds												
Benzene	na	—	—	—	—	—	—	—	0.0574	—	—	—
1,2,4-Trimethylbenzene	na	—	—	—	—	—	—	—	—	—	—	—
Ethylbenzene	na	—	—	—	—	—	—	—	0.287	—	—	—
Isopropylbenzene	na	—	—	—	—	—	—	—	—	—	—	—
Chloroform	na	—	—	—	—	—	—	—	0.102	—	—	—
1,1,1-Trichloroethane	na	—	—	—	—	—	—	—	2700	—	—	—
2-Hexanone	na	—	—	—	—	—	—	—	6.76	—	—	—
Toluene	na	—	—	—	—	—	—	—	108	—	—	—
Total Xylenes	na	—	—	—	—	—	—	—	270	—	—	—
Pesticides/PCBs												
Chlordane[2]	0.004	6.1	6.7	0.027	**0.0033**	2	0.25	0.06	0.00901	0.0086	**0.0011**	**0.00034**
DDD[2]	0.0005	—	—	—	—	—	—	0.054	0.0131	—	—	—
DDT[2]	0.0005	0.15	2.9	0.027	0.0034	2	0.25	0.054	0.00928	0.0089	0.0012	**0.00035**
Aroclor 1254	0.009	—	—	—	—	—	—	—	**0.00158**	—	—	—
Aroclor 1260[2]	0.007	—	—	—	—	—	—	—	**0.00158**	—	—	—
Total PCBs	0.009	3.4	1.7	**0.0047**	**0.00057**	0.08	0.0098	0.43	—	**0.0015**	**0.0002**	**0.00006**

Notes:

Bold represents an exceedance (maximum tissue concentration exceeds screening criteria).

— Indicates no criterion.

[1] Maximum concentration from fish tissue samples 9101820, 9101821, L12005-2, L12005-3, L17433-4, and L17433-5 (King County Database 1991).

[2] Value is one-half of the maximum method detection limit.

[3] Oregon DEQ ATLs and CTLs from Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment (Pub. No. 07-LQ-023A; ODEQ April 2007).

[4] USEPA Region 3 RSL Fish Ingestion Supporting Table, as queried from http://www.epa.gov/reg3hwmd/risk/human/pdf/MAY_2010_FISH.pdf.

[5] Northwest Regional Sediment Evaluation Framework Final Sediment Quality Guidelines BCOCs (RSET May 2009).

ATL: Acceptable tissue level

BCOC: Bioaccumulative chemical of concern

CTL: Critical tissue level

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

na: Not applicable

Oregon: Oregon Department of Environmental Quality

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

RSL: Regional screening level

RSET: Northwest Regional Sediment Evaluation Framework

SEF: Sediment Evaluation Framework

TTL: Target tissue level

USEPA: U.S. Environmental Protection Agency

Table 3-7 COPC Metals Comparison to Natural Background Soil Concentrations

A) Using Maximum Concentration

Possible COPC	GWSA Maximum Concentration (mg/kg)	*GWSA Average Concentration (mg/kg)*	Ecology Natural Background Soil Metals Concentrations[1]	
			Puget Sound Group	
			90th Percentile (mg/kg)	Does GWSA Maximum Exceed 90th?
Aluminum [2]	121000	*16400*	32581	Yes
Antimony	19	*4*	NA	NA
Arsenic (AA)	2400	*76*	7.3	Yes
Arsenic (ICP)	2400	*76*	22.8	Yes
Cadmium	4.0	*1.0*	0.77	Yes
Chromium	250	*49*	48.15	Yes
Cobalt	240	*54.2*	NA	NA
Copper	1050	*138*	36.36	Yes
Iron	33600	*24300*	**36128**	**No**
Lead	1100	*210*	16.83	Yes
Mercury	3.3	*0.83*	0.07	Yes
Nickel	630	*63*	38.19	Yes
Selenium	2.3	*0.98*	NA	NA
Silver	9.0	*1.8*	NA	NA
Vanadium	130	*64*	NA	NA
Zinc	1400	*220*	85.06	Yes

B) Using Average Concentration

Possible COPC	*GWSA Maximum Concentration (mg/kg)*	GWSA Average Concentration (mg/kg)	Ecology Natural Background Soil Metals Concentrations[1]	
			Puget Sound Group	
			90th Percentile (mg/kg)	Does GWSA Average Exceed 90th?
Aluminum [2]	*121000*	16400	**32581**	**No**
Antimony	*19*	4	NA	NA
Arsenic (AA)	*2400*	76	7.3	Yes
Arsenic (ICP)	*2400*	76	22.8	Yes
Cadmium	*4.0*	1.0	0.77	Yes
Chromium	*250*	49	48.15	Yes
Cobalt	*240*	54.2	NA	NA
Copper	*1050*	138	36.36	Yes
Iron	*33600*	24300	**36128**	**No**
Lead	*1100*	210	16.83	Yes
Mercury	*3.3*	0.83	0.07	Yes
Nickel	*630*	63	38.19	Yes
Selenium	*2.3*	0.98	NA	NA
Silver	*9.0*	1.8	NA	NA
Vanadium	*130*	64	NA	NA
Zinc	*1400*	220	85.06	Yes

Notes:

Bold indicates GWSA sediment concentration is below Puget Sound Group natural soil background concentrations.

[1] Ecology background values (1994):
http://www.ecy.wa.gov/pubs/94115.pdf
Table 7 (page 6-4 of report; page 37 of pdf)

[2] Note that 95 of the 96 samples analyzed for aluminum are below natural background concentrations; only one older sample (USEPA 1995) exceeds the 90th percentile Puget Sound Group natural background soil concentrations.

COPC: Chemical of potential concern

Ecology: Washington State Department of Ecology

GWSA: Gas Works Sediment Area

NA: Not applicable; no value given

Table 3-8 Revised COPC List

Draft RI/FS Lists		Revised COPC List
GWS-ESA	**GWS-WSA**	
SVOCs - PAHs (20^)	***SVOCs - PAHs (20^)***	***SVOCs - PAHs (20^)***
16 PAHs for TPAH	16 PAHs for TPAH	16 PAHs for TPAH
SVOC - other (13)	***SVOC - other (4)***	***SVOC - other (14)***
		Benzoic Acid #
Carbazole	Carbazole	Carbazole
Dibenzofuran		Dibenzofuran
		Retene #
Dimethylphthalate *		Dimethylphthalate
Diethylphthalate *		Diethylphthalate
Di-n-butylphthalate *	Di-n-butylphthalate	Di-n-butylphthalate
Butylbenzylphthalate *		Butylbenzylphthalate
Bis(2-Ethylhexyl)phthalate *	Bis(2-Ethylhexyl)phthalate	Bis(2-Ethylhexyl)phthalate
Di-n-octyl Phthalate *		Di-n-octyl Phthalate
Phenol	Phenol	Phenol
2-Methylphenol *		
4-Methylphenol *		4-Methylphenol
2,4-Dimethylphenol		2,4-Dimethylphenol
Pentachlorophenol *		Pentachlorophenol
VOCs (4)	***VOCs (3)***	***VOCs (5)***
Benzene	Benzene	Benzene
		1,2,4-Trimethylbenzene #
Ethylbenzene	Ethylbenzene	Ethylbenzene
Toluene	Toluene	Toluene
Xylenes		Xylenes
Metals (10)	***Metals (9)***	***Metals (13)***
Antimony *	Antimony	Antimony
Arsenic	Arsenic	Arsenic
Cadmium *	Cadmium	Cadmium
Chromium *		Chromium
		Cobalt #
Copper *	Copper	Copper
Lead *	Lead	Lead
Mercury *	Mercury	Mercury
Nickel *	Nickel	Nickel
		Selenium #
Silver *	Silver	Silver
		Vanadium #
Zinc *	Zinc	Zinc
Other (4[&])	***Other (2)***	***Other (8)***
Pesticides *		Chlordane
		DDD
		DDT
Cyanide		Cyanide
Total PCBs *	Total PCBs	Total PCBs; Aroclors 1254 and 1260
Tributyltin *	Tributyltin	Tributyltin
Total COPCs: 51	**38**	**60**

Notes:

* Indicates GWS-ESA Draft RI/FS Supplemental List.

COPC not previously listed.

^ TPAH, LPAH, HPAH, and 2-methylnaphthalene are included in the PAH count. Total benzofluoranthenes are not counted as a separate COPC.

& Pesticides, as a group, is counted as "1."

COPC: Chemical of potential concern

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

GWS-ESA: Gas Works Sediment - Eastern Study Area

GWS-WSA: Gas Works Sediment - Western Study Area

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

RI/FS: Remedial investigation/feasibility study

SVOC: Semivolatile organic compound

TPAH: Total polycyclic aromatic hydrocarbons

VOC: Volatile organic compound

Table 4-1 Eastern Shoreline Surface Sediment (0–10 cm) Concentrations[1]

Chemical of Potential Concern	Mean Concentration (mg/kg)	Maximum Concentration (mg/kg)
Conventionals/Misc.		
Total Cyanide	34	170
Metals		
Antimony[2]	6.8	20
Arsenic	20	70
Cadmium	0.86	3
Chromium[3]	38	63
Cobalt	7.4	7.4
Copper	128	408
Lead	89	240
Mercury	0.43	0.78
Nickel	160	270
Selenium	0.25	0.25
Silver	0.64	2.0
Vanadium	130	130
Zinc	279	909
Butyltins		
Tributyltin	0.11	0.25
LPAH		
Acenaphthene	7.1	40
Acenaphthylene	5.2	16
Anthracene	9.3	45
Fluorene	5.5	20
2-Methylnaphthalene	6.3	32
Naphthalene	21	98
Phenanthrene	31	120
Total LPAH	79	340
HPAH		
Benzo(a)anthracene	18	60
Benzo(a)pyrene	24	77
Benzo(b)fluoranthene	19	58
Benzo(k)fluoranthene	17	47
Benzo(g,h,i)perylene	17	57
Chrysene	20	68
Dibenzo(a,h)anthracene	3.3	14
Indeno(1,2,3-cd)pyrene	18	60
Fluoranthene	40	140
Pyrene	49	150
Retene	1.1	1.8
Total HPAH	250	730
Total PAH	300	1100
Phthalates		
Bis(2-Ethylhexyl)phthalate	0.68	1.6
Butylbenzylphthalate[2]	0.14	0.19
Di-n-butylphthalate[2]	0.61	2.7
Diethylphthalate[2]	0.14	0.19
Dimethylphthalate[2]	0.14	0.19
Di-n-octylphthalate[2]	0.14	0.19
Phenols		
2,4-Dimethylphenol[2]	0.094	0.19
4-Methylphenol	0.12	0.16
Pentachlorophenol[2]	0.47	0.90
Phenol	0.16	0.65
Misc. Extractables		
Benzoic Acid	1.6	3.4
Carbazole	1.3	5.5
Dibenzofuran	1.2	4.7
Volatile Organic Compounds		
Benzene[4]	0.0030	0.0030
Ethylbenzene[4]	0.0020	0.0020
Toluene[4]	0.016	0.016
Total Xylenes[4]	0.0027	0.0027
1,2,4-Trimethylbenzene[2,5]	17	17
Pesticides/PCBs		
Chlordane[2]	0.0039	0.010
DDD[2]	0.0082	0.020
DDT[2]	0.0096	0.020
PCB Aroclor 1254	0.050	0.050
PCB Aroclor 1260[4]	0.020	0.020
Total PCBs	0.065	0.090

Notes:

[1] Mean and maximum concentrations were derived from surface sediment samples 95042153 and 95042155 (USEPA 1995), and NLU53, NLU55, NLU58, NLU77, NLU78 (RETEC 2004a), NLU55-TX, NLU60 (RETEC 2006). Arithmetic mean calculation includes non-detects at half of the detection limit.

[2] Result reported as non-detect; therefore, half of the maximum reporting limit is designated the maximum exposure point concentration.

[3] For the purpose of risk calculations, chromium concentrations are assumed to be in a ratio of 1:6 for chromium VI:chromium III.

[4] Arithemetic mean calculation including non-detects resulted in a mean concentration above the maximum detected concentration. Mean concentration was defaulted to maximum.

[5] No result available for the beach play sample set; only one surface sediment result available across the entire GWSA. That value used as both maximum and mean.

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

GWSA: Gas Works Sediment Area

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyls

Table 4-2 Crayfish Tissue Concentrations[1]

Chemical of Potential Concern	Mean Concentration (mg/kg wet weight)	Maximum Concentration (mg/kg wet weight)
Conventionals/Misc.		
Total Cyanide	na	na
Metals		
Antimony[2]	0.16	0.30
Arsenic	0.40	0.57
Cadmium	0.13	0.37
Chromium[3]	0.055	0.090
Cobalt	na	na
Copper	7.81	14
Lead	1.1	3.2
Mercury	0.097	0.15
Nickel[4]	0.042	0.042
Selenium[4]	0.18	0.18
Silver	0.0090	0.0090
Vanadium	na	na
Zinc	13	14
Butyltins		
Tributyltin	0.0030	0.0030
LPAH		
Acenaphthene[2]	0.0038	0.0055
Acenaphthylene[2]	0.0055	0.0080
Anthracene[4]	0.0030	0.0030
Fluorene[2]	0.0055	0.0080
2-Methylnaphthalene[2]	0.015	0.022
Naphthalene[2]	0.015	0.022
Phenanthrene	0.013	0.028
Total LPAH	0.020	0.031
HPAH		
Benzo(a)anthracene	0.010	0.019
Benzo(a)pyrene	0.012	0.017
Benzo(b)fluoranthene[4]	0.011	0.011
Benzo(k)fluoranthene	0.015	0.015
Benzo(g,h,i)perylene[2]	0.0095	0.014
Chrysene	0.015	0.033
Dibenzo(a,h)anthracene[2]	0.015	0.022
Fluoranthene	0.0072	0.010
Indeno(1,2,3-cd)pyrene[2]	0.0095	0.014
Pyrene	0.041	0.11
Retene	na	na
Total HPAH	0.082	0.22
Total PAH	0.092	0.25

Table 4-2 Crayfish Tissue Concentrations[1]

Chemical of Potential Concern	Mean Concentration (mg/kg wet weight)	Maximum Concentration (mg/kg wet weight)
Phthalates		
Bis(2-Ethylhexy)lphthalate	0.013	0.022
Butylbenzyl phthalate[2]	0.0055	0.0080
Di-n-butylphthalate[2]	0.0095	0.014
Diethylphthalate[2]	0.0095	0.014
Dimethylphthalate[2]	0.0035	0.0055
Di-n-octylphthalate[2]	0.0055	0.0080
Phenols		
2,4-Dimethylphenol[2]	0.0095	0.014
4-Methylphenol[2]	0.0095	0.014
Pentachlorophenol[2]	0.0095	0.014
Phenol	3.9	7.9
Misc. Extractables		
Benzoic Acid	0.18	0.30
Carbazole[2]	0.0095	0.014
Dibenzofuran[2]	0.0095	0.014
Volatile Organic Compounds		
Benzene	na	na
Ethylbenzene	na	na
Toluene	na	na
Total Xylenes	na	na
1,2,4-Trimethylbenzene	na	na
Pesticides/PCBs		
Chlordane[2]	0.0023	0.0035
DDD[2]	0.00035	0.00050
DDT[2]	0.00035	0.00050
Aroclor 1254	0.040	0.11
Aroclor 1260	0.042	0.12
Total PCBs	0.070	0.26

Notes:

[1] Maximum concentration from crayfish tissue samples 870812 , 840912 (raw,whole), 9101514, and L12005-4 (tails, cleaned). Arithmetic mean calculation includes non-detects at half of the detection limit.

[2] Value is one-half of the maximum method detection limit.

[3] For the purpose of risk calculations, chromium concentrations are assumed to be in a ratio of 1:6 for chromium VI to chromium III.

[4] Arithemetic mean calculation including non-detects resulted in a mean concentration above the maximum detected concentration. Mean concentration was defaulted to maximum.

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

na: Not available

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

Table 4-3 Finfish Tissue Concentrations[1]

Chemical of Potential Concern	Mean Concentration (mg/kg wet weight)	Maximum Concentration (mg/kg wet weight)
Conventionals/Misc		
Total Cyanide	na	na
Metals		
Antimony[2]	0.10	0.15
Arsenic[3]	0.11	0.11
Cadmium[2]	0.0028	0.004
Chromuim[4]	0.17	0.34
Cobalt	na	na
Copper	0.32	0.39
Lead	0.032	0.10
Mercury	0.12	0.18
Nickel[2]	0.037	0.050
Selenium	0.31	0.60
Silver[2]	0.0023	0.0040
Vanadium	na	na
Zinc	6.6	9.9
Butyltins		
Tributyltin	0.093	0.093
LPAH		
Acenaphthene[2]	0.0033	0.0055
Acenaphthylene[2]	0.0045	0.0080
Anthracene[2]	0.0045	0.0080
Fluorene[2]	0.0045	0.0080
2-Methylnaphthalene[2]	0.013	0.022
Naphthalene[2]	0.013	0.022
Phenanthrene[2]	0.0045	0.0080
Total LPAH[2]	0.013	0.022
HPAH		
Benzo(a)anthracene[2]	0.0045	0.0080
Benzo(a)pyrene[2]	0.0082	0.014
Benzo(b)fluoranthene[2]	0.013	0.022
Benzo(k)fluoranthene[2]	0.013	0.022
Benzo(g,h,i)perylene[2]	0.0082	0.014
Chrysene[2]	0.0045	0.0080
Dibenzo(a,h)anthracene[2]	0.013	0.022
Fluoranthene[2]	0.0048	0.0080
Indeno(1,2,3-cd)pyrene[2]	0.0082	0.014
Pyrene[2]	0.0045	0.0080
Retene	na	na
Total HPAH[2]	0.013	0.022
Total PAH[2]	0.013	0.022
Phthalates		
Bis(2-Ethylhexylphthalate)[2]	0.0045	0.0080
Butylbenzylphthalate[2]	0.0045	0.0080
Di-n-butylphthalate[2]	0.0082	0.014
Diethylphthalate[2]	0.0082	0.014
Dimethylphthalate[2]	0.0028	0.0055
Di-n-octylphthalate[2]	0.0045	0.0080

Table 4-3 Finfish Tissue Concentrations[1]

Chemical of Potential Concern	Mean Concentration (mg/kg wet weight)	Maximum Concentration (mg/kg wet weight)
Phenols		
2,4-Dimethylphenol[2]	0.0082	0.014
4-Methylphenol[2]	0.0082	0.014
Pentachlorophenol[2]	0.0082	0.014
Phenol[2]	0.029	0.055
Misc. Extractables		
Benzoic Acid	0.088	0.14
Carbazole[2]	0.0082	0.014
Dibenzofuran[2]	0.0082	0.014
Volatile Organic Compounds		
Benzene	na	na
Ethylbenzene	na	na
Toluene	na	na
Total Xylenes	na	na
1,2,4-Trimethylbenzene	na	na
Pesticides/PCBs		
Chlordane[2]	0.0033	0.0035
DDD[2]	0.00050	0.00050
DDT[2]	0.00050	0.00050
Aroclor 1254	0.0071	0.0090
Aroclor 1260[2]	0.0044	0.0065
Total PCBs	0.0071	0.0090

Notes:

[1] Maximum concentration from fish tissue samples 9101820, 9101821, L12005-2, L12005-3, L17433-4, and L17433-5 (King County Database 1991). Arithmetic mean calculation includes non-detects at half of the detection limit.

[2] Non-detected results; one-half of the maximum method detection limit has been employed in calculations.

[3] Arithemetic mean calculation including non-detects resulted in a mean concentration above the maximum detected concentration. Mean concentration was defaulted to maximum.

[4] For the purpose of risk calculations, chromium concentrations are assumed to be in a ratio of 1:6 for chromium VI to chromium III.

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

na: Not available

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

Table 4-4 Surface Sediment (0–10 cm) Concentrations in GWSA[1]

Chemical of Potential Concern	Mean Concentration (mg/kg)	Maximum Concentration (mg/kg)
Conventionals/Misc.		
Total Cyanide	13	170
Metals		
Antimony	5.2	19
Arsenic	82	2400
Cadmium	1.9	4
Chromium[2]	64	250
Cobalt	54	240
Copper	291	1050
Lead	320	1100
Mercury	0.91	2.3
Nickel	99	630
Selenium	0.82	2.3
Silver	1.9	4.5
Vanadium	64	130
Zinc	432	956
Butyltins		
Tributyltin	0.76	7.0
LPAH		
Acenaphthene	14	230
Acenaphthylene	4.2	79
Anthracene	15	320
Fluorene	8.3	130
2-Methylnaphthalene	4.6	58
Naphthalene	8.5	120
Phenanthrene	47	1300
Total LPAH	93	2100
HPAH		
Benzo(a)anthracene	29	700
Benzo(a)pyrene	43	1100
Benzo(b)fluoranthene	33	800
Benzo(k)fluoranthene	20	430
Benzo(g,h,i)perylene	31	1100
Chrysene	32	770
Dibenzo(a,h)anthracene	5.5	150
Fluoranthene	87	1900
Indeno(1,2,3-cd)pyrene	28	890
Pyrene	100	2200
Retene	2.0	12
Total HPAH	410	10000
Total PAH	500	11000
Phthalates		
Bis(2-Ethylhexyl)phthalate	1.7	6.5
Butylbenzylphthalate	0.31	0.66
Di-n-butylphthalate	4.6	37
Diethylphthalate	2.6	4.5
Dimethylphthalate	0.19	0.42
Di-n-octylphthalate	0.48	0.48

Table 4-4 Surface Sediment (0–10 cm) Concentrations in GWSA[1]

Chemical of Potential Concern	Mean Concentration (mg/kg)	Maximum Concentration (mg/kg)
Phenols		
2,4-Dimethylphenol	0.12	0.17
4-Methylphenol	0.45	1.5
Pentachlorophenol	0.23	0.46
Phenol	0.62	1.9
Misc. Extractables		
Benzoic Acid	2.2	4.0
Carbazole	1.2	6.1
Dibenzofuran	2.1	34
Volatile Organic Compounds		
Benzene	3.1	34
Ethylbenzene	0.42	5.8
Toluene	0.0060	0.016
Total Xylenes	0.14	2.3
1,2,4-Trimethylbenzene[3,4]	17	17
Pesticides/PCBs		
Chlordane	0.11	0.12
DDD	0.020	0.089
DDT[3,4]	0.020	0.020
PCB Aroclor 1254	0.11	0.48
PCB Aroclor 1260	0.080	0.30
Total PCBs	0.17	0.70

Notes:

[1] Samples include all surface samples (0-10 cm) in the GWSA. Mean was calculated using the MTCA Stat software. MTCA Stat calculations do not incorporate non-detect results. This approach is not consistent with the calculation of averages in the beach play and fish ingestion scenarios, as these calculations do incorporate non-detect results.

[2] For the purpose of risk calculations, chromium concentrations are assumed to be in a ratio of 1:6 for chromium VI to chromium III.

[3] Mean could not be calculated in MTCA Stat as all results were non-detect. Mean concentration was defaulted to maximum.

[4] Result reported as non-detect; therefore, half of the maximum reporting limit is designated the maximum exposure point concentration.

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

GWSA: Gas Works Sediment Area

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

Table 4-5 Beach Play/Wading Parameters: Incidental Sediment Ingestion

Parameter	Units	Receptor	CT Scenario	Reference/Rationale	RME Scenario	Reference/Rationale
Maximum (RME) or Average (CT) Concentrations in Sediments (C)	mg/kg		Refer to Table 4-1		Refer to Table 4-1	
Exposure Frequency (EF)	days/year	Adult	8	Parametrix 2003. Table 15: 50th percentile, playing/digging in sand (in water).	81	Parametrix 2003. Table 15: 95th percentile, playing/digging in sand (in water).
		Child (0–6 years)	10	Parametrix 2003. Table 17: 50th percentile, playing/digging in sand (in water).	65	Parametrix 2003. Table 17: 95th percentile, playing/digging in sand (in water).
Exposure Duration (ED)	years	Adult	9	USEPA 1997a.	30	USEPA 1989.
		Child (0–6 years)	3		6	
Ingestion Rate (IR)	mg/day	Adult	50	USEPA 1997a. Recommended central tendency estimate.	100	USEPA 2002a. Default residential exposure factor.
		Child (0–6 years)	100		200	
Fractional Intake (fraction of sediment ingested derived from site) (FI)	unitless	Adult and Child	1	Conservative assumption that all sediment consumed is derived from the Site.	1	Conservative assumption that all sediment consumed is derived from the Site.
Unit Conversion Factor (CF)	kg/mg	Adult and Child	0.000001		0.000001	
Averaging Time (AT)	days	Adult—carcinogenic	25,550	USEPA 1989. Assumes carcinogenic effects may occur every day for a lifetime of 70 years.	25,550	USEPA 1989. Assumes carcinogenic effects may occur every day for a lifetime of 70 years.
		Child (0–6 years) — carcinogenic	25,550		25,550	
		Adult—non-carcinogenic	10,950	USEPA 1989.	10,950	USEPA 1989.
		Child (0–6 years) — non-carcinogenic	2,190		2,190	
Body Weight (BW)	kg	Adult	70	USEPA 1989.	70	USEPA 1989.
		Child (0–6 years)	15		15	

Notes:

CT: Central Tendency

RME: Reasonable Maximum Exposure

USEPA: U.S. Environmental Protection Agency

Table 4-6 Beach Play/Wading Parameters: Sediment Dermal Contact

Parameter	Units	Receptor	CT Scenario	Reference/Rationale	RME Scenario	Reference/Rationale
Maximum (RME) or Average (CT) Concentrations in Sediments (C)	mg/kg		Refer to Table 4-1		Refer to Table 4-1	
Exposure Frequency (EF)	days/year	Adult	8	Parametrix 2003. Table 15: 50th percentile, playing/digging in sand (in water).	81	Parametrix 2003. Table 15: 95th percentile, playing/digging in sand (in water).
		Child (0–6 years)	10	Parametrix 2003. Table 17: 50th percentile, playing/digging in sand (in water).	65	Parametrix 2003. Table 17: 95th percentile, playing/digging in sand (in water).
Exposure Duration (ED)	years	Adult	9	USEPA 1997a.	30	USEPA 1989.
		Child (0–6 years)	3		6	
Skin Surface Area Exposed (SA)	cm^2	Adult	5,700	USEPA 2004. Exposed skin surface is limited to the head, hands, forearms, and lower legs, recommended for recreational use.	5,700	USEPA 2004. Exposed skin surface is limited to the head, hands, forearms, and lower legs, recommended for recreational use.
		Child (0–6 years)	2,800		2,800	
Adherence Factor (AF)	mg/cm^2-event	Adult	0.01	USEPA 2004. Recommended CT factors, residential.	0.07	USEPA 2004. Recommended RME factors, residential.
		Child (0–6 years)	0.04		0.2	
Dermal Absorption Factor (ABS)	unitless		Refer to Table 4-11		Refer to Table 4-11	
Fractional Intake (fraction of sediment derived from site) (FI)	unitless	Adult and Child	1	Conservative assumption that all sediment contacted is derived from the Site.	1	Conservative assumption that all sediment contacted is derived from the Site.
Unit Conversion Factor (CF)	kg/mg	Adult and Child	0.000001		0.000001	
Averaging Time (AT)	days	Adult—carcinogenic	25,550	USEPA 1989. Assumes carcinogenic effects may occur every day for a lifetime of 70 years.	25,550	USEPA 1989. Assumes carcinogenic effects may occur every day for a lifetime of 70 years.
		Child (0–6 years)—carcinogenic	25,550		25,550	
		Adult—non-carcinogenic	10,950	USEPA 1989.	10,950	USEPA 1989.
		Child (0–6 years)—non-carcinogenic	2190		2190	
Body Weight (BW)	kg	Adult	70	USEPA 1989.	70	USEPA 1989.
		Child (0–6 years)	15		15	

Notes:

CT: Central Tendency

RME: Reasonable Maximum Exposure

USEPA: U.S. Environmental Protection Agency

Table 4-7 Recreational Parameters: Fish Consumption

Parameter	Units	Receptor	CT Scenario	Reference/Rationale	RME Scenario	Reference/Rationale
Maximum (RME) or Average (CT) Concentrations in Crayfish (C)	mg/kg		Refer to Table 4-2		Refer to Table 4-2	
Maximum (RME) or Average (CT) Concentrations in Finfish (C)	mg/kg		Refer to Table 4-3		Refer to Table 4-3	
Exposure Frequency (EF)	days/year	Adult	365	USEPA 2007a.	365	USEPA 2007a.
		Child (0–6 years)	365		365	
Exposure Duration (ED)	years	Adult	9	USEPA 1997a.	30	USEPA 1989.
		Child (0–6 years)	3		6	
Crayfish Ingestion Rate (IR)	g/day	Adult	2.85	Parametrix 2003. Table 31: 50th percentile for Lake Washington, split for crayfish and finfish.	27	MTCA, Ecology 2007.
		Child (0–6 years)	1.14	40% of adult ingestion rate, recommended by USEPA 2007.	10.8	40% of adult ingestion rate, recommended by USEPA 2007.
Finfish Ingestion Rate (IR)	g/day	Adult	2.85	Parametrix 2003. Table 31: 50th percentile for Lake Washington, split for crayfish and finfish.	27	MTCA, Ecology 2007.
		Child (0–6 years)	1.14	40% of adult ingestion rate, recommended by USEPA 2007.	10.8	40% of adult ingestion rate, recommended by USEPA 2007.
Fractional Intake (fraction of fish ingested derived from site) (FI)	unitless		0.25	Conservative assumption that 25% of fish consumed is derived from the Site.	0.5	MTCA, Ecology 2007.
Unit Conversion Factor (CF)	kg/g		0.001		0.001	
Averaging Time (AT)	days	Adult—carcinogenic	25,550	USEPA 1989. Assumes carcinogenic effects may occur every day for a lifetime of 70 years.	27,375	MTCA, Ecology 2007. Assumes carcinogenic effects may occur every day for a lifetime of 75 years, recommended by MTCA.
		Child (0–6 years)—carcinogenic	25,550		27,375	
		Adult—non-carcinogenic	10,950	USEPA 1989.	10,950	USEPA 1989.
		Child (0–6 years)—non-carcinogenic	2,190		2,190	
Body Weight (BW)	kg	Adult	70	USEPA 1989.	70	USEPA 1989.
		Child (0–6 years)	15		15	

Notes:

CT: Central Tendency

Ecology: Washington State Department of Ecology

MTCA: Washington State Model Toxics Control Act

RME: Reasonable Maximum Exposure

USEPA: U.S. Environmental Protection Agency

Table 4-8 Tribal Parameters: Fish Consumption

Parameter	Units	Receptor	CT Scenario	Reference/Rationale	RME Scenario	Reference/Rationale
Maximum (RME) or Average (CT) Concentrations in Crayfish (C)	mg/kg		Refer to Table 4-2		Refer to Table 4-2	
Maximum (RME) or Average (CT) Concentrations in Finfish (C)	mg/kg		Refer to Table 4-3		Refer to Table 4-3	
Exposure Frequency (EF)	days/year	Adult	365	USEPA 2007a.	365	USEPA 2007a.
		Child (0–6 years)	365		365	
Exposure Duration (ED)	years	Adult	30	USEPA 1989.	70	USEPA 2007a.
		Child (0–6 years)	6		6	
Crayfish Ingestion Rate (IR)	g/day	Adult	12.5	Windward, 2007.	81.9	USEPA 2007a. 95th percentile of shellfish consumption rate, Tulalip tribe.
		Child (0–6 years)	5	Assumed to be 40% of adult IR as per USEPA 2007a	32.8	Assumed to be 40% of adult IR as per USEPA 2007a.
Finfish Ingestion Rate (IR)	g/day	Adult	2.5	Windward, 2007.	15.6	USEPA 2007a. 95th percentile of finfish consumption rate (excluding salmon), Tulalip tribe.
		Child (0–6 years)	1	Assumed to be 40% of adult IR as per USEPA 2007a	6.2	Assumed to be 40% of adult IR as per USEPA 2007a.
Fractional Intake (fraction of fish ingested derived from site) (FI)	unitless		0.5	Conservative assumption that 50% of fish consumed is derived from the Site.	1	Conservative assumption that all fish consumed is derived from the Site.
Unit Conversion Factor (CF)	kg/g		0.001		0.001	
Averaging Time (AT)	days	Adult—carcinogenic	25,550	USEPA 1989. Assumes carcinogenic effects may occur every day for a lifetime of 70 years.	25,550	USEPA 1989. Assumes carcinogenic effects may occur every day for a lifetime of 70 years.
		Child (0–6 years)—carcinogenic	25,550		25,550	
		Adult—non-carcinogenic	10,950	USEPA 1989.	25,550	USEPA 2007a.
		Child (0–6 years)—non-carcinogenic	2,190		2,190	
Body Weight (BW)	kg	Adult	81.8	USEPA 2007a.	81.8	USEPA 2007a.
		Child (0–6 years)	15	USEPA 1989.	15	USEPA 1989.

Notes:

CT: Central Tendency

MTCA: Washington State Model Toxics Control Act

RME: Reasonable Maximum Exposure

USEPA: U.S. Environmental Protection Agency

Table 4-9 Netfishing Parameters: Incidental Sediment Ingestion

Parameter	Units	Receptor	CT Scenario	Reference/Rationale	RME Scenario	Reference/Rationale
Maximum (RME) or Average (CT) Concentration in Sediments (C)	mg/kg		Refer to Table 4-4		Refer to Table 4-4	
Exposure Frequency (EF)	days/year	Adult	63	Windward 2007 value, approved by Muckleshoot Indian Tribe.	119	Windward 2007 value, approved by Muckleshoot Indian Tribe.
Exposure Duration (ED)	years	Adult	29	Windward 2007 value, approved by Muckleshoot Indian Tribe.	44	Windward 2007 value, approved by Muckleshoot Indian Tribe.
Sediment Ingestion Rate (IR)	mg/day	Adult	50	USEPA 1991	50	USEPA 1991.
Fractional Intake (fraction of sediment ingested derived from site) (FI)	unitless	Adult	0.25	Conservative assumption that 25% of sediment consumed is derived from the Site; also used by Anchor and Aspect 2009.	0.25	Conservative assumption that 25% of sediment consumed is derived from the Site; also used by Anchor and Aspect 2009.
Unit Conversion Factor (CF)	kg/mg	Adult	0.000001		0.000001	
Averaging Time (AT)	days	Adult—carcinogenic	25,550	USEPA 1989.	25,550	USEPA 1989.
		Adult—non-carcinogenic	10,585		16,060	
Body Weight (BW)	kg	Adult	81.8	USEPA 2007a.	81.8	USEPA 2007a.

Notes:

CT: Central Tendency

RME: Reasonable Maximum Exposure

USEPA: U.S. Environmental Protection Agency

Table 4-10 Netfishing Parameters: Sediment Dermal Contact

Parameter	Units	Receptor	CT Scenario	Reference/Rationale	RME Scenario	Reference/Rationale
Maximum (RME) or Average (CT) Concentration in Sediments (C)	mg/kg		Refer to Table 4-4		Refer to Table 4-4	
Exposure Frequency (EF)	days/year	Adult	63	Windward 2007 value, approved by Muckleshoot Indian Tribe.	119	Windward 2007 value, approved by Muckleshoot Indian Tribe.
Exposure Duration (ED)	years	Adult	29	Windward 2007 value, approved by Muckleshoot Indian Tribe.	44	Windward 2007 value, approved by Muckleshoot Indian Tribe.
Skin Surface Area Exposed (SA)	cm^2	Adult	3,600	USEPA 2004. Exposed skin surface is limited to the head, hands, and forearms, recommended for commercial/industrial worker.	3,600	USEPA 2004. Exposed skin surface is limited to the head, hands, and forearms, recommended for commercial/industrial worker.
Adherence Factor (AF)	mg/cm^2-event	Adult	0.02	USEPA 2004. Recommended for commercial/industrial workers.	0.2	USEPA 2004. Recommended for commercial/industrial workers.
Dermal Absorption Factor (ABS)	unitless		Refer to Table 4.11		Refer to Table 4.11	
Fractional Intake (fraction of sediment ingested derived from site) (FI)	unitless		0.25	Conservative assumption that 25% of sediment consumed is derived from the Site; also used by Anchor and Aspect 2009.	0.25	Conservative assumption that 25% of sediment consumed is derived from the Site; also used by Anchor and Aspect 2009.
Unit Conversion Factor (CF)	kg/mg	Adult	0.000001		0.000001	
Averaging Time (AT)	days	Adult—carcinogenic	25,550	USEPA 1989. Assumes carcinogenic effects may occur every day for a lifetime of 70 years.	25,550	USEPA 1989. Assumes carcinogenic effects may occur every day for a lifetime of 70 years.
		Adult—non-carcinogenic	10,585	USEPA 1989.	16,060	USEPA 1989.
Body Weight (BW)	kg	Adult	81.8	USEPA 2007a.	81.8	USEPA 2007a.

Notes:

CT: Central Tendency

RME: Reasonable Maximum Exposure

USEPA: U.S. Environmental Protection Agency

Table 4-11 Dermal Absorption Factors

Chemical of Potential Concern	Dermal Absorption Factor[1]	Comments
Conventionals/Misc.		
Total Cyanide	na	
Metals		
Antimony	na	Metallic
Arsenic	0.03	Inorganic
Cadmium	0.001	
Chromium III	na	
Chromium VI	na	
Cobalt	na	
Copper	na	
Lead and Compounds	na	
Mercury	na	
Nickel	na	Soluble salts
Selenium	na	
Silver	na	
Vanadium	na	
Zinc	na	
Butyltins		
Tributyltin	0.1	
LPAHs		
Acenaphthene	0.13	
Acenapthylene	0.13	
Anthracene	0.13	
Fluorene	0.13	
2-Methylnaphthalene	0.13	
Naphthalene	0.13	
Phenanthrene	0.13	
Total LPAH	0.13	
HPAHs		
Benzo(a)anthracene	0.13	
Benzo(a)pyrene	0.13	
Benzo(b)fluoranthene	0.13	
Benzo(k)fluoranthene	0.13	
Benzo(g,h,i)perylene	0.13	
Chrysene	0.13	
Dibenzo(a,h)anthracene	0.13	
Fluoranthene	0.13	
Indeno(1,2,3-cd)pyrene	0.13	
Pyrene	0.13	
Retene	0.1	
Total HPAH	0.13	
Total PAH	0.13	

Table 4-11 Dermal Absorption Factors

Chemical of Potential Concern	Dermal Absorption Factor[1]	Comments
Phthalates		
Bis(2-Ethylhexy)lphthalate	0.1	
Butylbenzyl phthalate	0.1	
Di-n-butylphthalate	0.1	
Diethylphthalate	0.1	
Dimethylphthalate	0.1	
Di-n-octylphthalate	0.1	
Phenols		
2,4-Dimethylphenol	0.1	
4-Methylphenol	0.1	
Pentachlorophenol	0.25	
Phenol	0.1	
Misc. Extractables		
Benzoic Acid	0.1	
Carbazole	0.1	
Dibenzofuran	0.1	
Volatile Organic Compounds		
Benzene	na	
Ethylbenzene	na	
Toluene	na	
Total Xylenes	na	
1,2,4-Trimethylbenzene	na	
Pesticides/PCBs		
Chlordane	0.04	
DDD	0.03	not available, DDT as surrogate
DDT	0.03	
PCB Aroclor 1254	0.14	
PCB Aroclor 1260	0.14	
Total PCBs	0.14	

Notes:

[1] All values recommended in Exhibit 3-4 by USEPA (2004).

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

na: Not applicable

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

USEPA: U.S. Environmental Protection Agency

Table 4-12 COPC-specific Toxicity Factors

Chemical of Potential Concern	Cancer Slope Factor (kg-day/mg)	Chronic Reference Dose (mg/kg-day)	Source	Comments
Conventionals/Misc				
Total Cyanide	na	0.02	USEPA 2010	Free
Metals				
Antimony	na	0.0004	USEPA 2010	Metallic
Arsenic	1.5	0.0003	USEPA 2010	Inorganic
Cadmium	na	0.001	USEPA 2010	Diet
Chromium III	na	1.5	USEPA 2010	insoluble salts
Chromium VI	0.5	0.003	USEPA 2010	
Cobalt	na	0.0003	USEPA 2010	
Copper	na	0.04	USEPA 1997c	
Lead and Compounds	na	na		
Mercury	na	0.0003	USEPA 1997c	
Nickel	na	0.02	USEPA 2010	Soluble salts
Selenium	na	0.005	USEPA 2010	
Silver	na	0.005	USEPA 2010	
Vanadium	na	0.00007	USEPA 2009	
Zinc	na	0.3	USEPA 2010	
Butyltins				
Tributyltin	na	0.0003	PPRTV	Identified as "Tributyltin Compounds"
LPAH				
Acenaphthene	na	0.06	USEPA 2010	
Acenaphthylene	na	0.06	USEPA 2010	Acenapthene as surrogate
Anthracene	na	0.3	USEPA 2010	
Fluorene	na	0.04	USEPA 2010	
2-Methylnaphthalene	na	0.004	USEPA 2010	
Naphthalene	na	0.02	USEPA 2010	
Phenanthrene	na	0.3	USEPA 2010	Anthracene as surrogate
Total LPAH	na	na		
HPAH				
Benzo(a)anthracene	0.73	na	CALEPA 2005	Presented in Ecology 2007
Benzo(a)pyrene	7.3	na	USEPA 2010	
Benzo(b)fluoranthene	0.73	na	CALEPA 2005	Presented in Ecology 2007
Benzo(k)fluoranthene	0.73	na	CALEPA 2005	Presented in Ecology 2007
Benzo(g,h,i)perylene	na	0.03	na	Pyrene as surrogate
Chrysene	0.073	na	CALEPA 2005	Presented in Ecology 2007
Dibenzo(a,h)anthracene	0.73	na	CALEPA 2005	Presented in Ecology 2007
Fluoranthene	na	0.04	USEPA 2010	
Indeno(1,2,3-cd)pyrene	0.73	na	CALEPA 2005	Presented in Ecology 2007
Pyrene	na	0.03	USEPA 2010	
Retene	na	0.3	USEPA 2010	Chemical structure similar to the PAH phenanthrene (1-methyl-7-isopropyl phenanthrene). Anthracene as surrogate.
Total HPAH	na	na		
Total PAH	na	na		
Phthalates				
Bis(2-Ethylhexyl)phthalate	0.014	0.02	USEPA 2010	
Butylbenzylphthalate	0.0019	0.2	USEPA 2010, PPRTV	
Di-n-butylphthalate	na	0.1	USEPA 2010	
Diethylphthalate	na	0.8	USEPA 2010	
Dimethylphthalate	na	0.8	USEPA 2010	Diethylphthalate as surrogate
Di-n-octylphthalate	na	0.8	USEPA 2010	Diethylphthalate as surrogate

Table 4-12 COPC-specific Toxicity Factors

Chemical of Potential Concern	Cancer Slope Factor (kg-day/mg)	Chronic Reference Dose (mg/kg-day)	Source	Comments
Phenols				
2,4-Dimethylphenol	na	0.02	USEPA 2010	
4-Methylphenol	na	0.005	HEAST	
Pentachlorophenol	0.12	0.03	USEPA 2010	
Phenol	na	0.3	USEPA 2010	
Misc. Extractables				
Benzoic Acid	na	4	USEPA 2010	
Carbazole	0.02	na	USEPA 1997c	
Dibenzofuran	na	0.001	PPRTV	
Volatile Organic Compounds				
Benzene	0.055	0.004	USEPA 2010	
Ethylbenzene	0.011	0.1	CALEPA 2005, USEPA 2010	
Toluene	na	0.08	USEPA 2010	
Total Xylenes	na	0.2	USEPA 2010	
1,2,4-Trimethylbenzene	na	0.05	PPRTV	
Pesticides/PCBs				
Chlordane	0.35	0.0005	USEPA 2010	
DDD	0.24	na	USEPA 2010	
DDT	0.34	0.0005	USEPA 2010	
PCB Aroclor 1254	2	0.00002	USEPA 2010	
PCB Aroclor 1260	2	na	USEPA 2010	
Total PCBs	2	na	USEPA 2010	

Notes:
CALEPA: California Environmental Protection Agency
COPC: Chemical of potential concern
DDD: Dichlorodiphenyldichloroethane
DDT: Dichlorodiphenyltrichloroethane
Ecology: Washington State Department of Ecology
HEAST: USEPA Health Effects Assessment Summary Tables
HPAH: High-molecular weight polycyclic aromatic hydrocarbon
na: Not available
PAH: Polycyclic aromatic hydrocarbon
PCB: Polychlorinated biphenyl
PPRTV: USEPA Professional Peer Reviewed Toxicity Values
USEPA: U.S. Environmental Protection Agency

Table 4-13 Beach Play/Wading Risk Evaluation Results—Carcinogenic

Chemical of Potential Concern	CT Scenario			RME Scenario		
	Cancer Risk from Sediment Dermal Contact	Cancer Risk from Ingestion	Total Cancer Risk	Cancer Risk from Sediment Dermal Contact	Cancer Risk from Ingestion	Total Cancer Risk
Adult Cancer Risk Calculations						
Metals						
Arsenic, Inorganic	2.E-09	6.E-08	6.E-08	**2.E-06**	**1.E-05**	**2.E-05**
Chromium VI	—	5.E-09	5.E-09	—	6.E-07	6.E-07
HPAH						
Benzo[a]anthracene	4.E-09	3.E-08	3.E-08	**3.E-06**	**6.E-06**	**9.E-06**
Benzo[a]pyrene	5.E-08	4.E-07	4.E-07	**4.E-05**	**8.E-05**	**1.E-04**
Benzo[b]fluoranthene	4.E-09	3.E-08	3.E-08	**3.E-06**	**6.E-06**	**9.E-06**
Benzo[k]fluoranthene	4.E-09	2.E-08	3.E-08	**2.E-06**	**5.E-06**	**7.E-06**
Chrysene	4.E-10	3.E-09	3.E-09	3.E-07	7.E-07	1.E-06
Dibenzo[a,h]anthracene	7.E-10	5.E-09	6.E-09	7.E-07	1.E-06	**2.E-06**
Indeno[1,2,3-cd]pyrene	4.E-09	3.E-08	3.E-08	**3.E-06**	**6.E-06**	**9.E-06**
Total HPAH	—	—	5.E-07	—	—	**1.E-04**
Total PAH	—	—	5.E-07	—	—	**1.E-04**
Phthalates						
Bis(2-Ethylhexyl)phthalate	2.E-12	2.E-11	2.E-11	1.E-09	3.E-09	4.E-09
Butylbenzylphthalate	6.E-14	3.E-12	3.E-12	2.E-11	5.E-11	7.E-11
Phenols						
Pentachlorophenol	3.E-11	1.E-10	1.E-10	1.E-08	1.E-08	3.E-08
Misc. Extractables						
Carbazole	6.E-12	5.E-11	6.E-11	6.E-09	1.E-08	2.E-08
Volatile Organic Compounds						
Benzene	—	3.E-13	3.E-13	—	2.E-11	2.E-11
Ethylbenzene	—	6.E-14	6.E-14	—	3.E-12	3.E-12
Pesticides/PCBs						
Chlordane	1.E-13	3.E-12	3.E-12	8.E-11	5.E-10	6.E-10
DDD	1.E-13	2.E-12	2.E-12	8.E-11	7.E-10	7.E-10
DDT	2.E-13	6.E-12	6.E-12	1.E-10	9.E-10	1.E-09
PCB Aroclor 1254	3.E-11	4.E-11	7.E-11	7.E-09	1.E-08	2.E-08
PCB Aroclor 1260	1.E-11	2.E-10	2.E-10	3.E-09	6.E-09	9.E-09
Total PCBs	4.E-11	8.E-11	1.E-10	1.E-08	2.E-08	4.E-08
		Total	6.E-07		**Total**	**2.E-04**
Child Cancer Risk Calculations						
Metals						
Arsenic, Inorganic	8.E-09	2.E-07	2.E-07	**2.E-06**	**2.E-05**	**2.E-05**
Chromium VI	—	8.E-08	8.E-08	—	9.E-07	9.E-07
HPAH						
Benzo[a]anthracene	1.E-08	1.E-07	1.E-07	**3.E-06**	**9.E-06**	**1.E-05**
Benzo[a]pyrene	2.E-07	1.E-06	1.E-06	**4.E-05**	**1.E-04**	**2.E-04**
Benzo[b]fluoranthene	2.E-08	1.E-07	2.E-07	**3.E-06**	**9.E-06**	**1.E-05**
Benzo[k]fluoranthene	1.E-08	1.E-07	1.E-07	**3.E-06**	**7.E-06**	**1.E-05**
Chrysene	2.E-09	1.E-08	1.E-08	4.E-07	1.E-06	1.E-06
Dibenzo[a,h]anthracene	3.E-09	1.E-07	1.E-07	8.E-07	**2.E-06**	**3.E-06**
Indeno[1,2,3-cd]pyrene	1.E-08	2.E-08	3.E-08	**3.E-06**	**9.E-06**	**1.E-05**
Total HPAH	—	—	**2.E-06**	—	—	**2.E-04**
Total PAH	—	—	**2.E-06**	—	—	**2.E-04**
Phthalates						
Bis(2-Ethylhexyl)phthalate	8.E-12	7.E-11	8.E-11	1.E-09	5.E-09	6.E-09
Butylbenzylphthalate	2.E-13	1.E-11	1.E-11	2.E-11	7.E-11	9.E-11
Phenols						
Pentachlorophenol	1.E-10	4.E-10	6.E-10	2.E-08	2.E-08	4.E-08
Misc. Extractables						
Carbazole	2.E-11	2.E-10	2.E-10	6.E-09	2.E-08	3.E-08
Volatile Organic Compounds						
Benzene	—	1.E-12	1.E-12	—	3.E-11	3.E-11
Ethylbenzene	—	2.E-13	2.E-13	—	4.E-12	4.E-12
Pesticides/PCBs						
Chlordane	5.E-13	1.E-11	1.E-11	8.E-11	7.E-10	8.E-10
DDD	5.E-13	7.E-12	8.E-12	8.E-11	1.E-09	1.E-09
DDT	9.E-13	2.E-11	2.E-11	1.E-10	1.E-09	2.E-09
PCB Aroclor 1254	1.E-10	2.E-10	3.E-10	7.E-09	2.E-08	3.E-08
PCB Aroclor 1260	5.E-11	8.E-10	8.E-10	3.E-09	9.E-09	1.E-08
Total PCBs	2.E-10	3.E-10	5.E-10	1.E-08	4.E-08	5.E-08
		Total	**2.E-06**		**Total**	**2.E-04**

Notes:

BOLD and Shaded: Signifies a risk greater than 1 x 10-6 for individual chemicals or cumulative risk.

— Dermal absorption factor was not available or chemical was not analyzed, calculations could not be completed.

CT: Central Tendency

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

RME: Reasonable Maximum Exposure

Table 4-14 Beach Play/Wading Risk Evaluation Results—Non-Carcinogenic

Chemical of Potential Concern	CT Scenario			RME Scenario		
	Sediment Dermal Contact HQ	Oral HQ	Total HQ	Sediment Dermal Contact HQ	Oral HQ	Total HQ
Adult Non-Cancer Risk Calculations						
Conventionals/Misc.						
Total Cyanide	—	8.E-06	8.E-06	—	3.E-03	3.E-03
Metals						
Antimony	—	5.E-04	5.E-04	—	1.E-01	1.E-01
Arsenic	1.E-05	3.E-04	3.E-04	9.E-03	7.E-02	8.E-02
Cadmium	5.E-09	4.E-06	4.E-06	4.E-06	1.E-03	1.E-03
Chromium III	—	1.E-07	1.E-07	—	1.E-05	1.E-05
Chromium VI	—	8.E-06	8.E-06	—	1.E-03	1.E-03
Cobalt	—	1.E-04	1.E-04	—	8.E-03	8.E-03
Copper	—	2.E-05	2.E-05	—	3.E-03	3.E-03
Lead and Compounds[1]	—	—	—	—	—	—
Mercury	—	1.E-04	1.E-04	—	1.E-02	1.E-02
Nickel Soluble Salts	—	4.E-05	4.E-05	—	4.E-03	4.E-03
Selenium	—	2.E-07	2.E-07	—	2.E-05	2.E-05
Silver	—	2.E-05	2.E-05	—	3.E-03	3.E-03
Vanadium	—	9.E-03	9.E-03	—	6.E-01	6.E-01
Zinc	—	4.E-06	4.E-06	—	1.E-03	1.E-03
Butyltins						
Tributyltin	2.E-07	2.E-06	2.E-06	1.E-04	3.E-04	4.E-04
LPAH						
Acenaphthene	8.E-08	6.E-07	6.E-07	1.E-04	2.E-04	3.E-04
Acenaphthylene	6.E-08	4.E-07	5.E-07	4.E-05	8.E-05	1.E-04
Anthracene	2.E-08	1.E-07	2.E-07	2.E-05	5.E-05	7.E-05
Fluorene	1.E-07	6.E-07	7.E-07	8.E-05	2.E-04	2.E-04
2-Methylnaphthalene	1.E-06	7.E-06	8.E-06	1.E-03	3.E-03	4.E-03
Naphthalene	7.E-07	5.E-06	6.E-06	8.E-04	2.E-03	2.E-03
Phenanthrene	7.E-08	5.E-07	6.E-07	7.E-05	1.E-04	2.E-04
Total LPAH	—	—	2.E-05	—	—	7.E-03
HPAH						
Benzo(g,h,i)perylene	4.E-07	3.E-06	3.E-06	3.E-04	6.E-04	9.E-04
Fluoranthene	7.E-07	5.E-06	5.E-06	6.E-04	1.E-03	2.E-03
Pyrene	1.E-06	8.E-06	9.E-06	8.E-04	2.E-03	2.E-03
Retene	2.E-09	2.E-08	2.E-08	8.E-07	2.E-06	3.E-06
Total HPAH	—	—	2.E-05	—	—	5.E-03
Total PAH	—	—	3.E-05	—	—	1.E-02
Phthalates						
Bis(2-Ethylhexyl)phthalate	2.E-08	2.E-07	2.E-07	1.E-05	3.E-05	4.E-05
Butylbenzylphthalate	4.E-10	3.E-09	4.E-09	1.E-07	3.E-07	4.E-07
Di-n-butylpthalate	3.E-09	3.E-08	3.E-08	3.E-06	9.E-06	1.E-05
Diethylphthalate	9.E-11	8.E-10	9.E-10	3.E-08	8.E-08	1.E-07
Dimethylphthalate	9.E-11	8.E-10	9.E-10	3.E-08	8.E-08	1.E-07
Di-n-octylphthalate	9.E-11	8.E-10	9.E-10	3.E-08	8.E-08	1.E-07
Phenols						
2,4-Dimethylphenol	3.E-09	2.E-08	2.E-08	1.E-06	3.E-06	4.E-06
4-Methylphenol	1.E-08	1.E-07	1.E-07	4.E-06	1.E-05	1.E-05
Pentachlorophenol	2.E-08	7.E-08	9.E-08	9.E-06	1.E-05	2.E-05
Phenol	3.E-10	3.E-09	3.E-09	3.E-07	7.E-07	1.E-06

Table 4-14 Beach Play/Wading Risk Evaluation Results—Non-Carcinogenic

Chemical of Potential Concern	CT Scenario			RME Scenario		
	Sediment Dermal Contact HQ	Oral HQ	Total HQ	Sediment Dermal Contact HQ	Oral HQ	Total HQ
Misc. Extractables						
Benzoic Acid	2.E-10	2.E-09	2.E-09	1.E-07	3.E-07	4.E-07
Dibenzofuran	6.E-07	6.E-06	6.E-06	6.E-04	1.E-03	2.E-03
Volatile Organics						
Benzene	—	4.E-09	4.E-09	—	2.E-07	2.E-07
Ethylbenzene	—	9.E-11	9.E-11	—	6.E-09	6.E-09
Toluene	—	9.E-10	9.E-10	—	6.E-08	6.E-08
Total Xylenes	—	6.E-11	6.E-11	—	4.E-09	4.E-09
1,2,4-Trimethylbenzene	—	2.E-06	2.E-06	—	1.E-04	1.E-04
Pesticides/PCBs						
Chlordane	2.E-09	4.E-08	4.E-08	—	6.E-06	6.E-06
DDT	3.E-09	9.E-08	9.E-08	2.E-06	1.E-05	1.E-05
PCB Aroclor 1254	2.E-06	1.E-05	1.E-05	4.E-04	8.E-04	1.E-03
Total PCBs	—	—	1.E-05	—	—	1.E-03
Child Non-Cancer Risk Calculations						
Conventionals/Misc.						
Total Cyanide	—	2.E-04	2.E-04	—	2.E-02	2.E-02
Metals						
Antimony	—	1.E-02	1.E-02	—	8.E-01	8.E-01
Arsenic	2.E-04	6.E-03	6.E-03	5.E-02	6.E-01	6.E-01
Cadmium	9.E-08	8.E-05	8.E-05	2.E-05	7.E-03	7.E-03
Chromium III	—	2.E-06	2.E-06	—	9.E-05	9.E-05
Chromium VI	—	2.E-04	2.E-04	—	7.E-03	7.E-03
Cobalt	—	2.E-03	2.E-03	—	6.E-02	6.E-02
Copper	—	3.E-04	3.E-04	—	2.E-02	2.E-02
Lead and Compounds[1]	—	—	—	—	—	—
Mercury	—	2.E-03	2.E-03	—	9.E-02	9.E-02
Nickel Soluble Salts	—	7.E-04	7.E-04	—	3.E-02	3.E-02
Selenium	—	5.E-06	5.E-06	—	1.E-04	1.E-04
Silver	—	3.E-04	3.E-04	—	2.E-02	2.E-02
Vanadium	—	2.E-01	2.E-01	—	**4.E+00**	**4.E+00**
Zinc	—	8.E-05	8.E-05	—	7.E-03	7.E-03
Butyltins						
Tributyltin	4.E-06	3.E-05	4.E-05	6.E-04	2.E-03	3.E-03
LPAH						
Acenaphthene	2.E-06	1.E-05	1.E-05	6.E-04	2.E-03	2.E-03
Acenaphthylene	1.E-06	8.E-06	9.E-06	2.E-04	6.E-04	9.E-04
Anthracene	4.E-07	3.E-06	3.E-06	1.E-04	4.E-04	5.E-04
Fluorene	2.E-06	1.E-05	1.E-05	4.E-04	1.E-03	2.E-03
2-Methylnaphthalene	2.E-05	1.E-04	2.E-04	7.E-03	2.E-02	3.E-02
Naphthalene	1.E-05	1.E-04	1.E-04	4.E-03	1.E-02	2.E-02
Phenanthrene	1.E-06	9.E-06	1.E-05	3.E-04	9.E-04	1.E-03
Total LPAH	—	—	3.E-04	—	—	6.E-02
HPAH						
Benzo(g,h,i)perylene	8.E-06	5.E-05	6.E-05	2.E-03	5.E-03	6.E-03
Fluoranthene	1.E-05	9.E-05	1.E-04	3.E-03	8.E-03	1.E-02
Pyrene	2.E-05	1.E-04	2.E-04	4.E-03	1.E-02	2.E-02
Retene	4.E-08	3.E-07	4.E-07	4.E-06	1.E-05	1.E-05
Total HPAH	—	—	4.E-04	—	—	4.E-02
Total PAH	—	—	7.E-04	—	—	9.E-02

Table 4-14 Beach Play/Wading Risk Evaluation Results—Non-Carcinogenic

Chemical of Potential Concern	CT Scenario			RME Scenario		
	Sediment Dermal Contact HQ	Oral HQ	Total HQ	Sediment Dermal Contact HQ	Oral HQ	Total HQ
Phthalates						
Bis(2-Ethylhexyl)phthalate	3.E-07	3.E-06	3.E-06	5.E-05	2.E-04	2.E-04
Butylbenzylphthalate	7.E-09	6.E-08	7.E-08	6.E-07	2.E-06	3.E-06
Di-n-butylpthalate	6.E-08	6.E-07	6.E-07	2.E-05	1.E-04	1.E-04
Diethylphthalate	2.E-09	2.E-08	2.E-08	2.E-07	6.E-07	7.E-07
Dimethylphthalate	2.E-09	2.E-08	2.E-08	2.E-07	6.E-07	7.E-07
Di-n-octylphthalate	2.E-09	2.E-08	2.E-08	2.E-07	6.E-07	7.E-07
Phenols						
2,4-Dimethylphenol	5.E-08	4.E-07	5.E-07	6.E-06	2.E-05	3.E-05
4-Methylphenol	2.E-07	2.E-06	2.E-06	2.E-05	8.E-05	1.E-04
Pentachlorophenol	4.E-07	1.E-06	2.E-06	5.E-05	7.E-05	1.E-04
Phenol	5.E-09	5.E-08	5.E-08	1.E-06	5.E-06	7.E-06
Misc. Extractables						
Benzoic Acid	4.E-09	4.E-08	4.E-08	6.E-07	2.E-06	3.E-06
Dibenzofuran	1.E-05	1.E-04	1.E-04	3.E-03	1.E-02	1.E-02
Volatile Organics						
Benzene	—	7.E-08	7.E-08	—	2.E-06	2.E-06
Ethylbenzene	—	2.E-09	2.E-09	—	5.E-08	5.E-08
Toluene	—	2.E-08	2.E-08	—	5.E-07	5.E-07
Total Xylenes	—	1.E-09	1.E-09	—	3.E-08	3.E-08
1,2,4-Trimethylbenzene	—	3.E-05	3.E-05	—	8.E-04	8.E-04
Pesticides/PCBs						
Chlordane	3.E-08	7.E-07	7.E-07	5.E-06	5.E-05	5.E-05
DDT	6.E-08	2.E-06	2.E-06	8.E-06	9.E-05	1.E-04
PCB Aroclor 1254	4.E-05	2.E-04	3.E-04	2.E-03	6.E-03	8.E-03
Total PCBs	—	—	3.E-04	—	—	8.E-03

Notes:

BOLD and Shaded: Signifies a Hazard Quotient greater than 1 for individual chemicals.

— Dermal absorption factor or toxicity factor were not available; calculations could not be completed.

[1] The maximum sediment lead concentration from beach play samples (240 mg/kg) was compared to MTCA Method A Cleanup Level (250 mg/kg). See Section 4.2.5.1 in the text for further discussion. The concentration is below this value; therefore, exposure to lead while playing on the beach is not likely to pose a significant risk in the Gas Works Sediment Area (GWSA).

CT: Central Tendency

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

HQ: Hazard Quotient

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

MTCA: Washington State Model Toxics Control Act

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

RME: Reasonable Maximum Exposure

Table 4-15 Fish Ingestion Results—Carcinogenic

Chemical of Potential Concern	CT Scenario Cancer Risk - Recreational			CT Scenario Cancer Risk - Tribal			RME Scenario Cancer Risk - Recreational			RME Scenario Cancer Risk - Tribal		
	Crayfish	Finfish	Total Ingestion Risk	Crayfish	Finfish	Total Ingestion Risk	Crayfish	Finfish	Total Ingestion Risk	Crayfish	Finfish	Total Ingestion Risk
Adult Cancer Risk Calculations												
Metals												
Arsenic	8.E-07	2.E-07	1.E-06	**2.E-05**	1.E-06	**2.E-05**	**7.E-05**	**1.E-05**	**8.E-05**	**9.E-04**	**3.E-05**	**9.E-04**
Chromium VI	5.E-09	1.E-08	2.E-08	1.E-07	7.E-08	2.E-07	5.E-07	**2.E-06**	**2.E-06**	**7.E-06**	**5.E-06**	**1.E-05**
HPAH												
Benzo[a]anthracene	1.E-08	4.E-09	1.E-08	2.E-07	2.E-08	3.E-07	1.E-06	5.E-07	**2.E-06**	**1.E-05**	1.E-06	**2.E-05**
Benzo[a]pyrene	1.E-07	8.E-08	2.E-07	**3.E-06**	4.E-07	**3.E-06**	**1.E-05**	**8.E-06**	**2.E-05**	**1.E-04**	**2.E-05**	**1.E-04**
Benzo[b]fluoranthene	1.E-08	1.E-08	2.E-08	3.E-07	6.E-08	3.E-07	6.E-07	1.E-06	**2.E-06**	**8.E-06**	**3.E-06**	**1.E-05**
Benzo[k]fluoranthene	1.E-08	1.E-08	3.E-08	4.E-07	6.E-08	4.E-07	8.E-07	1.E-06	**2.E-06**	**1.E-05**	**3.E-06**	**1.E-05**
Chrysene	1.E-09	4.E-10	2.E-09	4.E-08	2.E-09	4.E-08	2.E-07	5.E-08	2.E-07	**2.E-06**	1.E-07	**3.E-06**
Dibenzo[a,h]anthracene	1.E-08	1.E-08	3.E-08	4.E-07	6.E-08	4.E-07	1.E-06	1.E-06	**2.E-06**	**2.E-05**	**3.E-06**	**2.E-05**
Indeno[1,2,3-cd]pyrene	9.E-09	8.E-09	2.E-08	2.E-07	4.E-08	3.E-07	8.E-07	8.E-07	**2.E-06**	**1.E-05**	**2.E-06**	**1.E-05**
Total HPAH	—	—	3.E-07	—	—	**5.E-06**	—	—	**3.E-05**	—	—	**2.E-04**
Total PAH	—	—	3.E-07	—	—	**5.E-06**	—	—	**3.E-05**	—	—	**2.E-04**
Phthalates												
Bis(2-Ethylhexyl)phthalate	2.E-10	8.E-11	3.E-10	6.E-09	4.E-10	6.E-09	2.E-08	9.E-09	3.E-08	3.E-07	2.E-08	3.E-07
Butylbenzylphthalate	1.E-11	1.E-11	2.E-11	3.E-10	6.E-11	4.E-10	1.E-09	1.E-09	2.E-09	2.E-08	3.E-09	2.E-08
Phenols												
Pentachlorophenol	1.E-09	1.E-09	3.E-09	4.E-08	6.E-09	4.E-08	1.E-07	1.E-07	3.E-07	**2.E-06**	3.E-07	**2.E-06**
Misc. Extractables												
Carbazole	2.E-10	2.E-10	5.E-10	6.E-09	1.E-09	7.E-09	2.E-08	2.E-08	4.E-08	3.E-07	5.E-08	3.E-07
Volatile Organic Compounds												
Benzene	—	—	—	—	—	—	—	—	—	—	—	—
Ethylbenzene	—	—	—	—	—	—	—	—	—	—	—	—
Pesticides/PCBs												
Chlordane	1.E-09	2.E-09	3.E-09	3.E-08	8.E-09	3.E-08	1.E-07	1.E-07	2.E-07	1.E-06	3.E-07	**2.E-06**
DDD	1.E-10	2.E-10	3.E-10	3.E-09	8.E-10	4.E-09	9.E-09	9.E-09	2.E-08	1.E-07	2.E-08	1.E-07
DDT	2.E-10	2.E-10	4.E-10	4.E-09	1.E-09	5.E-09	1.E-08	1.E-08	3.E-08	2.E-07	3.E-08	2.E-07
PCB Aroclor 1254	1.E-07	2.E-08	1.E-07	**3.E-06**	9.E-08	**3.E-06**	**2.E-05**	1.E-06	**2.E-05**	**2.E-04**	**3.E-06**	**2.E-04**
PCB Aroclor 1260	1.E-07	1.E-08	1.E-07	**3.E-06**	6.E-08	**3.E-06**	**2.E-05**	1.E-06	**2.E-05**	**2.E-04**	**3.E-06**	**2.E-04**
Total PCBs	2.E-07	2.E-08	2.E-07	**5.E-06**	9.E-08	**5.E-06**	**4.E-05**	**2.E-06**	**4.E-05**	**5.E-04**	**6.E-06**	**5.E-04**
		Total	**2.E-06**		**Total**	**3.E-05**		**Total**	**1.E-04**		**Total**	**2.E-03**
Child Cancer Risk Calculations												
Metals												
Arsenic	5.E-07	1.E-07	6.E-07	**9.E-06**	5.E-07	**9.E-06**	**2.E-05**	**5.E-06**	**3.E-05**	**2.E-04**	**6.E-06**	**2.E-04**
Chromium VI	3.E-09	8.E-09	1.E-08	6.E-08	3.E-08	9.E-08	2.E-07	7.E-07	9.E-07	**1.E-06**	**9.E-07**	**2.E-06**
HPAH												
Benzo[a]anthracene	6.E-09	3.E-09	9.E-09	1.E-07	9.E-09	1.E-07	4.E-07	2.E-07	6.E-07	**3.E-06**	2.E-07	**3.E-06**
Benzo[a]pyrene	7.E-08	5.E-08	1.E-07	1.E-06	2.E-07	1.E-06	**4.E-06**	**3.E-06**	**7.E-06**	**2.E-05**	**4.E-06**	**3.E-05**
Benzo[b]fluoranthene	7.E-09	8.E-09	1.E-08	1.E-07	3.E-08	1.E-07	2.E-07	5.E-07	7.E-07	**2.E-06**	6.E-07	**2.E-06**
Benzo[k]fluoranthene	9.E-09	8.E-09	2.E-08	2.E-07	3.E-08	2.E-07	3.E-07	5.E-07	8.E-07	**2.E-06**	6.E-07	**3.E-06**
Chrysene	9.E-10	3.E-10	1.E-09	2.E-08	9.E-10	2.E-08	7.E-08	2.E-08	9.E-08	5.E-07	2.E-08	5.E-07
Dibenzo[a,h]anthracene	9.E-09	8.E-09	2.E-08	2.E-07	3.E-08	2.E-07	5.E-07	5.E-07	9.E-07	**3.E-06**	6.E-07	**4.E-06**
Indeno[1,2,3-cd]pyrene	6.E-09	5.E-09	1.E-08	1.E-07	2.E-08	1.E-07	3.E-07	3.E-07	6.E-07	**2.E-06**	4.E-07	**2.E-06**
Total HPAH	—	—	2.E-07	—	—	**2.E-06**	—	—	**1.E-05**	—	—	**4.E-05**
Total PAH	—	—	2.E-07	—	—	**2.E-06**	—	—	**1.E-05**	—	—	**4.E-05**

Table 4-15 Fish Ingestion Results—Carcinogenic

Chemical of Potential Concern	CT Scenario Cancer Risk - Recreational			CT Scenario Cancer Risk - Tribal			RME Scenario Cancer Risk - Recreational			RME Scenario Cancer Risk - Tribal		
	Crayfish	Finfish	Total Ingestion Risk	Crayfish	Finfish	Total Ingestion Risk	Crayfish	Finfish	Total Ingestion Risk	Crayfish	Finfish	Total Ingestion Risk
Phthalates												
Bis(2-Ethylhexyl)phthalate	1.E-10	5.E-11	2.E-10	3.E-09	2.E-10	3.E-09	9.E-09	3.E-09	1.E-08	6.E-08	4.E-09	6.E-08
Butylbenzylphthalate	9.E-12	7.E-12	2.E-11	1.E-10	2.E-11	2.E-10	4.E-10	4.E-10	9.E-10	3.E-09	5.E-10	3.E-09
Phenols												
Pentachlorophenol	9.E-10	8.E-10	2.E-09	2.E-08	3.E-09	2.E-08	5.E-08	5.E-08	1.E-07	3.E-07	6.E-08	4.E-07
Misc. Extractables												
Carbazole	2.E-10	1.E-10	3.E-10	3.E-09	5.E-10	3.E-09	8.E-09	8.E-09	2.E-08	5.E-08	1.E-08	6.E-08
Volatile Organic Compounds												
Benzene	—	—	—	—	—	—	—	—	—	—	—	—
Ethylbenzene	—	—	—	—	—	—	—	—	—	—	—	—
Pesticides/PCBs												
Chlordane	7.E-10	9.E-10	2.E-09	1.E-08	3.E-09	1.E-08	4.E-08	4.E-08	8.E-08	3.E-07	5.E-08	3.E-07
DDD	7.E-11	1.E-10	2.E-10	1.E-09	3.E-10	2.E-09	3.E-09	3.E-09	7.E-09	2.E-08	4.E-09	3.E-08
DDT	1.E-10	1.E-10	2.E-10	2.E-09	5.E-10	2.E-09	5.E-09	5.E-09	1.E-08	3.E-08	6.E-09	4.E-08
PCB Aroclor 1254	7.E-08	1.E-08	8.E-08	1.E-06	4.E-08	1.E-06	**6.E-06**	5.E-07	**7.E-06**	**4.E-05**	6.E-07	**4.E-05**
PCB Aroclor 1260	7.E-08	7.E-09	8.E-08	1.E-06	3.E-08	1.E-06	**7.E-06**	4.E-07	**7.E-06**	**4.E-05**	5.E-07	**4.E-05**
Total PCBs	1.E-07	1.E-08	2.E-07	**2.E-06**	4.E-08	**2.E-06**	**1.E-05**	9.E-07	**1.E-05**	**9.E-05**	1.E-06	**9.E-05**
		Total	1.E-06		**Total**	**1.E-05**		**Total**	**5.E-05**		**Total**	**3.E-04**

Notes:

BOLD and Shaded: Signifies a risk greater than 1 x 10-6 for individual chemicals or cumulative risk.

— Chemical was not analyzed; calculations could not be completed.

CT: Central Tendency

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

RME: Reasonable Maximum Exposure

Table 4-16 Fish Ingestion Results—Non-Carcinogenic

Chemical of Potenial Concern	CT Scenario Hazard Quotient - Recreational			CT Scenario Hazard Quotient - Tribal			RME Scenario Hazard Quotient - Recreational			RME Scenario Hazard Quotient - Tribal		
	Crayfish HQ	Finfish HQ	Total HQ	Crayfish HQ	Finfish HQ	Total HQ	Crayfish HQ	Finfish HQ	Total HQ	Crayfish HQ	Finfish HQ	Total HQ
Adult Non-Cancer Risk Calculations												
Conventionals/Misc.												
Total Cyanide	—	—	—	—	—	—	—	—	—	—	—	—
Metals												
Antimony	1.E-03	8.E-04	2.E-03	1.E-02	2.E-03	1.E-02	1.E-01	7.E-02	2.E-01	8.E-01	7.E-02	8.E-01
Arsenic	4.E-03	1.E-03	5.E-03	4.E-02	2.E-03	5.E-02	4.E-01	7.E-02	4.E-01	**2.E+00**	7.E-02	**2.E+00**
Cadmium	4.E-04	9.E-06	4.E-04	4.E-03	2.E-05	4.E-03	7.E-02	8.E-04	7.E-02	4.E-01	8.E-04	4.E-01
Chromium III	1.E-07	3.E-07	4.E-07	1.E-06	6.E-07	2.E-06	1.E-05	4.E-05	5.E-05	5.E-05	4.E-05	9.E-05
Chromium VI	8.E-06	2.E-05	3.E-05	9.E-05	5.E-05	1.E-04	8.E-04	3.E-03	4.E-03	4.E-03	3.E-03	7.E-03
Cobalt	—	—	—	—	—	—	—	—	—	—	—	
Copper	6.E-04	2.E-05	6.E-04	6.E-03	5.E-05	6.E-03	7.E-02	2.E-03	7.E-02	4.E-01	2.E-03	4.E-01
Lead and Compounds[1]	—	—	—	—	—	—	—	—	—	—	—	—
Mercury	1.E-03	1.E-03	2.E-03	1.E-02	3.E-03	1.E-02	1.E-01	1.E-01	2.E-01	5.E-01	1.E-01	6.E-01
Nickel Soluble Salts	6.E-06	6.E-06	1.E-05	7.E-05	1.E-05	8.E-05	4.E-04	5.E-04	9.E-04	2.E-03	5.E-04	3.E-03
Selenium	1.E-04	2.E-04	3.E-04	1.E-03	4.E-04	2.E-03	7.E-03	2.E-02	3.E-02	4.E-02	2.E-02	6.E-02
Silver	5.E-06	1.E-06	7.E-06	6.E-05	3.E-06	6.E-05	3.E-04	2.E-04	5.E-04	2.E-03	2.E-04	2.E-03
Vanadium	—	—	—	—	—	—	—	—	—	—	—	—
Zinc	1.E-04	7.E-05	2.E-04	1.E-03	1.E-04	2.E-03	9.E-03	6.E-03	2.E-02	5.E-02	6.E-03	5.E-02
Butyltins												
Tributyltin	3.E-05	9.E-04	1.E-03	3.E-04	2.E-03	2.E-03	2.E-03	6.E-02	6.E-02	1.E-02	6.E-02	7.E-02
LPAH												
Acenaphthene	2.E-07	2.E-07	4.E-07	2.E-06	4.E-07	2.E-06	2.E-05	2.E-05	4.E-05	1.E-04	2.E-05	1.E-04
Acenaphthylene	3.E-07	2.E-07	5.E-07	3.E-06	5.E-07	3.E-06	3.E-05	3.E-05	5.E-05	1.E-04	3.E-05	2.E-04
Anthracene	3.E-08	5.E-08	8.E-08	3.E-07	1.E-07	4.E-07	2.E-06	5.E-06	7.E-06	1.E-05	5.E-06	2.E-05
Fluorene	4.E-07	3.E-07	8.E-07	5.E-06	7.E-07	5.E-06	4.E-05	4.E-05	8.E-05	2.E-04	4.E-05	2.E-04
2-Methylnaphthalene	1.E-05	1.E-05	2.E-05	1.E-04	2.E-05	1.E-04	1.E-03	4.E-04	2.E-03	6.E-03	1.E-03	7.E-03
Naphthalene	2.E-06	2.E-06	4.E-06	2.E-05	4.E-06	3.E-05	2.E-04	2.E-04	4.E-04	1.E-03	2.E-04	1.E-03
Phenanthrene	1.E-07	5.E-08	2.E-07	1.E-06	1.E-07	2.E-06	1.E-05	1.E-05	3.E-05	9.E-05	5.E-06	1.E-04
Total LPAH	—	—	3.E-05	—	—	1.E-04	—	—	3.E-03	—	—	9.E-03
HPAH												
Benzo(g,h,i)perylene	1.E-06	8.E-07	2.E-06	1.E-05	2.E-06	1.E-05	9.E-05	9.E-05	2.E-04	5.E-04	9.E-05	6.E-04
Fluoranthene	5.E-07	4.E-07	9.E-07	6.E-06	8.E-07	7.E-06	5.E-05	4.E-05	9.E-05	3.E-04	4.E-05	3.E-04
Pyrene	4.E-06	5.E-07	5.E-06	4.E-05	1.E-06	5.E-05	7.E-04	5.E-05	8.E-04	4.E-03	5.E-05	4.E-03
Retene	—	—	—	—	—	—	—	—	—	—	—	—
Total HPAH	—	—	8.E-06	—	—	7.E-05	—	—	1.E-03	—	—	5.E-03
Total PAH	—	—	3.E-05	—	—	2.E-04	—	—	4.E-03	—	—	1.E-02
Phthalates												
Bis(2-Ethylhexyl)phthalate	2.E-06	7.E-07	3.E-06	2.E-05	1.E-06	2.E-05	2.E-04	8.E-05	3.E-04	1.E-03	8.E-05	1.E-03
Butylbenzylphthalate	8.E-08	7.E-08	2.E-07	9.E-07	1.E-07	1.E-06	8.E-06	8.E-06	2.E-05	4.E-05	8.E-06	5.E-05
Di-n-butylpthalate	3.E-07	3.E-07	5.E-07	3.E-06	5.E-07	4.E-06	3.E-05	3.E-05	5.E-05	1.E-04	3.E-05	2.E-04
Diethylphthalate	4.E-08	3.E-08	7.E-08	4.E-07	7.E-08	5.E-07	3.E-06	3.E-06	7.E-06	2.E-05	3.E-06	2.E-05
Dimethylphthalate	1.E-08	1.E-08	2.E-08	1.E-07	2.E-08	2.E-07	1.E-06	1.E-06	3.E-06	8.E-06	1.E-06	9.E-06
Di-n-octylphthalate	2.E-08	2.E-08	4.E-08	2.E-07	4.E-08	3.E-07	2.E-06	2.E-06	4.E-06	1.E-05	2.E-06	1.E-05
Phenols												
2,4-Dimethylphenol	1.E-06	1.E-06	3.E-06	2.E-05	3.E-06	2.E-05	1.E-04	1.E-04	3.E-04	7.E-04	1.E-04	8.E-04
4-Methylphenol	6.E-06	5.E-06	1.E-05	6.E-05	1.E-05	7.E-05	5.E-04	5.E-04	1.E-03	3.E-03	5.E-04	3.E-03
Pentachlorophenol	1.E-06	8.E-07	2.E-06	1.E-05	2.E-06	1.E-05	9.E-05	9.E-05	2.E-04	5.E-04	9.E-05	6.E-04
Phenol	4.E-05	3.E-07	4.E-05	4.E-04	6.E-07	4.E-04	5.E-03	4.E-05	5.E-03	3.E-02	3.E-05	3.E-02

Table 4-16 Fish Ingestion Results—Non-Carcinogenic

Chemical of Potenial Concern	CT Scenario Hazard Quotient - Recreational			CT Scenario Hazard Quotient - Tribal			RME Scenario Hazard Quotient - Recreational			RME Scenario Hazard Quotient - Tribal		
	Crayfish HQ	Finfish HQ	Total HQ	Crayfish HQ	Finfish HQ	Total HQ	Crayfish HQ	Finfish HQ	Total HQ	Crayfish HQ	Finfish HQ	Total HQ
Misc. Extractables												
Benzoic Acid	1.E-07	7.E-08	2.E-07	1.E-06	1.E-07	2.E-06	1.E-05	7.E-06	2.E-05	8.E-05	7.E-06	8.E-05
Dibenzofuran	3.E-05	3.E-05	5.E-05	3.E-04	5.E-05	4.E-04	3.E-03	3.E-03	6.E-03	1.E-02	3.E-03	2.E-02
Volatile Organic Compounds												
Benzene	—	—	—	—	—	—	—	—	—	—	—	—
Ethylbenzene	—	—	—	—	—	—	—	—	—	—	—	—
Toluene	—	—	—	—	—	—	—	—	—	—	—	—
Total Xylenes	—	—	—	—	—	—	—	—	—	—	—	—
1,2,4-Trimethylbenzene	—	—	—	—	—	—	—	—	—	—	—	—
Pesticides/PCBs												
Chlordane	1.E-05	2.E-05	3.E-05	2.E-04	4.E-05	2.E-04	2.E-03	2.E-03	3.E-03	8.E-03	2.E-03	1.E-02
DDT	2.E-06	3.E-06	5.E-06	2.E-05	7.E-06	3.E-05	2.E-04	2.E-04	4.E-04	1.E-03	2.E-04	1.E-03
PCB Aroclor 1254	6.E-03	1.E-03	7.E-03	7.E-02	2.E-03	7.E-02	1.E+00	9.E-02	1.E+00	**6.E+00**	9.E-02	**6.E+00**
Total PCBs	—	—	7.E-03	—	—	7.E-02	—	—	1.E+00	—	—	**6.E+00**
Child Non-Cancer Risk Calculations												
Conventionals/Misc.												
Total Cyanide	—	—	—	—	—	—	—	—	—	—	—	—
Metals												
Antimony	4.E-03	2.E-03	6.E-03	7.E-02	8.E-03	8.E-02	3.E-01	1.E-01	4.E-01	**2.E+00**	2.E-01	**2.E+00**
Arsenic	1.E-02	3.E-03	2.E-02	2.E-01	1.E-02	2.E-01	7.E-01	1.E-01	8.E-01	**4.E+00**	2.E-01	**4.E+00**
Cadmium	1.E-03	3.E-05	1.E-03	2.E-02	9.E-05	2.E-02	1.E-01	1.E-03	1.E-01	8.E-01	2.E-03	8.E-01
Chromium III	3.E-07	9.E-07	1.E-06	5.E-06	3.E-06	8.E-06	2.E-05	7.E-05	9.E-05	1.E-04	8.E-05	2.E-04
Chromium VI	3.E-05	8.E-05	1.E-04	4.E-04	3.E-04	7.E-04	2.E-03	6.E-03	7.E-03	9.E-03	7.E-03	2.E-02
Cobalt	—	—	—	—	—	—	—	—	—	—	—	—
Copper	2.E-03	8.E-05	2.E-03	3.E-02	3.E-04	3.E-02	1.E-01	4.E-03	1.E-01	8.E-01	4.E-03	8.E-01
Lead and Compounds[1]	—	—	—	—	—	—	—	—	—	—	—	—
Mercury	3.E-03	4.E-03	7.E-03	5.E-02	1.E-02	7.E-02	2.E-01	2.E-01	4.E-01	1.E+00	2.E-01	1.E+00
Nickel Soluble Salts	2.E-05	2.E-05	4.E-05	4.E-04	6.E-05	4.E-04	8.E-04	9.E-04	2.E-03	5.E-03	1.E-03	6.E-03
Selenium	3.E-04	6.E-04	9.E-04	6.E-03	2.E-03	8.E-03	1.E-02	4.E-02	6.E-02	8.E-02	5.E-02	1.E-01
Silver	2.E-05	4.E-06	2.E-05	3.E-04	2.E-05	3.E-04	6.E-04	3.E-04	9.E-04	4.E-03	3.E-04	4.E-03
Vanadium	—	—	—	—	—	—	—	—	—	—	—	—
Zinc	4.E-04	2.E-04	6.E-04	7.E-03	7.E-04	8.E-03	2.E-02	1.E-02	3.E-02	1.E-01	1.E-02	1.E-01
Butyltins												
Tributyltin	1.E-04	3.E-03	3.E-03	2.E-03	1.E-02	1.E-02	4.E-03	1.E-01	1.E-01	2.E-02	1.E-01	2.E-01
LPAH												
Acenaphthene	6.E-07	5.E-07	1.E-06	1.E-05	2.E-06	1.E-05	4.E-05	4.E-05	7.E-05	2.E-04	4.E-05	3.E-04
Acenaphthylene	9.E-07	7.E-07	2.E-06	2.E-05	3.E-06	2.E-05	5.E-05	5.E-05	1.E-04	3.E-04	6.E-05	3.E-04
Anthracene	1.E-07	1.E-07	2.E-07	2.E-06	5.E-07	2.E-06	4.E-06	1.E-05	1.E-05	2.E-05	1.E-05	3.E-05
Fluorene	1.E-06	1.E-06	2.E-06	2.E-05	4.E-06	3.E-05	7.E-05	7.E-05	1.E-04	4.E-04	8.E-05	5.E-04
2-methylnaphthalene	4.E-05	3.E-05	7.E-05	6.E-04	1.E-04	7.E-04	2.E-03	7.E-04	3.E-03	2.E-02	8.E-04	2.E-02
Naphthalene	7.E-06	6.E-06	1.E-05	1.E-04	2.E-05	1.E-04	4.E-04	4.E-04	8.E-04	2.E-03	5.E-04	3.E-03
Phenanthrene	4.E-07	1.E-07	6.E-07	7.E-06	5.E-07	8.E-06	3.E-05	3.E-05	6.E-05	2.E-04	3.E-05	2.E-04
Total LPAH	—	—	9.E-05	—	—	9.E-04	—	—	4.E-03	—	—	2.E-02
HPAH												
Benzo[g,h,i]perylene	3.E-06	3.E-06	6.E-06	5.E-05	9.E-06	6.E-05	2.E-04	2.E-04	3.E-04	1.E-03	2.E-04	1.E-03
Fluoranthene	2.E-06	1.E-06	3.E-06	3.E-05	4.E-06	3.E-05	9.E-05	7.E-05	2.E-04	5.E-04	8.E-05	6.E-04
Pyrene	1.E-05	1.E-06	1.E-05	2.E-04	5.E-06	2.E-04	1.E-03	1.E-04	1.E-03	8.E-03	1.E-04	8.E-03
Retene	—	—	—	—	—	—	—	—	—	—	—	—
Total HPAH	—	—	2.E-05	—	—	3.E-04	—	—	2.E-03	—	—	1.E-02
Total PAH	—	—	1.E-04	—	—	1.E-03	—	—	6.E-03	—	—	3.E-02

Table 4-16 Fish Ingestion Results—Non-Carcinogenic

Chemical of Potenial Concern	CT Scenario Hazard Quotient - Recreational			CT Scenario Hazard Quotient - Tribal			RME Scenario Hazard Quotient - Recreational			RME Scenario Hazard Quotient - Tribal		
	Crayfish HQ	Finfish HQ	Total HQ	Crayfish HQ	Finfish HQ	Total HQ	Crayfish HQ	Finfish HQ	Total HQ	Crayfish HQ	Finfish HQ	Total HQ
Phthalates												
Bis(2-Ethylhexyl)phthalate	6.E-06	2.E-06	8.E-06	1.E-04	8.E-06	1.E-04	4.E-04	1.E-04	5.E-04	2.E-03	2.E-04	3.E-03
Butylbenzylphthalate	3.E-07	2.E-07	5.E-07	5.E-06	8.E-07	5.E-06	1.E-05	1.E-05	3.E-05	9.E-05	2.E-05	1.E-04
Di-n-butylpthalate	9.E-07	8.E-07	2.E-06	2.E-05	3.E-06	2.E-05	5.E-05	5.E-05	1.E-04	3.E-04	6.E-05	4.E-04
Diethylphthalate	1.E-07	1.E-07	2.E-07	2.E-06	3.E-07	2.E-06	6.E-06	6.E-06	1.E-05	4.E-05	7.E-06	5.E-05
Dimethylphthalate	4.E-08	3.E-08	7.E-08	7.E-07	1.E-07	8.E-07	3.E-06	3.E-06	5.E-06	2.E-05	3.E-06	2.E-05
Di-n-octylphthalate	7.E-08	5.E-08	1.E-07	1.E-06	2.E-07	1.E-06	4.E-06	4.E-06	7.E-06	2.E-05	4.E-06	3.E-05
Phenols												
2,4-Dimethylphenol	5.E-06	4.E-06	8.E-06	8.E-05	1.E-05	9.E-05	3.E-04	3.E-04	5.E-04	2.E-03	3.E-04	2.E-03
4-Methylphenol	2.E-05	2.E-05	3.E-05	3.E-04	5.E-05	4.E-04	1.E-03	1.E-03	2.E-03	6.E-03	1.E-03	7.E-03
Pentachlorophenol	3.E-06	3.E-06	6.E-06	5.E-05	9.E-06	6.E-05	2.E-04	2.E-04	3.E-04	1.E-03	2.E-04	1.E-03
Phenol	1.E-04	9.E-07	1.E-04	2.E-03	3.E-06	2.E-03	9.E-03	7.E-05	1.E-02	6.E-02	8.E-05	6.E-02
Misc. Extractables												
Benzoic Acid	4.E-07	2.E-07	6.E-07	8.E-06	7.E-07	8.E-06	3.E-05	1.E-05	4.E-05	2.E-04	1.E-05	2.E-04
Dibenzofuran	9.E-05	8.E-05	2.E-04	2.E-03	3.E-04	2.E-03	5.E-03	5.E-03	1.E-02	3.E-02	6.E-03	4.E-02
Volatile Organic Compounds												
Benzene	—	—	—	—	—	—	—	—	—	—	—	—
Ethylbenzene	—	—	—	—	—	—	—	—	—	—	—	—
Toluene	—	—	—	—	—	—	—	—	—	—	—	—
Total Xylenes	—	—	—	—	—	—	—	—	—	—	—	—
1,2,4-Trimethylbenzene	—	—	—	—	—	—	—	—	—	—	—	—
Pesticides/PCBs												
Chlordane	4.E-05	6.E-05	1.E-04	8.E-04	2.E-04	1.E-03	3.E-03	3.E-03	6.E-03	2.E-02	3.E-03	2.E-02
DDT	7.E-06	1.E-05	2.E-05	1.E-04	3.E-05	2.E-04	4.E-04	4.E-04	7.E-04	2.E-03	4.E-04	3.E-03
PCB Aroclor 1254	2.E-02	3.E-03	2.E-02	3.E-01	1.E-02	3.E-01	**2.E+00**	2.E-01	**2.E+00**	**1.E+01**	2.E-01	**1.E+01**
Total PCBs	—	—	2.E-02	—	—	3.E-01	—	—	**2.E+00**	—	—	**1.E+01**

Notes:

BOLD and Shaded: Signifies a Hazard Quotient greater than 1 for individual chemicals.

— Toxicological information was not available or chemical was not analyzed; calculations could not be completed.

[1] Fish tissue concentrations in the Gas Works Sediment Area (GWSA) were compared to lead tissue levels derived by the USEPA (2002) and recommended by Oregon DEQ (2007) with the potential to exert a toxic effect (0.5 mg/kg). See Section 4.2.6.2 in the text for further discussion. The maximum crayfish tissue concentration in the GWSA is above this value, indicating exposure to lead during fish consumption may pose a health risk to Tribal fish consumers in the GWSA.

CT: Central Tendency
DDT: Dichlorodiphenyltrichloroethane
HPAH: High-molecular weight polycyclic aromatic hydrocarbon
HQ: Hazard Quotient
LPAH: Low-molecular weight polycyclic aromatic hydrocarbon
Oregon DEQ: Oregon Department of Environmental Quality
PAH: Polycyclic aromatic hydrocarbon
PCB: Polychlorinated biphenyl
RME: Reasonable Maximum Exposure
USEPA: U.S. Environmental Protection Agency

Table 4-17 Netfishing Results—Carcinogenic

Chemical of Potential Concern	CT Scenario			RME Scenario		
	Cancer Risk from Dermal Contact	Cancer Risk from Ingestion	Total Cancer Risk	Cancer Risk from Dermal Contact	Cancer Risk from Ingestion	Total Cancer Risk
Adult Cancer Risk Calculations						
Metals						
Arsenic	6.E-08	**2.E-06**	**2.E-06**	**5.E-05**	**1.E-04**	**2.E-04**
Chromium VI	—	7.E-08	7.E-08	**—**	6.E-07	6.E-07
HPAH						
Benzo[a]anthracene	4.E-08	3.E-07	4.E-07	**3.E-05**	**2.E-05**	**5.E-05**
Benzo[a]pyrene	6.E-07	**5.E-06**	**5.E-06**	**5.E-04**	**3.E-04**	**7.E-04**
Benzo[b]fluoranthene	5.E-08	4.E-07	4.E-07	**3.E-05**	**2.E-05**	**5.E-05**
Benzo[k]fluoranthene	3.E-08	2.E-07	3.E-07	**2.E-05**	**1.E-05**	**3.E-05**
Chrysene	5.E-09	4.E-08	4.E-08	**3.E-06**	**2.E-06**	**5.E-06**
Dibenzo[a,h]anthracene	8.E-09	6.E-08	7.E-08	**6.E-06**	**3.E-06**	**1.E-05**
Indeno[1,2,3-cd]pyrene	4.E-08	3.E-07	4.E-07	**4.E-05**	**2.E-05**	**6.E-05**
Total HPAH	**—**	**—**	**7.E-06**	**—**	**—**	**9.E-04**
Total PAH	**—**	**—**	**7.E-06**	**—**	**—**	**9.E-04**
Phthalates						
Bis(2-Ethylhexyl)phthalate	4.E-11	4.E-10	4.E-10	4.E-09	3.E-09	7.E-09
Butylbenzylphthalate	9.E-13	9.E-12	1.E-11	6.E-11	4.E-11	1.E-10
Phenols						
Pentaclorophenol	1.E-10	4.E-10	5.E-10	6.E-09	2.E-09	8.E-09
Misc. Extractables						
Carbazole	4.E-11	4.E-10	4.E-10	6.E-09	4.E-09	9.E-09
Volatile Organics						
Benzene	—	3.E-09	3.E-09	—	6.E-08	6.E-08
Ethylbenzene	—	7.E-11	7.E-11	—	2.E-09	2.E-09
Pesticides/PCBs						
Chlordane	2.E-11	6.E-10	6.E-10	8.E-10	1.E-09	2.E-09
DDD	2.E-12	7.E-11	8.E-11	3.E-10	7.E-10	1.E-09
DDT	3.E-12	1.E-10	1.E-10	9.E-11	2.E-10	3.E-10
PCB Aroclor 1254	5.E-10	3.E-09	4.E-09	6.E-08	3.E-08	9.E-08
PCB Aroclor 1260	4.E-10	2.E-09	3.E-09	4.E-08	2.E-08	6.E-08
Total PCBs	7.E-10	5.E-09	6.E-09	9.E-08	4.E-08	1.E-07
		Total	**9.E-06**		**Total**	**1.E-03**

Notes:

BOLD and Shaded: Signifies a risk greater than 1 x 10-6 for individual chemicals or cumulative risk.

— Dermal absorption factor was not available; calculations could not be completed.

CT: Central Tendency

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

RME: Reasonable Maximum Exposure

Table 4-18 Netfishing Results—Non-Carcinogenic

Chemical of Potential Concern	CT Scenario			RME Scenario		
	Dermal Contact HQ	Oral HQ	Total HQ	Dermal Contact HQ	Oral HQ	Total HQ
Adult Non-Cancer Risk Calculations						
Conventionals/Misc.						
Total Cyanide	—	2.E-05	2.E-05	—	4.E-04	4.E-04
Metals						
Antimony	—	3.E-04	3.E-04	—	2.E-03	2.E-03
Arsenic	3.E-04	7.E-03	8.E-03	2.E-01	4.E-01	6.E-01
Cadmium	7.E-08	5.E-05	5.E-05	3.E-06	2.E-04	2.E-04
Chromium III	—	1.E-06	1.E-06	—	7.E-06	7.E-06
Chromium VI	—	8.E-05	8.E-05	—	6.E-04	6.E-04
Cobalt	—	5.E-03	5.E-03	—	4.E-02	4.E-02
Copper	—	2.E-04	2.E-04	—	1.E-03	1.E-03
Lead and Compounds [1]	—	—	—	—	—	—
Mercury	—	8.E-05	8.E-05	—	3.E-04	3.E-04
Nickel Soluble Salts	—	1.E-04	1.E-04	—	2.E-03	2.E-03
Selenium		4.E-06	4.E-06		2.E-05	2.E-05
Silver	—	1.E-05	1.E-05	—	5.E-05	5.E-05
Vanadium	—	2.E-04	2.E-04	—	9.E-04	9.E-04
Zinc	—	4.E-05	4.E-05	—	2.E-04	2.E-04
Butyltins						
Tributyltin	1.E-05	7.E-05	8.E-05	2.E-03	1.E-03	3.E-03
LPAH						
Acenaphthene	1.E-06	6.E-06	7.E-06	4.E-04	2.E-04	5.E-04
Acenaphthylene	3.E-07	2.E-06	2.E-06	1.E-04	7.E-05	2.E-04
Anthracene	2.E-07	1.E-06	2.E-06	1.E-04	5.E-05	2.E-04
Fluorene	1.E-06	5.E-06	6.E-06	3.E-04	2.E-04	5.E-04
2-methylnaphthalene	6.E-06	3.E-05	4.E-05	1.E-03	7.E-04	2.E-03
Naphthalene	2.E-06	1.E-05	1.E-05	6.E-04	3.E-04	9.E-04
Phenanthrene	8.E-07	4.E-06	5.E-06	4.E-04	2.E-04	6.E-04
Total LPAH	—	—	7.E-05	—	—	5.E-03
HPAH						
Benzo[g,h,i]perylene	5.E-06	3.E-05	3.E-05	3.E-03	2.E-03	5.E-03
Fluoranthene	1.E-05	6.E-05	7.E-05	4.E-03	2.E-03	7.E-03
Pyrene	2.E-05	9.E-05	1.E-04	7.E-03	4.E-03	1.E-02
Retene	3.E-08	2.E-07	2.E-07	3.E-06	2.E-06	5.E-06
Total HPAH	—	—	2.E-04	—	—	2.E-02
Total PAH	—	—	3.E-04	—	—	3.E-02
Phthalates						
Bis(2-Ethylhexyl)phthalate	3.E-07	2.E-06	3.E-06	2.E-05	2.E-05	4.E-05
Butylbenzylphthalate	6.E-09	4.E-08	5.E-08	3.E-07	2.E-07	4.E-07
Di-n-butylpthalate	2.E-07	1.E-06	1.E-06	3.E-05	2.E-05	5.E-05
Diethylphthalate	1.E-08	8.E-08	1.E-07	4.E-07	3.E-07	7.E-07
Dimethylphthalate	9.E-10	6.E-09	7.E-09	4.E-08	3.E-08	6.E-08
Di-n-octylphthalate	2.E-09	2.E-08	2.E-08	4.E-08	3.E-08	7.E-08
Phenols						
2,4-Dimethylphenol	2.E-08	2.E-07	2.E-07	6.E-07	4.E-07	1.E-06
4-Methylphenol	3.E-07	2.E-06	3.E-06	2.E-05	1.E-05	3.E-05
Pentachlorophenol	7.E-08	2.E-07	3.E-07	3.E-06	8.E-07	4.E-06
Phenol	8.E-09	5.E-08	6.E-08	5.E-07	3.E-07	8.E-07

Table 4-18 Netfishing Results—Non-Carcinogenic

Chemical of Potential Concern	CT Scenario			RME Scenario		
	Dermal Contact HQ	Oral HQ	Total HQ	Dermal Contact HQ	Oral HQ	Total HQ
Misc. Extractables						
Benzoic Acid	2.E-09	1.E-08	2.E-08	7.E-08	5.E-08	1.E-07
Dibenzofuran	8.E-06	6.E-05	6.E-05	2.E-03	2.E-03	2.E-03
Volatile Organics						
Benzene	—	2.E-05	2.E-05	—	4.E-04	4.E-04
Ethylbenzene	—	1.E-07	1.E-07	—	3.E-06	3.E-06
Toluene	—	2.E-09	2.E-09	—	1.E-08	1.E-08
Total Xylenes	—	2.E-08	2.E-08	—	6.E-07	6.E-07
1,2,4-Trimethylbenzene	—	9.E-06	9.E-06	—	2.E-05	2.E-05
Pesticides/PCBs						
Chlordane	3.E-07	6.E-06	6.E-06	7.E-06	1.E-05	1.E-05
DDT	5.E-08	1.E-06	1.E-06	9.E-07	2.E-06	9.E-06
PCB Aroclor 1254	3.E-05	1.E-04	1.E-04	2.E-03	1.E-03	1.E-03
Total PCBs	—	—	1.E-04	—	—	1.E-03

Notes:

BOLD and Shaded: Signifies an HQ greater than 1 for individual chemicals. No chemicals exceeded this threshold.

— Toxicological information or dermal absorption factor was not available or chemical was not analyzed; calculations could not be completed.

[1] The maximum sediment lead concentration in the GWSA (1,120mg/kg) was compared to the USEPA Region 9 Regional Screening Level (800 mg/kg, industrial soils). See Section 4.2.6.3 in the text for further discussion. The sediment average concentration in the GWSA is well below this value; therefore, exposure to lead while netfishing poses a limited health risk in the GWSA.

CT: Central Tendency

DDT: Dichlorodiphenyltrichloroethane

GWSA: Gas Works Sediment Area

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

HQ: Hazard Quotient

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

RME: Reasonable Maximum Exposure

USEPA: U.S. Environmental Protection Agency

Table 4-19 Maximum Nearshore Surface Sediment Concentrations (0–10 cm)[1]

Chemical of Potential Concern	Sample Name	Date	Concentration (mg/kg)
Conventionals/Misc.			
Total Cyanide	95042153	01/26/95	168
Metals			
Antimony	NLU-122-SS-0010	11/13/02	9
Arsenic	NLU55TX-SS-0010	04/15/05	70
Cadmium	NLU58-SS-0010	12/06/04	3
Chromium[2]	94492356	12/08/94	101
Cobalt	94492356	12/08/94	101
Copper	GWS-SG17	12/06/04	687
Lead	NLU-120-SS-0010	11/13/02	328
Mercury	94492356	12/08/94	1.06
Nickel	NLU53-SS-0010	12/06/04	268
Selenium	94492356	01/26/95	0.52
Silver	94492356	12/08/94	3.04
Vanadium	95042153	01/26/95	132
Zinc	NLU58-SS-0010	12/06/04	909
Butyltins			
Tributyltin	NLU-122-SS-0010	11/13/02	0.409
LPAH			
Acenaphthene	NLU65-SS-0010	12/11/04	210
Acenaphthylene	NLU65-SS-0010	12/11/04	79
Anthracene	NLU65-SS-0010	12/11/04	160
Fluorene	NLU65-SS-0010	12/11/04	74
2-Methylnaphthalene	NLU-122-SS-0010	11/13/02	46
Naphthalene	NLU55TX-SS-0010	04/15/05	98
Phenanthrene	NLU65-SS-0010	12/11/04	510
Total LPAH	NLU65-SS-0010	12/11/04	1,100
HPAH			
Benzo(a)anthracene	NLU65-SS-0010	12/11/04	700
Benzo(a)pyrene	NLU65-SS-0010	12/11/04	1,100
Benzo(b)fluoranthene	NLU65-SS-0010	12/11/04	800
Benzo(k)fluoranthene	NLU65-SS-0010	12/11/04	430
Benzo(g,h,i)perylene	NLU65-SS-0010	12/11/04	1,100
Chrysene	NLU65-SS-0010	12/11/04	770
Dibenzo(a,h)anthracene	NLU65-SS-0010	12/11/04	150
Fluoranthene	NLU65-SS-0010	12/11/04	1,900
Indeno(1,2,3-cd)pyrene	NLU65-SS-0010	12/11/04	890
Pyrene	NLU65-SS-0010	12/11/04	2,200
Retene	94492356	12/08/94	3.71
Total HPAH	NLU65-SS-0010	12/11/04	10,040
Total PAH	NLU65-SS-0010	12/11/04	11,154
Phthalates			
Bis(2-Ethylhexyl)phthalate	GWS-SG13	05/23/05	2.7
Butylbenzylphthalate[3]	94492356	12/08/94	2.41
Di-n-butylphthalate	94492356	12/08/94	6.61
Diethylphthalate[3]	NLU130-SS-0010	11/12/02	0.55
Dimethylphthalate	GWS-SG07	05/23/05	0.22
Di-n-octylphthalate[3]	NLU130-SS-0010	11/12/02	0.55

Table 4-19 Maximum Nearshore Surface Sediment Concentrations (0–10 cm)[1]

Chemical of Potential Concern	Sample Name	Date	Concentration (mg/kg)
Phenols			
2,4-Dimethylphenol[3]	NLU130-SS-0010	11/12/02	0.55
4-Methylphenol	NLU-122-SS-0010	11/13/02	0.17
Pentachlorophenol[3]	NLU130-SS-0010	11/12/02	2.8
Phenol	95042153	01/26/95	0.648
Misc. Extractables			
Benzoic Acid	95042153	01/26/95	3.41
Carbazole	NLU55TX-SS-0010	04/15/05	5.5
Dibenzofuran	NLU-122-SS-0010	11/13/02	14
Volatile Organic Compounds			
Benzene	94492356	12/08/94	0.005
Ethylbenzene	NLU78-SS-0010	12/06/04	0.002
Toluene	NLU53-SS-0010	12/06/04	0.016
Total Xylenes	94492356	12/08/94	0.013
1,2,4-Trimethylbenzene[3,4]	NLU117TX-US-0010	11/20/02	17
Pesticides/PCBs			
Chlordane[3]	NLU55TX-SS-0010	04/15/05	0.01
DDD[3]	NLU55TX-SS-0010	04/15/05	0.02
DDT[3]	NLU55TX-SS-0010	04/15/05	0.02
PCB Aroclor 1254	GWS-SG17	05/23/05	0.48
PCB Aroclor 1260	NLU-122-SS-0010	11/13/02	0.17
Total PCBs	GWS-SG17	05/23/05	0.48

Notes:

[1] Maximum concentration from shoreline surface sample 94492356, 95042153 (EPA 1995); NLU 120, NLU 122, NLU 130, NLU131, NLU133, NLU134 (RETEC 2002); NLU53, NLU55, NLU58, NLU65, NLU77, NLU78 (RETEC 2004a); NLU55-TX, NLU60 (RETEC 2006); GWS-SG07, GWS-SG13, GWS-SG17 (Floyd|Snider 2005).

[2] For the purpose of risk calculations, chromium concentrations were assumed to be in a ratio of 1:6 for chromium VI to chromium III. Toxicity values are not available for total chromium, only for chromium VI and chromium III.

[3] Result reported as non-detect; therefore, half of the maximum reporting limit was designated the maximum exposure point concentration.

[4] Shoreline results not available. To be conservative, maximum concentrations from across the Gas Works Sediment Area (GSWA) were employed.

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

EPA: U.S. Environmental Protection Agency

Table 4-20 Exposure Parameters: Great Blue Heron

Parameter	Units	Value	Reference/Rationale
Maximum Concentration in Sediments (C)	mg/kg	Refer to Table 4-19	
Maximum Crayfish Tissue Concentration (C)	mg/kg	Refer to Table 4-2	
Maximum Finfish Tissue Concentration (C)	mg/kg	Refer to Table 4-3	
Sediment Ingestion Rate (SIR)	kg dw/day	0.002	Recommended by Windward 2007 and 2009 (2% of dietary intake in dry weight).
Food Ingestion Rate (FIR)	kg ww/day	0.39	RSET 2009. Converted to dry weight of 0.107 kg/day based on average prety moisture content promulgated by USEPA 1993.
Dietary Crayfish Fraction (DF)	unitless	0.020	USEPA 1993.
Dietary Finfish Fraction (DF)	years	0.98	USEPA 1993.
Fractional Intake (fraction of sediment and fish ingested derived from site) (FI)	unitless	0.5	Conservative assumption that 50% of sediment and fish consumed is derived from the Site.
Body Weight (BW)	kg	2.2	Female, RSET 2009.

Notes:

RSET: Regional Sediment Evaluation Team

USEPA: U. S. Environmental Protection Agency

Table 4-21 Exposure Parameters: American Mallard

Parameter	Units	Value	Reference/Rationale
Maximum Concentration in Sediments (C)	mg/kg	Refer to Table 4-19	
Maximum Crayfish Tissue Concentration (C)	mg/kg	Refer to Table 4-2	
Maximum Finfish Tissue Concentration (C)	mg/kg	Refer to Table 4-3	
Sediment Ingestion Rate (SIR)	kg dw/day	0.0019	Beyer et al. 1994—3.3% of dry weight food intake.
Food Ingestion Rate (FIR)	kg ww/day	0.31	USEPA 1993. Converted to dry weight of 0.065 kg/day based on average prey moisture content promulgated by USEPA 1993.
Dietary Crayfish Fraction (DF)	unitless	1.0	Best professional judgment.
Dietary Finfish Fraction (DF)	years	0.0	USEPA 1993.
Fractional Intake (fraction of sediment and fish ingested derived from site) (FI)	unitless	1.0	Conservative assumption that all sediment and fish consumed are derived from the Site.
Body Weight (BW)	kg	1.1	Average female, USEPA 1993.

Notes:

USEPA: U. S. Environmental Protection Agency

Table 4-22 Exposure Parameters: Northern River Otter

Parameter	Units	Value	Reference/Rationale
Maximum Concentration in Sediments (C)	mg/kg	Refer to Table 4-4	
Maximum Crayfish Tissue Concentration (C)	mg/kg	Refer to Table 4-2	
Maximum Finfish Tissue Concentration (C)	mg/kg	Refer to Table 4-3	
Sediment Ingestion Rate (SIR)	kg dw/day	0.017	Windward 2009—2% of dry weight food intake.
Food Ingestion Rate (FIR)	kg ww/day	0.759	RSET 2009. Converted to dry weight of 0.206 kg/day based on average prey moisture content promulgated by USEPA 1993.
Dietary Crayfish Fraction (DF)	unitless	0.12	Recommended values from Windward 2007 and 2009.
Dietary Finfish Fraction (DF)	years	0.88	Recommended values from Windward 2007 and 2009.
Fractional Intake (fraction of sediment and fish ingested derived from site) (FI)	unitless	1.0	Conservative assumption that all sediment and fish consumed are derived from the Site.
Body Weight (BW)	kg	7.7	Female, RSET 2009.

Notes:

RSET: Regional Sediment Evaluation Team

USEPA: U. S. Environmental Protection Agency

Table 4-23 Exposure Parameters: Juvenile Chinook Salmon

Parameter	Units	Value	Reference/Rationale
Maximum Concentration in Sediments (C)	mg/kg	Refer to Table 4-4	
Maximum Crayfish Tissue Concentration (C)	mg/kg	Refer to Table 4-2	
Maximum Finfish Tissue Concentration (C)	mg/kg	Refer to Table 4-3	
Sediment Ingestion Rate (SIR)	kg dw/day	2.3×10^{-5}	Best professional judgment—10% of dry diet.
Food Ingestion Rate (FIR)	kg ww/day	1.1×10^{-3}	Arnot and Gobas 2004. Converted to dry weight of 2.31×10^{-4} kg/day based on average prey moisture content promulgated by USEPA 1993.
Dietary Crayfish Fraction (DF)	unitless	1.0	Best professional judgment.
Dietary Finfish Fraction (DF)	years	0.0	Best professional judgment—juvenile salmon have a diet of invertebrates.
Fractional Intake (fraction of sediment and fish ingested derived from site) (FI)	unitless	1.0	Conservative assumption that all sediment and fish consumed are derived from the Site.
Body Weight (BW)	kg	0.012	Windward 2009—site-specific data.

Notes:

USEPA: U. S. Environmental Protection Agency

Table 4-24 Avian Toxicity Reference Values (TRV)

Chemical of Potential Concern	Test Species	NOAEL (mg/kg BW/day)	Effect Endpoints	LOAEL (mg/kg BW/day)	Effect Endpoints	Source
Conventionals/Misc.						
Total Cyanide	n/a	n/a	n/a	n/a	n/a	n/a
Metals						
Antimony	n/a	n/a	n/a	n/a	n/a	n/a
Arsenic	Chicken	2.24	survival	11.2	survival	RSET 2009
Cadmium	Japanese Quail	1.47	growth	4	reproduction	USEPA 2005b, Richardson et al. (1974) as cited in Windward 2009
Chromium (III)	Chicken	2.66	reproduction	13.3	estimated assuming UF=5	USEPA 2008b
Chromium (VI)	n/a	n/a	n/a	n/a	n/a	n/a
Cobalt	Chicken, Duck	7.61	growth	38.1	estimated assuming UF=5	USEPA 2005c
Copper	Chicken, Duck	4.05	growth	62	growth	USEPA 2007b, Mehring et al. (1960) as cited in Windward 2009
Lead and Compounds	Chicken	1.63	reproduction	8.2	reproduction	RSET 2009
Mercury (methyl)	n/a	0.013	growth	0.026	growth	RSET 2009
Nickel	Chicken, Mallard	6.7	growth	107	growth	USEPA 2007c, Cain and Pafford (1981) as cited in Windward 2007
Selenium	Chicken	0.29	survival	1.45	estimated assuming UF=5	USEPA 2007d
Silver	Turkey	2.02	growth	10.1	estimated assuming UF=5	USEPA 2006b
Vanadium	Chicken	0.34	growth	1.72	estimated assuming UF=5	USEPA 2005d
Zinc	Mallard, Japanese Quail, Chicken	66.10	reproduction	124	reproduction	USEPA 2007e, Roberson and Schaible (1960) as cited in Windward 2009
Butyltins						
Tributyltin	Japanese Quail	6.8	reproduction	17	reproduction	RSET 2009
LPAH						
Acenaphthene	n/a	n/a	n/a	n/a	n/a	n/a
Acenaphthylene	n/a	n/a	n/a	n/a	n/a	n/a
Anthracene	n/a	n/a	n/a	n/a	n/a	n/a
Fluorene	n/a	n/a	n/a	n/a	n/a	n/a
2-Methylnaphthalene	n/a	n/a	n/a	n/a	n/a	n/a
Naphthalene	n/a	n/a	n/a	n/a	n/a	n/a
Phenanthrene	n/a	n/a	n/a	n/a	n/a	n/a
Total LPAH	n/a	n/a	n/a	n/a	n/a	n/a

Table 4-24 Avian Toxicity Reference Values (TRV)

Chemical of Potential Concern	Test Species	NOAEL (mg/kg BW/day)	Effect Endpoints	LOAEL (mg/kg BW/day)	Effect Endpoints	Source
HPAH						
Benzo(a)anthracene	n/a	n/a	n/a	n/a	n/a	n/a
Benzo(a)pyrene	Pigeon	0.28	reproduction	1.4	reproduction	Hough et al. (1993) as cited in Windward 2009
Benzo(b)fluoranthene	n/a	n/a	n/a	n/a	n/a	n/a
Benzo(k)fluoranthene	n/a	n/a	n/a	n/a	n/a	n/a
Benzo(g,h,i)perylene	n/a	n/a	n/a	n/a	n/a	n/a
Chrysene	n/a	n/a	n/a	n/a	n/a	n/a
Dibenzo(a,h)anthracene	n/a	n/a	n/a	n/a	n/a	n/a
Fluoranthene	n/a	n/a	n/a	n/a	n/a	n/a
Indeno(1,2,3-cd)pyrene	n/a	n/a	n/a	n/a	n/a	n/a
Pyrene	n/a	n/a	n/a	n/a	n/a	n/a
Retene	n/a	n/a	n/a	n/a	n/a	n/a
Total HPAH	n/a	n/a	n/a	n/a	n/a	n/a
Total PAH	Mallard	40.00	reproduction	200	reproduction	Patton and Dieter (1980) as cited in Windward 2009
Phthalates						
Bis(2-Ethylhexy)lphthalate	Chicken	1.11	reproduction	329	reproduction	Peakall (1974), Ishida et al. (1982) as cited in Windward 2009
Butylbenzyl phthalate	Chicken	1.11	reproduction	329	reproduction	Bis(2-ethylhexyl) phthalate as a surrogate
Di-n-butylphthalate[9]						
Diethylphthalate						
Dimethylphthalate						
Di-n-octylphthalate						
Phenols						
2,4-Dimethylphenol	n/a	n/a	n/a	n/a	n/a	n/a
4-Methylphenol	n/a	n/a	n/a	n/a	n/a	n/a
Pentachlorophenol	Chicken	6.73	survival	33.650	estimated assuming UF=5	USEPA 2007f
Phenol	n/a	n/a	n/a	n/a	n/a	n/a
Misc. Extractables						
Benzoic Acid	n/a	n/a	n/a	n/a	n/a	n/a
Carbazole	n/a	n/a	n/a	n/a	n/a	n/a
Dibenzofuran	n/a	n/a	n/a	n/a	n/a	n/a
Volatile Organic Compounds						
Benzene	n/a	n/a	n/a	n/a	n/a	n/a
Ethylbenzene	n/a	n/a	n/a	n/a	n/a	n/a
Toluene	n/a	n/a	n/a	n/a	n/a	n/a
Total Xylenes	n/a	n/a	n/a	n/a	n/a	n/a
1,2,4-Trimethylbenzene	n/a	n/a	n/a	n/a	n/a	n/a

Table 4-24 Avian Toxicity Reference Values (TRV)

Chemical of Potential Concern	Test Species	NOAEL (mg/kg BW/day)	Effect Endpoints	LOAEL (mg/kg BW/day)	Effect Endpoints	Source
Pesticides/PCBs						
Chlordane	Bobwhite Quail	0.60	growth, survival	2	survival	Ludke (1976), Hill et al. (1975), Heath et al. (1972) as cited in Windward 2007
DDD	Chicken	0.227	survival	1.14	survival	RSET 2009, DDT as surrogate
DDT	Chicken	0.227	survival	1.14	survival	RSET 2009
PCB Aroclor 1254	n/a	n/a	n/a	n/a	n/a	n/a
PCB Aroclor 1260	n/a	n/a	n/a	n/a	n/a	n/a
Total PCBs	n/a	0.2	reproduction	0.6	reproduction	RSET 2009

Notes:

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

LOAEL: Lowest Observed Adverse Effect Level

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

n/a: Not available

NOAEL: No Observed Adverse Effect Level

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

RSET: Regional Sediment Evaluation Team

UF: Uncertainty factor

USEPA: U. S. Environmental Protection Agency

Table 4-25 Mammalian Toxicity Reference Values (TRV)

Chemical of Potential Concern	Test Species	NOAEL (mg/kg BW/day)	Effect Endpoints	LOAEL (mg/kg BW/day)	Effect Endpoints	Source
Conventionals/Misc.						
Total Cyanide	Rat	10.8	body weight	30.0	body weight	USEPA 2010
Metals						
Antimony	Rat	0.77	growth, reproduction	3.9	estimated assuming UF=5	USEPA 2005e
Arsenic	Dog	1.04	growth	5.2	growth	RSET 2009
Cadmium	Rat	0.77	growth, reproduction	3.9	estimated assuming UF=5	USEPA 2005b
Chromium (III)	Geometric mean of several species	2.4	growth, reproduction	12	estimated assuming UF=5	USEPA 2008b
Chromium (VI)	Geometric mean of several species	9.24	growth, reproduction	46	estimated assuming UF=5	USEPA 2008b
Cobalt	Geometric mean of several species	7.33	growth	36.5	growth	USEPA 2005c
Copper	Pig	5.6	growth, survival	26	reproduction	USEPA 2007b, Aulerich et al. (1982) as cited in Windward 2009
Lead and Compounds	Rat	4.7	growth	24	estimated assuming UF=5	RSET 2009
Mercury	n/a	0.016	growth	0.027	growth	RSET 2009
Nickel	Rat	1.7	growth	20	reproduction	USEPA 2007c, Ambrose et al. 1976 as cited in Windward 2007
Selenium	Pig	0.143	growth, reproduction	0.7	estimated assuming UF=5	USEPA 2007d, Schlicker and Cox (1968) as cited in Windward 2007
Silver	Pig	6	growth	60.2	growth	USEPA 2006b
Vanadium	Mouse	4.16	growth	20.80	estimated assuming UF=5	USEPA 2005d
Zinc	Geometric mean of several species	75.4	growth, reproduction	320	reproduction	USEPA 2007e, Schlicker and Cox (1968) as cited in Windward 2007
Butyltins						
Tributyltin	Mouse	2.3	growth, survival	3.5	growth	RSET 2009
LPAH						
Acenaphthene	Mouse	35	hepatic effects	175	hepatic effects	USEPA 2010
Acenaphthylene	Mouse	35	hepatic effects	175	hepatic effects	Acenaphthene as a surrogate
Anthracene	Mouse	200	gross histopathology	1000	gross histopathology	USEPA 2010
Fluorene	Rat	65.6	growth	328	estimated assuming UF=5	RSET 2009
2-Methylnaphthalene	Mouse	10.5	lung lesions	52.3	lung lesions	USEPA 2010
Naphthalene	Rat	14.2	body weight	71	body weight	USEPA 2010
Phenanthrene	Mouse	200	gross histopathology	1000	gross histopathology	Antracene as surrogate
Total LPAH	Rat	65.6	growth	328	estimated assuming UF=5	USEPA 2007g

Table 4-25 Mammalian Toxicity Reference Values (TRV)

Chemical of Potential Concern	Test Species	NOAEL (mg/kg BW/day)	Effect Endpoints	LOAEL (mg/kg BW/day)	Effect Endpoints	Source
HPAH						
Benzo(a)anthracene	Mouse	2	reproduction	10	estimated assuming UF=5	Benzo(a)pyrene as surrogate
Benzo(a)pyrene	Mouse	2	reproduction	10	estimated assuming UF=5	Sample et al. 1996
Benzo(b)fluoranthene	Mouse	2	reproduction	10	estimated assuming UF=5	Benzo(a)pyrene as surrogate
Benzo(k)fluoranthene	Mouse	2	reproduction	10	estimated assuming UF=5	Benzo(a)pyrene as surrogate
Benzo(g,h,i)perylene	Mouse	2	reproduction	10	estimated assuming UF=5	Benzo(a)pyrene as surrogate
Chrysene	Mouse	15	kidney effects	75	estimated assuming UF=5	Benzo(a)pyrene as surrogate
Dibenzo(a,h)anthracene	Mouse	2	reproduction	10	estimated assuming UF=5	Benzo(a)pyrene as surrogate
Fluoranthene	Mouse	0.6	survival	3.1	estimated assuming UF=5	RSET 2009
Indeno(1,2,3-cd)pyrene	Mouse	2	reproduction	10	estimated assuming UF=5	Benzo(a)pyrene as surrogate
Pyrene	Mouse	0.6	survival	3.1	estimated assuming UF=5	RSET 2009
Retene	Mouse	200	gross histopathology	1000	gross histopathology	Antracene as surrogate
Total HPAH	Mouse	0.6	survival	3.1	estimated assuming UF=5	USEPA 2007g
Total PAH	n/a	n/a	n/a	n/a	n/a	n/a
Phthalates						
Bis(2-Ethylhexyl)phthalate	Mouse	44	reproduction	91	reproduction	Tyl et al. 1988 as cited in Windward 2007
Butylbenzyl phthalate	Rat	250	reproduction	750	reproduction	Tyl et al. 2004 as cited in Windward 2007
Di-n-butylphthalate[9]	Rat	16	reproduction	80	reproduction	Wine et al. 1997 as cited in Windward 2007
Diethylphthalate	Mouse	1860	growth, reproduction	3721	growth, reproduction	Lamb et al. 1987 as cited in Windward 2007
Dimethylphthalate	Rat	16	reproduction	80	reproduction	Di-n-butylphthalate as a surrogate
Di-n-octylphthalate	Rat	16	reproduction	80	reproduction	Di-n-butylphthalate as a surrogate
Phenols						
2,4-Dimethylphenol	Rat	60	growth, reproduction	120	growth, reproduction	phenol as a surrogate
4-Methylphenol	Rat	60	growth, reproduction	120	n/a	phenol as a surrogate
Pentachlorophenol	Geometric mean of several species	8.42	growth, reproduction	42.1	estimated assuming UF=5	USEPA 2007f
Phenol	Rat	60	growth, reproduction	120	growth, reproduction	Argus Research Laboratories 1997 as cited in USEPA 2010

Table 4-25 Mammalian Toxicity Reference Values (TRV)

Chemical of Potential Concern	Test Species	NOAEL (mg/kg BW/day)	Effect Endpoints	LOAEL (mg/kg BW/day)	Effect Endpoints	Source
Misc. Extractables						
Benzoic Acid	Rat	80	growth, survival	750	growth	USEPA 2010
Carbazole	n/a	n/a	n/a	n/a	n/a	n/a
Dibenzofuran	n/a	n/a	n/a	n/a	n/a	n/a
Volatile Organic Compounds						
Benzene	Mouse	52.7	reproduction	264	reproduction	Sample et al. 1996
Ethylbenzene	n/a	n/a	n/a	n/a	n/a	n/a
Toluene	n/a	n/a	n/a	n/a	n/a	n/a
Total Xylenes	n/a	n/a	n/a	n/a	n/a	n/a
1,2,4-Trimethylbenzene	n/a	n/a	n/a	n/a	n/a	n/a
Pesticides/PCBs						
Chlordane	Mouse	0.18	growth	0.92	growth	Khasawinah and Grutsch 1989 as cited in Windward 2007
DDD	Rat	0.15	reproduction	0.74	estimated assuming UF=5	RSET 2009
DDT	Rat	0.15	reproduction	0.74	estimated assuming UF=5	RSET 2009
PCB Aroclor 1254	n/a	n/a	n/a	n/a	n/a	n/a
PCB Aroclor 1260	n/a	n/a	n/a	n/a	n/a	n/a
Total PCBs	Mink	0.12	reproduction	0.23	reproduction	RSET 2009

Notes:

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

LOAEL: Lowest Observed Adverse Effect Level

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

n/a: Not available

NOAEL: No Observed Adverse Effect Level

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

RSET: Regional Sediment Evaluation Team

UF: Uncertainty factor

USEPA: U. S. Environmental Protection Agency

Table 4-26 Salmonid Toxicity Reference Values (TRV)

Chemical of Potential Concern	Test Species	NOAEL (mg/kg BW/day)	Effect Endpoints	LOAEL (mg/kg BW/day)	Effect Endpoints	Source
Conventionals/Misc.						
Total Cyanide	n/a	n/a	n/a	n/a	n/a	n/a
Metals						
Antimony	n/a	n/a	n/a	n/a	n/a	n/a
Arsenic	Rainbow Trout	1.8	body weight	2.8	body weight	Olademeji, et al., 1984 as cited in Windward 2007
Cadmium	Juvenile Rainbow Trout	4.6	survival	28	survival	Szebedinsky et al. 2001 as cited in Windward 2009
Chromium III	n/a	n/a	n/a	n/a	n/a	n/a
Chromium VI	n/a	n/a	n/a	n/a	n/a	n/a
Cobalt	n/a	n/a	n/a	n/a	n/a	n/a
Copper	Salmonids (trout, Atlantic salmon)	7.4	body weight	18.8	body weight	10th percentile of available salmonid data from: Lundebye et al. 1999 and Lanno et al. 1985, cited in Windward 2009
Lead and Compounds	Rainbow Trout	134	growth	670	estimated assuming UF=5	Goettl 1976, as cited in Windward 2009
Mercury	Rainbow Trout	0.047	survival	0.062	hatchling body weight	10th percentile of available salmonid data from: Phillips and Buhler 1978; McKim et al., 1976; Lock 1975; McKim et al., 1976; Olsen et al., 1975; and Nimi and Lowe-Jinde 1984 as cited in Windward 2007
Nickel	n/a	n/a	n/a	n/a	n/a	n/a
Selenium	Fish	0.022	Survival, Growth	0.029	Survival, Growth	USEPA 2004 as cited in Windward 2007
Silver	n/a	n/a	n/a	n/a	n/a	n/a
Vanadium	Juvenile Rainbow Trout	0.187		0.935		Hilton JW, Bettger WJ. 1988 as cited in Windward 2007
Zinc	Rainbow Trout	19	growth	38	growth	Takeda and Shimma 1977, as cited in Windward 2009
Butyltins						
Tributyltin	Japanese Flounder Larvae	0.00042		0.0021	body weight; increased sex reversal	Shimasaki et al. 2003, as cited in Windward 2009
LPAH						
Acenaphthene	n/a	n/a	n/a	n/a	n/a	n/a
Acenaphthylene	n/a	n/a	n/a	n/a	n/a	n/a
Anthracene	n/a	n/a	n/a	n/a	n/a	n/a
Fluorene	n/a	n/a	n/a	n/a	n/a	n/a
2-Methylnaphthalene	n/a	n/a	n/a	n/a	n/a	n/a
Naphthalene	n/a	n/a	n/a	n/a	n/a	n/a
Phenanthrene	n/a	n/a	n/a	n/a	n/a	n/a
Total LPAH	n/a	n/a	n/a	n/a	n/a	n/a

Table 4-26 Salmonid Toxicity Reference Values (TRV)

Chemical of Potential Concern	Test Species	NOAEL (mg/kg BW/day)	Effect Endpoints	LOAEL (mg/kg BW/day)	Effect Endpoints	Source
HPAH						
Benzo(a)anthracene	n/a	n/a	n/a	n/a	n/a	n/a
Benzo(a)pyrene	Juvenile Rainbow Trout	1.9	body weight	3.7	body weight	Hart and Heddle 1991, Hendricks et al. 1985, as cited in Windward 2009
Benzo(b)fluoranthene	n/a	n/a	n/a	n/a	n/a	n/a
Benzo(k)fluoranthene	n/a	n/a	n/a	n/a	n/a	n/a
Benzo(g,h,i)perylene	n/a	n/a	n/a	n/a	n/a	n/a
Chrysene	n/a	n/a	n/a	n/a	n/a	n/a
Dibenzo(a,h)anthracene	n/a	n/a	n/a	n/a	n/a	n/a
Fluoranthene	n/a	n/a	n/a	n/a	n/a	n/a
Indeno(1,2,3-cd)pyrene	n/a	n/a	n/a	n/a	n/a	n/a
Pyrene	n/a	n/a	n/a	n/a	n/a	n/a
Retene	n/a	n/a	n/a	n/a	n/a	n/a
Total HPAH	n/a	n/a	n/a	n/a	n/a	n/a
Total PAH	Juvenile Chinook Salmon	6.1	body weight	18	body weight	Meador, et al. 2006 as cited in Windward 2009
Phthalates						
Bis(2-Ethylhexyl)phthalate	n/a	0.0071	estimated assuming UF=5	0.036	n/a	Mehrle and Mayer 1976 as cited in Windward 2007
Butylbenzylphthalate	n/a	n/a	n/a	n/a	n/a	n/a
Di-n-butylphthalate	n/a	n/a	n/a	n/a	n/a	n/a
Diethylphthalate	n/a	n/a	n/a	n/a	n/a	n/a
Dimethylphthalate	n/a	n/a	n/a	n/a	n/a	n/a
Di-n-octylphthalate	n/a	n/a	n/a	n/a	n/a	n/a
Phenols						
2,4-Dimethylphenol	n/a	n/a	n/a	n/a	n/a	n/a
4-Methylphenol	n/a	n/a	n/a	n/a	n/a	n/a
Pentachlorophenol	n/a	n/a	n/a	n/a	n/a	n/a
Phenol	n/a	n/a	n/a	n/a	n/a	n/a
Misc. Extractables						
Benzoic Acid	n/a	n/a	n/a	n/a	n/a	n/a
Carbazole	n/a	n/a	n/a	n/a	n/a	n/a
Dibenzofuran	n/a	n/a	n/a	n/a	n/a	n/a

Table 4-26 Salmonid Toxicity Reference Values (TRV)

Chemical of Potential Concern	Test Species	NOAEL (mg/kg BW/day)	Effect Endpoints	LOAEL (mg/kg BW/day)	Effect Endpoints	Source
Volatile Organic Compounds						
Benzene	Rainbow Trout	81.8	estimated assuming UF=5	409	biochemical	USACE and USEPA 2009
Ethylbenzene	n/a	n/a	n/a	n/a	n/a	n/a
Toluene	n/a	n/a	n/a	n/a	n/a	n/a
Total Xylenes	n/a	n/a	n/a	n/a	n/a	n/a
1,2,4-Trimethylbenzene	n/a	n/a	n/a	n/a	n/a	n/a
Pesticides/PCBs						
Chlordane	n/a	1.6	estimated assuming UF=5	8	n/a	Parrish et al., 1976 as cited Windward 2007
DDD	Mummichog, Summer Flouder	0.2	growth; survival	2.2	growth; survival	DDT as a surrogate
DDT	Mummichog, Summer Flouder	0.2	growth; survival	2.2	growth; survival	Hamelink, et al., 1971
PCB Aroclor 1254	Rainbow Trout	0.16	growth; survival	0.8	estimated assuming UF=5	USACE and USEPA 2009
PCB Aroclor 1260	n/a	n/a	n/a	n/a	n/a	n/a
Total PCBs	n/a	n/a	n/a	n/a	n/a	n/a

Notes:

BW: Body weight

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

LOAEL: Lowest Observed Adverse Effect Level

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

n/a: Not available

NOAEL: No Observed Adverse Effect Level

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

USACE: U.S. Army Corps of Engineers

USEPA: U. S. Environmental Protection Agency

Table 4-27 Ecological Risk Evaluation Results

Chemical of Potential Concern	Great Blue Heron		American Mallard		Northern River Otter		Juvenile Chinook Salmon	
	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ
Conventionals/Misc.								
Total Cyanide	—	—	—	—	8.3E-03	3.0E-03	—	—
Metals								
Antimony	—	—	—	—	1.9E-02	3.8E-03	—	—
Arsenic	1.7E-02	3.3E-03	7.6E-02	1.5E-02	1.2E+00	2.5E-01	**2.6E+00**	**1.6E+00**
Cadmium	1.4E-03	5.0E-04	1.9E-02	6.9E-03	4.4E-03	8.8E-04	3.2E-03	5.3E-04
Chromium III	1.8E-02	3.7E-03	6.5E-02	1.3E-02	5.1E-02	1.0E-02	—	—
Chromium VI	—	—	—	—	2.2E-03	4.4E-04	—	—
Cobalt	6.5E-03	1.3E-03	2.6E-02	5.2E-03	1.8E-02	3.6E-03	—	—
Copper	8.9E-02	5.8E-03	5.4E-01	3.5E-02	1.1E-01	2.4E-02	3.1E-01	1.2E-01
Lead	1.0E-01	2.0E-02	5.1E-01	1.0E-01	1.3E-01	2.6E-02	1.7E-02	3.3E-03
Mercury	3.7E-01	1.9E-01	8.4E-01	4.2E-01	3.7E-01	2.2E-01	1.6E-01	1.2E-01
Nickel	2.0E-02	1.2E-03	7.8E-02	4.9E-03	2.0E-01	1.7E-02	—	—
Selenium	5.0E-02	9.9E-03	4.0E-02	8.0E-03	1.1E-01	2.3E-02	3.6E-01	2.7E-01
Silver	7.9E-04	1.6E-04	3.2E-03	6.4E-04	4.2E-04	4.2E-05	—	—
Vanadium	1.9E-01	9.4E-02	7.5E-01	3.7E-01	1.7E-02	8.5E-03	**1.4E+00**	2.7E-01
Zinc	1.0E-02	5.6E-03	3.9E-02	2.1E-02	1.0E-02	2.5E-03	1.1E-01	5.6E-02
Butyltins								
Tributyltin	3.5E-04	1.4E-04	1.4E-04	5.7E-05	2.6E-03	1.7E-03	**3.2E+01**	**6.5E+00**
LPAH								
Acenaphthene	—	—	—	—	3.5E-03	7.0E-04	—	—
Acenaphthylene	—	—	—	—	1.2E-03	2.4E-04	—	—
Anthracene	—	—	—	—	8.7E-04	1.7E-04	—	—
Flourene	—	—	—	—	1.0E-03	2.1E-04	—	—
2-Methylnaphthalene	—	—	—	—	3.0E-03	6.1E-04	—	—
Naphthalene	—	—	—	—	4.6E-03	9.1E-04	—	—
Phenanthrene	—	—	—	—	3.5E-03	7.1E-04	—	—
Total LPAH	—	—	5.4E-02	1.1E-02	1.7E-02	3.4E-03	—	—
HPAH								
Benzo(a)anthracene	—	—	—	—	1.9E-01	3.8E-02	—	—
Benzo(a)pyrene	**1.9E+00**	3.8E-01	**7.7E+00**	**1.5E+00**	2.9E-01	5.9E-02	1.1E+00	5.7E-01
Benzo(b)fluoranthene	—	—	—	—	2.1E-01	4.3E-02	—	—
Benzo(k)fluoranthene	—	—	—	—	1.2E-01	2.3E-02	—	—
Benzo(g,h,i)perylene	—	—	—	—	2.9E-01	5.9E-02	—	—
Chrysene	—	—	—	—	2.8E-02	5.5E-03	—	—
Dibenzo(a,h)anthracene	—	—	—	—	4.0E-02	8.1E-03	—	—
Fluoranthene	—	—	—	—	**1.7E+00**	3.3E-01	—	—
Indeno(1,2,3-cd)pyrene	—	—	—	—	2.4E-01	4.8E-02	—	—
Pyrene	—	—	—	—	**1.9E+00**	3.9E-01	—	—
Retene	—	—	—	—	3.2E-05	6.4E-06	—	—
Total HPAH	—	—	—	—	**8.7E+00**	**1.7E+00**	—	—
Total PAH	1.4E-01	2.7E-02	5.4E-01	1.1E-01	—	—	**3.5E+00**	1.2E+00

Table 4-27 Ecological Risk Evaluation Results

Chemical of Potential Concern	Great Blue Heron		American Mallard		Northern River Otter		Juvenile Chinook Salmon	
	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ
Phthalates								
Bis(2-Ethylhexyl)phthalate	1.4E-03	4.6E-06	5.9E-03	2.0E-05	8.5E-05	4.1E-05	**1.8E+00**	3.6E-01
Butylbenzylphthalate	1.2E-03	4.2E-06	4.7E-03	1.6E-05	2.3E-06	7.6E-07	—	—
Di-n-butylphthalate	3.2E-03	1.1E-05	1.2E-02	4.2E-05	1.3E-03	2.6E-04	—	—
Diethylphthalate	5.5E-04	1.9E-06	1.7E-03	5.8E-06	1.5E-06	7.5E-07	—	—
Dimethylphthalate	2.3E-04	7.7E-07	7.1E-04	2.4E-06	2.4E-05	4.8E-06	—	—
Di-n-octylphthalate	4.2E-04	1.4E-06	1.4E-03	4.7E-06	2.9E-05	5.9E-06	—	—
Phenols								
2,4-Dimethylphenol	—	—	—	—	7.8E-06	3.9E-06	—	—
4-Methylphenol	—	—	—	—	2.0E-05	9.8E-06	—	—
Pentachlorophenol	2.5E-04	5.1E-05	9.3E-04	1.9E-04	7.4E-05	1.5E-05	—	—
Phenol	—	—	—	—	4.6E-04	2.3E-04	—	—
Misc. Extractables								
Benzoic Acid	—	—	—	—	8.0E-05	8.5E-06	—	—
Carbazole	—	—	—	—	—	—	—	—
Dibenzofuran	—	—	—	—	—	—	—	—
Volatile Organic Compounds								
Benzene	—	—	—	—	3.5E-04	6.9E-05	1.1E-02	2.1E-03
Ethylbenzene	—	—	—	—	—	—	—	—
Toluene	—	—	—	—	—	—	—	—
Total Xylenes	—	—	—	—	—	—	—	—
1,2,4-Trimethylbenzene	—	—	—	—	—	—	—	—
Pesticides/PCBs								
Chlordane	1.7E-04	5.1E-05	4.3E-04	1.3E-04	9.5E-04	1.9E-04	1.1E-02	2.1E-03
DDD	9.7E-05	1.9E-05	3.0E-04	6.0E-05	4.2E-04	8.2E-05	1.1E-02	2.1E-03
DDT	9.7E-05	1.9E-05	3.0E-04	6.0E-05	1.6E-04	3.3E-05	1.1E-02	2.1E-03
PCB Aroclor 1254	—	—	—	—	—	—	1.1E-02	2.1E-03
PCB Aroclor 1260	—	—	—	—	—	—	—	—
Total PCBs	3.8E-03	1.3E-03	8.2E-02	2.7E-02	1.2E-02	6.2E-03	—	—

Notes:

BOLD and Shaded: Signifies HQ greater than 1.0.

— Toxicological information was not available or chemical not analyzed; calculations could not be completed.

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

HQ: Hazard Quotient

LOAEL: Lowest Observed Adverse Effect Level

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

NOAEL: No Observed Adverse Effect Level

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

Table 4-28 Summary of COPCs Retained Following Risk Evaluations

Revised COPC List (see Table 3-8)	Not Retained as COPCs (below Site-Specific Risk Thresholds)[1]	COPCs Retained for Further Evaluation	Rationale
SVOCs - PAHs			
LPAH			
Naphthalene	X		Not retained; does not exceed risk thresholds
Acenaphthylene	X		Not retained; does not exceed risk thresholds
Acenaphthene	X		Not retained; does not exceed risk thresholds
Fluorene	X		Not retained; does not exceed risk thresholds
Phenanthrene	X		Not retained; does not exceed risk thresholds
Anthracene	X		Not retained; does not exceed risk thresholds
2-Methylnaphthalene	X		Not retained; does not exceed risk thresholds
Total LPAH	X		Not retained; does not exceed risk thresholds
HPAH			
Fluoranthene	X		Not retained; does not exceed risk thresholds
Pyrene	X		Not retained; does not exceed risk thresholds
Benzo(a)anthracene		X	Human health risk threshold exceedances
Chrysene		X	Human health risk threshold exceedances
Benzo(b)fluoranthene		X	Human health risk threshold exceedances
Benzo(k)fluoranthene		X	Human health risk threshold exceedances
Benzo(a)pyrene		X	Human health and ecological risk threshold exceedances
Indeno(1,2,3-cd)pyrene		X	Human health risk threshold exceedances
Dibenzo(a,h)anthracene		X	Human health risk threshold exceedances
Benzo(g,h,i)perylene	X		Not retained; does not exceed risk thresholds
Total HPAH		X	Human health and ecological risk threshold exceedances
Total PAH		X	Human health and ecological risk threshold exceedances
SVOC - other			
Benzoic Acid	X		Not retained; does not exceed risk thresholds
Carbazole		X	No risk threshold exceedances, but further evaluated
Dibenzofuran		X	No risk threshold exceedances, but further evaluated
Retene[2]	X		Not retained; does not exceed risk thresholds
Dimethylphthalate	X		Not retained; does not exceed risk thresholds
Diethylphthalate	X		Not retained; does not exceed risk thresholds
Di-n-butylphthalate	X		Not retained; does not exceed risk thresholds
Butylbenzylphthalate	X		Not retained; does not exceed risk thresholds
Bis(2-Ethylhexyl)phthalate		X	Ecological risk threshold exceedances
Di-n-octyl Phthalate	X		Not retained; does not exceed risk thresholds
Phenol	X		Not retained; does not exceed risk thresholds
4-Methylphenol	X		Not retained; does not exceed risk thresholds
2,4-Dimethylphenol	X		Not retained; does not exceed risk thresholds
Pentachlorophenol		X	Human health risk threshold exceedances
VOCs			
Benzene	X		Not retained; does not exceed risk thresholds
Ethylbenzene		X	No risk threshold exceedances, but further evaluated
Toluene		X	No risk threshold exceedances, but further evaluated
Xylenes		X	No risk threshold exceedances, but further evaluated
1,2,4-Trimethylbenzene		X	No risk threshold exceedances, but further evaluated
Metals			
Antimony		X	Human health risk threshold exceedances
Arsenic		X	Human health and ecological risk threshold exceedances
Cadmium	X		Not retained; does not exceed risk thresholds
Chromium		X	Human health risk threshold exceedances
Cobalt	X		Not retained; does not exceed risk thresholds
Copper	X		Not retained; does not exceed risk thresholds
Lead		X	Human health risk threshold exceedances
Mercury	X		Not retained; does not exceed risk thresholds
Nickel	X		Not retained; does not exceed risk thresholds
Selenium	X		Not retained; does not exceed risk thresholds
Silver	X		Not retained; does not exceed risk thresholds
Vanadium		X	Human health and ecological risk threshold exceedances
Zinc	X		Not retained; does not exceed risk thresholds
Other			
Chlordane		X	Human health risk threshold exceedances
DDD	X		Not retained; does not exceed risk thresholds
DDT	X		Not retained; does not exceed risk thresholds
Cyanide	X		Not retained; does not exceed risk thresholds
Aroclor 1254		X	Human health risk threshold exceedances
Aroclor 1260		X	Human health risk threshold exceedances
Total PCBs		X	Human health risk threshold exceedances
Tributyltin		X	Ecological risk threshold exceedances

Notes:

[1] Applies to COPCs that were evaluated for at least one human health and one ecological risk evaluation pathway.

[2] Chemical structure similar to the PAH phenanthrene (1-methyl-7-isopropyl phenanthrene). Used anthracene as surrogate for risk evaluation.

COPC: Chemical of potential concern

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

SVOC: Semivolatile organic compound

VOC: Volatile organic compound

Table 4-29 Further Evaluation of COPCs Assessed for Limited Number of Pathways[1]

Parameter	Retain?	Rationale
SVOC - other		
Carbazole	No	Not retained due to: * no human health risk threshold exceedances; * no detected concentrations in finfish or crayfish tissue; * relatively high potential to adsorb to sediments; and * not readily bioavailable
Dibenzofuran	No	Not retained due to: * physical structure and environmental behavior similar to that of LPAHs, which had no human health or ecological risk evaluation threshold exceedances; * no detected concentrations in finfish or crayfish tissue; * limited toxicity and relatively high potential to adsorb to sediments; and * not readily bioavailable
VOCs		
1,2,4-Trimethylbenzene	No	Not retained due to: * no human health risk threshold exceedances; * the more toxic related VOC, benzene, resulted in no ecological risk threshold exceedances; and * no detects within the GWSA
Ethylbenzene	No	Not retained due to: * no human health risk threshold exceedances; * the more toxic related VOC, benzene, resulted in no ecological risk threshold exceedances; * limited detects within the GWSA (largely from 1995 data); and * fate and transport characteristics that indicate limited persistence and bioaccumulation, including dispersion, and biodegradation and low bioconcentration potential
Toluene	No	Not retained due to: * no human health risk threshold exceedances; * the more toxic related VOC, benzene, resulted in no ecological risk threshold exceedances; * limited detects within the GWSA (largely from 1995 data); and * fate and transport characteristics that indicate limited persistence and bioaccumulation, including dispersion and biodegradation and low bioconcentration potential
Xylenes	No	Not retained due to: * no human health risk threshold exceedances; * the more toxic related VOC, benzene, resulted in no ecological risk threshold exceedances; * limited detects within the GWSA (largely from 1995 data); and * fate and transport characteristics that indicate limited persistence and bioaccumulation, including dispersion and biodegradation and low bioconcentration potential

Notes:

[1] COPCs were below site-specific risk thresholds for limited pathways, but were further evaluated because they could not be assessed for at least one ecological and one human health pathway, or did not have adequate surrogate compounds that were evaluated.

COPC: Chemical of potential concern

GWSA: Gas Works Sediment Area

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

SVOC: Semivolatile organic compound

VOC: Volatile organic compound

Table 4-30 Risk Evaluation Summary Results

Chemical of Potential Concern	CT Scenario				RME Scenario				CT Scenario				RME Scenario				CT Scenario				RME Scenario				CT Scenario		RME Scenario		Ecological Risk			
	Beach Play/Wading (Oral and Dermal Summed) Adult		Beach Play/Wading (Oral and Dermal Summed) Child		Beach Play/Wading (Oral and Dermal Summed) Adult		Beach Play/Wading (Oral and Dermal Summed) Child		Fish Consumption General Adult		Fish Consumption General Child		Fish Consumption General Adult		Fish Consumption General Child		Fish Consumption Tribal Adult		Fish Consumption Tribal Child		Fish Consumption Tribal Adult		Fish Consumption Tribal Child		Netfishing (Oral and Dermal Summed) Tribal Adult		Netfishing (Oral and Dermal Summed) Tribal Adult					
	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	HQ LOAEL Heron	HQ LOAEL Mallard	HQ LOAEL Otter	HQ NOAEL Salmonid
Conventionals/Misc.																																
Total Cyanide	—	8.E-06	—	2.E-04	—	3.E-03	—	2.E-02	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.E-05	—	4.E-04	—	—	3.0E-03	—
Metals																																
Antimony	—	5.E-04	—	1.E-02	—	1.E-01	—	8.E-01	—	2.E-03	—	6.E-03	—	2.E-01	—	4.E-01	—	1.E-02	—	8.E-02	—	8.E-01	—	**2.E+00**	—	3.E-04	—	2.E-03	—	—	3.8E-03	—
Arsenic	6.E-08	3.E-04	2.E-07	6.E-03	**2.E-05**	8.E-02	**2.E-05**	6.E-01	1.E-06	5.E-03	6.E-07	2.E-02	**8.E-05**	4.E-01	**3.E-05**	8.E-01	**2.E-05**	5.E-02	**9.E-06**	2.E-01	**9.E-04**	**2.E+00**	**2.E-04**	**4.E+00**	**2.E-06**	8.E-03	**2.E-04**	6.E-01	3.3E-03	1.5E-02	2.5E-01	**2.6E+00**
Cadmium	—	4.E-06	—	8.E-05	—	1.E-03	—	7.E-03	—	4.E-04	—	1.E-03	—	7.E-02	—	1.E-01	—	4.E-03	—	2.E-02	—	4.E-01	—	8.E-01	—	5.E-05	—	2.E-04	5.0E-04	6.9E-03	8.8E-04	3.2E-03
Chromium III	—	1.E-07	—	2.E-06	—	1.E-05	—	9.E-05	—	4.E-07	—	1.E-06	—	5.E-05	—	9.E-05	—	2.E-06	—	8.E-06	—	9.E-05	—	2.E-04	—	1.E-06	—	7.E-06	3.7E-03	1.3E-02	1.0E-02	—
Chromium VI	5.E-09	8.E-06	8.E-08	2.E-04	6.E-07	1.E-03	9.E-07	7.E-03	2.E-08	3.E-05	1.E-08	1.E-04	**2.E-06**	4.E-03	9.E-07	7.E-03	2.E-07	1.E-04	9.E-08	7.E-04	**1.E-05**	7.E-03	**2.E-06**	2.E-02	7.E-08	8.E-05	6.E-07	6.E-04	—	—	4.4E-04	—
Cobalt	—	1.E-04	—	2.E-03	—	8.E-03	—	6.E-02	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5.E-03	—	4.E-02	1.3E-03	5.2E-03	3.6E-03	—
Copper		2.E-05	—	3.E-04		3.E-03	—	2.E-02	—	6.E-04	—	2.E-03	—	7.E-02	—	1.E-01	—	6.E-03	—	3.E-02	—	4.E-01	—	8.E-01	—	2.E-04	—	1.E-03	5.8E-03	3.5E-02	2.4E-02	3.1E-01
Lead[1]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.0E-02	1.0E-01	2.6E-02	1.7E-02
Mercury	—	1.E-04	—	2.E-03	—	1.E-02	—	9.E-02	—	2.E-03	—	7.E-03	—	2.E-01	—	4.E-01	—	1.E-02	—	7.E-02	—	6.E-01	—	1.E+00	—	8.E-05	—	3.E-04	1.9E-01	4.2E-01	2.2E-01	1.6E-01
Nickel	—	4.E-05	—	7.E-04	—	4.E-03	—	3.E-02	—	1.E-05	—	4.E-05	—	9.E-04	—	2.E-03	—	8.E-05	—	4.E-04	—	3.E-03	—	6.E-03	—	1.E-04	—	2.E-03	1.2E-03	4.9E-03	1.7E-02	—
Selenium	—	2.E-07	—	5.E-06	—	2.E-05	—	1.E-04	—	3.E-04	—	9.E-04	—	3.E-02	—	6.E-02	—	2.E-03	—	8.E-03	—	6.E-02	—	1.E-01	—	4.E-06	—	2.E-05	9.9E-03	8.0E-03	2.3E-02	3.6E-01
Silver	—	2.E-05	—	3.E-04	—	3.E-03	—	2.E-02	—	7.E-06	—	2.E-05	—	5.E-04	—	9.E-04	—	6.E-05	—	3.E-04	—	2.E-03	—	4.E-03	—	1.E-05	—	5.E-05	1.6E-04	6.4E-04	4.2E-05	—
Vanadium	—	9.E-03	—	2.E-01	—	6.E-01	—	**4.E+00**	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.E-04	—	9.E-04	9.4E-02	3.7E-01	8.5E-03	**1.4E+00**
Zinc	—	4.E-06	—	8.E-05	—	1.E-03	—	7.E-03	—	2.E-04	—	6.E-04	—	2.E-02	—	3.E-02	—	2.E-03	—	8.E-03	—	5.E-02	—	1.E-01	—	4.E-05	—	2.E-04	5.6E-03	2.1E-02	2.5E-03	1.1E-01
Butyltins																																
Tributyltin	—	2.E-06	—	4.E-05	—	4.E-04	—	3.E-03	—	1.E-03	—	3.E-03	—	6.E-02	—	1.E-01	—	2.E-03	—	1.E-02	—	7.E-02	—	2.E-01	—	8.E-05	—	3.E-03	1.4E-04	5.7E-05	1.7E-03	**3.2E+01**
LPAH																																
Acenaphthene	—	6.E-07	—	1.E-05	—	3.E-04	—	2.E-03	—	4.E-07	—	1.E-06	—	4.E-05	—	7.E-05	—	2.E-06	—	1.E-05	—	1.E-04	—	3.E-04	—	7.E-06	—	5.E-04	—	—	7.0E-04	—
Acenaphthylene	—	5.E-07	—	9.E-06	—	1.E-04	—	9.E-04	—	5.E-07	—	2.E-06	—	5.E-05	—	1.E-04	—	3.E-06	—	2.E-05	—	2.E-04	—	3.E-04	—	2.E-06	—	2.E-04	—	—	2.4E-04	—
Anthracene	—	2.E-07	—	3.E-06	—	7.E-05	—	5.E-04	—	8.E-08	—	2.E-07	—	7.E-06	—	1.E-05	—	4.E-07	—	2.E-06	—	2.E-05	—	3.E-05	—	2.E-06	—	2.E-04	—	—	1.7E-04	—
Fluorene	—	7.E-07	—	1.E-05	—	2.E-04	—	2.E-03	—	8.E-07	—	2.E-06	—	8.E-05	—	1.E-04	—	5.E-06	—	3.E-05	—	2.E-04	—	5.E-04	—	6.E-06	—	5.E-04	—	—	2.1E-04	—
2-Methylnaphthalene	—	8.E-06	—	2.E-04	—	4.E-03	—	3.E-02	—	2.E-05	—	7.E-05	—	2.E-03	—	3.E-03	—	1.E-04	—	7.E-04	—	7.E-03	—	2.E-02	—	4.E-05	—	2.E-03	—	—	6.1E-04	—
Naphthalene	—	6.E-06	—	1.E-04	—	2.E-03	—	2.E-02	—	4.E-06	—	1.E-05	—	4.E-04	—	8.E-04	—	3.E-05	—	1.E-04	—	1.E-03	—	3.E-03	—	1.E-05	—	9.E-04	—	—	9.1E-04	—
Phenanthrene	—	6.E-07	—	1.E-05	—	2.E-04	—	1.E-03	—	2.E-07	—	6.E-07	—	3.E-05	—	6.E-05	—	2.E-06	—	8.E-06	—	1.E-04	—	2.E-04	—	5.E-06	—	6.E-04	—	—	7.1E-04	—
Total LPAH[2]		2.E-05		3.E-04		7.E-03		6.E-02		3.E-05		9.E-05		3.E-03		4.E-03		1.E-04		9.E-04		9.E-03		2.E-02		7.E-05		5.E-03	—	1.1E-02	3.4E-03	—
HPAH																																
Benzo(a)anthracene	3.E-08	—	1.E-07	—	**9.E-06**	—	**1.E-05**	—	1.E-08	—	9.E-09	—	**2.E-06**	—	6.E-07	—	3.E-07	—	1.E-07	—	**2.E-05**	—	**3.E-06**	—	4.E-07	—	**5.E-05**	—	—	—	3.8E-02	—
Benzo(a)pyrene	4.E-07	—	1.E-06	—	**1.E-04**	—	**2.E-04**	—	2.E-07	—	1.E-07	—	**2.E-05**	—	**7.E-06**	—	**3.E-06**	—	1.E-06	—	**1.E-04**	—	**3.E-05**	—	**5.E-06**	—	**7.E-04**	—	3.8E-01	**1.5E+00**	5.9E-02	**1.1E+00**
Benzo(b)fluoranthene	3.E-08	—	2.E-07	—	**9.E-06**	—	**1.E-05**	—	2.E-08	—	1.E-08	—	**2.E-06**	—	7.E-07	—	3.E-07	—	1.E-07	—	**1.E-05**	—	**2.E-06**	—	4.E-07	—	**5.E-05**	—	—	—	4.3E-02	—
Benzo(k)fluoranthene	3.E-08	—	1.E-07	—	**7.E-06**	—	**1.E-05**	—	3.E-08	—	2.E-08	—	**2.E-06**	—	8.E-07	—	4.E-07	—	2.E-07	—	**1.E-05**	—	**3.E-06**	—	3.E-07	—	**3.E-05**	—	—	—	2.3E-02	—
Benzo(g,h,i)perylene	—	3.E-06	—	6.E-05	—	9.E-04	—	6.E-03	—	2.E-06		6.E-06	—	2.E-04		3.E-04	—	1.E-05	—	6.E-05	—	6.E-04	—	1.E-03	—	3.E-05	—	5.E-03	—	—	5.9E-02	—
Chrysene	3.E-09	—	1.E-08	—	1.E-06	—	1.E-06	—	2.E-09	—	1.E-09	—	2.E-07	—	9.E-08	—	4.E-08	—	2.E-08	—	**3.E-06**	—	5.E-07	—	4.E-08	—	**5.E-06**	—	—	—	5.5E-03	—
Dibenzo(a,h)anthracene	6.E-09	—	1.E-07	—	**2.E-06**	—	**3.E-06**	—	3.E-08	—	2.E-08	—	**2.E-06**	—	9.E-07	—	4.E-07	—	2.E-07	—	**2.E-05**	—	**4.E-06**	—	7.E-08	—	**1.E-05**	—	—	—	8.1E-03	—
Indeno(1,2,3-cd)pyrene	3.E-08	—	3.E-08	—	**9.E-06**	—	**1.E-05**	—	2.E-08	—	1.E-08	—	**2.E-06**	—	6.E-07	—	3.E-07	—	1.E-07	—	**1.E-05**	—	**2.E-06**	—	4.E-07	—	**6.E-05**	—	—	—	3.3E-01	—
Fluoranthene	—	5.E-06	—	1.E-04	—	2.E-03	—	1.E-02	—	9.E-07	—	3.E-06	—	9.E-05	—	2.E-04	—	7.E-06	—	3.E-05	—	3.E-04	—	6.E-04	—	7.E-05	—	7.E-03	—	—	4.8E-02	—
Pyrene	—	9.E-06	—	2.E-04	—	2.E-03	—	2.E-02	—	5.E-06	—	1.E-05	—	8.E-04	—	1.E-03	—	5.E-05	—	2.E-04	—	4.E-03	—	8.E-03	—	1.E-04	—	1.E-02	—	—	3.9E-01	—
Retene	—	2.E-08	—	4.E-07	—	3.E-06	—	1.E-05	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.E-07	—	5.E-06	—	—	6.4E-06	—
Total HPAH[2]	5.E-07	2.E-05	**2.E-06**	4.E-04	**1.E-04**	5.E-03	**2.E-04**	4.E-02	3.E-07	8.E-06	2.E-07	2.E-05	**3.E-05**	1.E-03	**1.E-05**	2.E-03	**5.E-06**	7.E-05	**2.E-06**	3.E-04	**2.E-04**	5.E-03	**4.E-05**	1.E-02	**7.E-06**	2.E-04	**9.E-04**	2.E-02	—	—	**1.7E+00**	—
Total PAH[2]	5.E-07	3.E-05	**2.E-06**	7.E-04	**1.E-04**	1.E-02	**2.E-04**	9.E-02	3.E-07	3.E-05	2.E-07	1.E-04	**3.E-05**	4.E-03	**1.E-05**	6.E-03	**5.E-06**	2.E-04	**2.E-06**	1.E-03	**2.E-04**	1.E-02	**4.E-05**	3.E-02	**7.E-06**	3.E-04	**9.E-04**	3.E-02	2.7E-02	1.1E-01	—	**3.5E+00**
Phthalates																																
Bis(2-Ethylhexylphthalate	2.E-11	2.E-07	8.E-11	3.E-06	4.E-09	4.E-05	6.E-09	2.E-04	3.E-10	3.E-06	2.E-10	8.E-06	3.E-08	3.E-04	1.E-08	5.E-04	6.E-09	2.E-05	3.E-09	1.E-04	3.E-07	1.E-03	6.E-08	3.E-03	4.E-10	3.E-06	7.E-09	4.E-05	4.6E-06	2.0E-05	4.1E-05	**1.8E+00**
Butylbenzylphthalate	3.E-12	4.E-09	1.E-11	7.E-08	7.E-11	4.E-07	9.E-11	3.E-06	2.E-11	2.E-07	2.E-11	5.E-07	2.E-09	2.E-05	9.E-10	3.E-05	4.E-10	1.E-06	2.E-10	5.E-06	2.E-08	5.E-05	3.E-09	1.E-04	1.E-11	5.E-08	1.E-10	4.E-07	4.2E-06	1.6E-05	7.6E-07	—
Di-n-butylphthalate	—	3.E-08	—	6.E-07	—	1.E-05	—	1.E-04	—	5.E-07	—	2.E-06	—	5.E-05	—	1.E-04	—	4.E-06	—	2.E-05	—	2.E-04	—	4.E-04	—	1.E-06	—	5.E-05	1.1E-05	4.2E-05	2.6E-04	—
Diethylphthalate	—	9.E-10	—	2.E-08	—	1.E-07	—	7.E-07	—	7.E-08	—	2.E-07	—	7.E-06	—	1.E-05	—	5.E-07	—	2.E-06	—	2.E-05	—	5.E-05	—	1.E-07	—	7.E-07	1.9E-06	5.8E-06	7.5E-07	—
Dimethylphthalate	—	9.E-10	—	2.E-08	—	1.E-07	—	7.E-07	—	2.E-08	—	7.E-08	—	3.E-06	—	5.E-06	—	2.E-07	—	8.E-07	—	9.E-06	—	2.E-05	—	7.E-09	—	6.E-08	7.7E-07	2.4E-06	4.8E-06	—
Di-n-octylphthalate	—	9.E-10	—	2.E-08	—	1.E-07	—	7.E-07	—	4.E-08	—	1.E-07	—	4.E-06	—	7.E-06	—	3.E-07	—	1.E-06	—	1.E-05	—	3.E-05	—	2.E-08	—	7.E-08	1.4E-06	4.7E-06	5.9E-06	—
Phenols																																
2,4-Dimethylphenol	—	2.E-08	—	5.E-07	—	4.E-06	—	3.E-05	—	3.E-06	—	8.E-06	—	3.E-04	—	5.E-04	—	2.E-05	—	9.E-05	—	8.E-04	—	2.E-03	—	2.E-07	—	1.E-06	—	—	3.9E-06	—
4-Methylphenol	—	1.E-07	—	2.E-06	—	1.E-05	—	1.E-04	—	1.E-05	—	3.E-05	—	1.E-03	—	2.E-03	—	7.E-05	—	4.E-04	—	3.E-03	—	7.E-03	—	3.E-06	—	3.E-05	—	—	9.8E-06	—
Pentachlorophenol	1.E-10	9.E-08	6.E-10	2.E-06	3.E-08	2.E-05	4.E-08	1.E-04	3.E-09	2.E-06	2.E-09	6.E-06	3.E-07	2.E-04	1.E-07	3.E-04	4.E-08	1.E-05	2.E-08	6.E-05	**2.E-06**	6.E-04	4.E-07	1.E-03	5.E-10	3.E-07	8.E-09	4.E-06	5.1E-05	1.9E-04	1.5E-05	—
Phenol	—	3.E-09	—	5.E-08	—	1.E-06	—	7.E-06	—	4.E-05	—	1.E-04	—	5.E-03	—	1.E-02	—	4.E-04	—	2.E-03	—	3.E-02	—	6.E-02	—	6.E-08	—	8.E-07	—	—	2.3E-04	—

Table 4-30 Risk Evaluation Summary Results

Chemical of Potential Concern	CT Scenario		RME Scenario		CT Scenario		RME Scenario		CT Scenario		RME Scenario		CT Scenario		RME Scenario		CT Scenario		RME Scenario		Ecological Risk			
	Beach Play/Wading (Oral and Dermal Summed) Adult		Beach Play/Wading (Oral and Dermal Summed) Child		Beach Play/Wading (Oral and Dermal Summed) Adult		Beach Play/Wading (Oral and Dermal Summed) Child		Fish Consumption General Adult		Fish Consumption General Child		Fish Consumption General Adult		Fish Consumption General Child		Fish Consumption Tribal Adult		Fish Consumption Tribal Child		Fish Consumption Tribal Adult		Fish Consumption Tribal Child		Netfishing (Oral and Dermal Summed) Tribal Adult		Netfishing (Oral and Dermal Summed) Tribal Adult					
	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	Cancer Risk	HQ	HQ LOAEL Heron	HQ LOAEL Mallard	HQ LOAEL Otter	HQ NOAEL Salmonid
Misc. Extractables																																
Benzoic Acid	—	2.E-09	—	4.E-08	—	4.E-07	—	3.E-06	—	2.E-07	—	6.E-07	—	2.E-05	—	4.E-05		2.E-06	—	8.E-06		8.E-05	—	2.E-04	—	2.E-08	—	1.E-07	—	—	—	—
Carbazole	6.E-11	—	2.E-10	—	2.E-08	—	3.E-08	—	5.E-10	—	3.E-10	—	4.E-08	—	2.E-08	—	7.E-09	—	3.E-09	—	3.E-07	—	6.E-08	—	4.E-10	—	9.E-09	—	—	—	—	—
Dibenzofuran	—	6.E-06	—	1.E-04	—	2.E-03	—	1.E-02	—	5.E-05	—	2.E-04	—	6.E-03	—	1.E-02	—	4.E-04	—	2.E-03	—	2.E-02	—	4.E-02	—	6.E-05	—	2.E-03	—	—	—	—
Volatile Organic Compounds																																
Benzene	3.E-13	4.E-09	1.E-12	7.E-08	2.E-11	2.E-07	3.E-11	2.E-06	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3.E-09	2.E-05	6.E-08	4.E-04	—	—	6.9E-05	1.1E-02
Ethylbenzene	6.E-14	9.E-11	2.E-13	2.E-09	3.E-12	6.E-09	4.E-12	5.E-08	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7.E-11	1.E-07	2.E-09	3.E-06	—	—	—	—
Toluene	—	9.E-10	—	2.E-08	—	6.E-08	—	5.E-07	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.E-09	—	1.E-08	—	—	—	—
Total Xylenes	—	6.E-11	—	1.E-09	—	4.E-09	—	3.E-08	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.E-08	—	6.E-07	—	—	—	—
1,2,4-Trimethylbenzene	—	2.E-06	—	3.E-05	—	1.E-04	—	8.E-04	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	9.E-06	—	2.E-05	—	—	—	—
Pesticides/PCBs																																
Chlordane	3.E-12	4.E-08	1.E-11	7.E-07	6.E-10	6.E-06	8.E-10	5.E-05	3.E-09	3.E-05	2.E-09	1.E-04	2.E-07	3.E-03	8.E-08	6.E-03	3.E-08	2.E-04	1.E-08	1.E-03	**2.E-06**	1.E-02	3.E-07	2.E-02	6.E-10	6.E-06	2.E-09	1.E-05	5.1E-05	1.3E-04	1.9E-04	1.1E-02
DDD	2.E-12	—	8.E-12	—	7.E-10	—	1.E-09	—	3.E-10	—	2.E-10	—	2.E-08	—	7.E-09	—	4.E-09	—	2.E-09	—	1.E-07	—	3.E-08	—	8.E-11	—	1.E-09	—	1.9E-05	6.0E-05	8.2E-05	1.1E-02
DDT	6.E-12	9.E-08	2.E-11	2.E-06	1.E-09	1.E-05	2.E-09	1.E-04	4.E-10	5.E-06	2.E-10	2.E-05	3.E-08	4.E-04	1.E-08	7.E-04	5.E-09	3.E-05	2.E-09	2.E-04	2.E-07	1.E-03	4.E-08	3.E-03	1.E-10	1.E-06	3.E-10	9.E-06	1.9E-05	6.0E-05	3.3E-05	1.1E-02
PCB Aroclor 1254	7.E-11	1.E-05	3.E-10	3.E-04	2.E-08	1.E-03	3.E-08	8.E-03	1.E-07	7.E-03	8.E-08	2.E-02	**2.E-05**	1.E+00	**7.E-06**	**2.E+00**	**3.E-06**	7.E-02	1.E-06	3.E-01	**2.E-04**	**6.E+00**	**4.E-05**	**1.E+01**	4.E-09	1.E-04	9.E-08	1.E-03	—	—	—	1.1E-02
PCB Aroclor 1260	2.E-10	—	8.E-10	—	9.E-09	—	1.E-08	—	1.E-07	—	8.E-08	—	**2.E-05**	—	**7.E-06**	—	**3.E-06**	—	1.E-06	—	**2.E-04**	—	**4.E-05**	—	3.E-09	—	6.E-08	—	—	—	—	—
Total PCBs	1.E-10	1.E-05	5.E-10	3.E-04	4.E-08	1.E-03	5.E-08	8.E-03	2.E-07	7.E-03	2.E-07	2.E-02	**4.E-05**	1.E+00	**1.E-05**	**2.E+00**	**5.E-06**	7.E-02	**2.E-06**	3.E-01	**5.E-04**	**6.E+00**	**9.E-05**	**1.E+01**	6.E-09	1.E-04	1.E-07	1.E-03	1.3E-03	2.7E-02	6.2E-03	—

Notes:

Signifies a COPC identified to be further evaluated in Section 5.

BLUE Signifies a HQ greater than 1.0 for individual COPCs.

GREEN Signifies a risk greater than 10^{-6} for individual COPCs.

— Toxicological information was not available or chemical was not analyzed; calculations could not be completed.

[1] Human health risk evaluation of lead has been presented primarily in the text, as risk calculations were not conducted.

[2] These results represent the sums of individual PAH results.

COPC: Chemical of potential concern

CT: Central Tendency

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbons

HQ: Hazard Quotient

LOAEL: Lowest Observed Adverse Effect Level

LPAH: Low-molecular weight polycyclic aromatic hydrocarbons

NOAEL: No Observed Adverse Effect Level

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

RME: Reasonable Maximum Exposure

Table 4-31 Risk Driver Analysis Summary

COPCs Retained for Risk Driver Analysis	Risk-Drivers [1]								
	Human Health - Percent of Cumulative Carcinogenic Risk				Human Health - Non-Carcinogenic (HQ>5)		Ecological (HQ>5)		
Tables 4-28 and 4-29	Beach Play/Wading (Oral and Dermal) Child	Fish Ingestion General (Adult)	Fish Ingestion Tribal (Adult)	Tribal Netfishing (Oral and Dermal) Adult	Fish Ingestion Tribal (Adult)	Fish Ingestion Tribal (Child)	Salmon	Non-Risk Driver COPCs	Risk Driver COPCs [1]
SVOCs - PAHs									
Benzo(a)anthracene	4	1	1	5				Benzo(a)anthracene	
Chrysene								Chrysene	
Benzo(b)fluoranthene	4	1		5				Benzo(b)fluoranthene	
Benzo(k)fluoranthene	4	1		3				Benzo(k)fluoranthene	
Benzo(a)pyrene	**75**	**13**	6	**63**					**Benzo(a)pyrene**
Indeno(1,2,3-cd)pyrene	4	1		5				Indeno(1,2,3-cd)pyrene	
Dibenzo(a,h)anthracene	1	1	1	1				Dibenzo(a,h)anthracene	
Total HPAH	**92**	**20**	**11**	**82**					**HPAH**
Total PAH	**92**	**20**	**11**	**82**					**TPAH**
SVOC - other									
Bis(2-Ethylhexyl)phthalate								Bis(2-Ethylhexyl)phthalate	
Pentachlorophenol								Pentachlorophenol	
Metals									
Antimony								Antimony	
Arsenic	8	**52**	**57**	**18**					**Arsenic**
Chromium IV		1						Chromium IV	
Lead [2]								Lead	
Vanadium								Vanadium	
Other									
Chlordane								Chlordane	
Aroclor 1254		**13**	**13**		**6**	**11**			**Aroclor 1254**
Aroclor 1260		**13**	**13**						**Aroclor 1260**
Total PCBs		**26**	**31**		**6**	**11**			**Total PCBs**
Tributyltin							**32**		**Tributyltin**

Notes:

Pathways that were evaluated, but are not shown in this summary table, had no risk threshold exceedances or no identified risk drivers.

All beach play and fish ingestion exposure pathways were evaluated for both adult and child; only the worst case pathway is shown in this summary table; for complete results see Appendix F, Table F1.

Bold: Individual COPC risk drivers as defined in Note 1 below.

[1] Risk Driver definition: For human health carcinogenic risk, risk drivers included any individual COPC with a cumulative percent risk of 10% or more for at least one exposure pathway that exceeds acceptable risk thresholds; for human health non-carcinogenic risk and ecological risk, risk drivers included any ndividual COPC with an HQ greater than 5 for at least one exposure pathway.

[2] Although lead is not able to be included in the risk driver analysis because standard risk calculations were not conducted, it was not determined to be a risk driver because although the maximum GWSA concentration exceeded the acceptable risk threshold for the adult tribal netfishing scenario, the more representative exposure conentration, the GWSA 90th percentile, is well below this threshold.

COPC: Chemical of potential concern

HQ: Hazard Quotient

PCB: Polychlorinated biphenyl

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

SVOC: Semivolatile organic compound

TPAH: Total polycyclic aromatic hydrocarbon

Table 5-1 Summary of COCs Retained Following Risk Evaluations

COCs Retained for Further Evaluation (Table 4-31)	
Non-Risk Driver	**Risk Driver**
SVOCs - PAHs	
HPAH	
Benzo(a)anthracene	
Chrysene	
Benzo(b)fluoranthene	
Benzo(k)fluoranthene	
	Benzo(a)pyrene
Indeno(1,2,3-cd)pyrene	
Dibenzo(a,h)anthracene	
	Total HPAH
	Total PAH
SVOC – other	
Bis(2-Ethylhexyl)phthalate	
Pentachlorophenol	
Metals	
Antimony	
	Arsenic
Chromium	
Lead [1]	
Vanadium	
Other	
Chlordane	
	Aroclor 1254
	Aroclor 1260
	Total PCBs
	Tributyltin

Notes

[1] Although lead is not able to be included in the risk driver analysis because standard risk calculations were not conducted, it was not determined to be a risk driver because although the maximum GWSA concentration exceeded the acceptable risk threshold for the adult tribal netfishing scenario, the more representative exposure concentration, the GWSA 90th percentile, is well below this threshold.

COC: Chemical of concern

GWSA: Gas Works Sediment Area

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

SVOC: Semivolatile organic compound

Table 5-2 GWSA Sediment Quality Characteristics[1]

Parameter[2]	No. of Samples	No. of Non-Detects[3]	% Non-Detects	Mean (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)
SVOCs - PAHs						
Benzo(a)anthracene	128	0	0.0	29	0.24	700
Chrysene	128	0	0.0	32	0.29	770
Benzo(b)fluoranthene	127	0	0.0	33	0.36	800
Benzo(k)fluoranthene	127	0	0.0	20	0.35	430
Benzo(a)pyrene	128	0	0.0	43	0.35	1100
Indeno(1,2,3-cd)pyrene	128	0	0.0	28	0.14	890
Dibenzo(a,h)anthracene	128	14	10.9	4.9	0.023	150
Total HPAH	127	0	0.0	410	3.1	10000
Total PAH	128	0	0.0	500	3.4	11000
SVOC - other						
Bis(2-Ethylhexyl)phthalate	95	29	30.5	1.46	0.0095	6.5
Pentachlorophenol	76	69	90.8	0.57	0.048	2.8
Metals						
Antimony	63	48	76.2	7.6	0.30	20
Arsenic	113	41	36.3	59	3	2400
Chromium	74	0	0.0	64	20	250
Lead	87	0	0.0	320	9.9	1100
Other						
Chlordane	28	26	92.9	0.010	0.00047	0.12
Aroclor 1254	50	29	58.0	0.082	0.0095	0.40
Aroclor 1260	50	25	50.0	0.066	0.0095	0.30
Total PCBs	50	24	48.0	0.12	0.010	0.70
Tributyltin	35	2	5.7	0.54	0.0019	7.0

Notes:

[1] Characteristics for the GWSA data set: locations within the study area boundary, surface sediment only, 1994/1995 to present, excluding locations west of the Area Boundary line impacted by Northlake Shipyard.

[2] COCs identified for further evaluation through the risk evaluations.

[3] Non-detects were set to one-half the reporting limit.

COC: Chemical of concern

GWSA: Gas Works Sediment Area

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

SVOC: Semivolatile organic compound

Table 5-3 Ambient Lake Union Sediment Quality Characteristics[1]

Parameter[2]	No. of Samples	No. of Non-Detects[3]	% Non-Detects	Mean (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)
SVOCs - PAHs						
Benzo(a)anthracene	49	0	0.0	2.8	0.11	16
Chrysene	49	0	0.0	3.3	0.15	20
Benzo(b)fluoranthene	41	0	0.0	3.2	0.14	14
Benzo(k)fluoranthene	41	0	0.0	2.5	0.10	12
Benzo(a)pyrene	49	1	2.0	4.2	0.065	25
Indeno(1,2,3-cd)pyrene	49	1	2.0	2.5	0.076	15
Dibenzo(a,h)anthracene	49	8	16.3	0.72	0.016	3.8
Total HPAH	49	0	0.0	39	1.2	210
Total PAH	49	0	0.0	46	1.4	250
SVOC - other						
Bis(2-Ethylhexyl)phthalate	44	6	13.6	7.23	0.055	190
Pentachlorophenol	37	20	54.1	1.2	0.0097	13
Metals						
Antimony	19	3	15.8	4.6	0.98	16
Arsenic	43	7	16.3	54	10	270
Chromium	41	4	9.8	70	28	410
Lead	41	0	0.0	520	160	3900
Other						
Chlordane	10	7	70.0	0.95	0.00050	4.2
Aroclor 1254	21	6	28.6	0.34	0.011	1.5
Aroclor 1260	21	2	9.5	0.31	0.0165	1.2
Total PCBs	24	2	8.3	0.93	0.0165	6.4
Tributyltin	14	0	0.0	1.7	0.043	4.1

Notes

[1] Characteristics for the ambient Lake Union (ALU) data set: locations outside the GWSA, surface sediment only, 1986 to present, excluding locations that occur within 300 feet of the shoreline and those stations near potential nearshore impacts (e.g., Northlake Shipyard).

[2] COCs identified for further evaluation through the risk evaluations.

[3] Non-detects were set to one-half the reporting limit.

COC: Chemical of concern

GWSA: Gas Works Sediment Area

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

SVOC: Semivolatile organic compound

Table 5-4 Summary of Significant Differences between ALU and GWSA COC Concentrations

Parameter[1]	Mann-Whitney Test [2]			GWSA COCs *(Retained: GWSA > ALU, Statistically)*	ALU COCs *(Not Retained: GWSA ≤ ALU, Statistically)*
	p-value	Significantly Different?	GWSA > ALU?		
SVOCs - PAHs					
Benzo(a)anthracene	0.000	Yes	Yes	Benzo(a)anthracene	
Chrysene	0.000	Yes	Yes	Chrysene	
Benzo(b)fluoranthene	0.000	Yes	Yes	Benzo(b)fluoranthene	
Benzo(k)fluoranthene	0.000	Yes	Yes	Benzo(k)fluoranthene	
Benzo(a)pyrene	0.000	Yes	Yes	Benzo(a)pyrene *	
Indeno(1,2,3-cd)pyrene	0.000	Yes	Yes	Indeno(1,2,3-cd)pyrene	
Dibenzo(a,h)anthracene	0.000	Yes	Yes	Dibenzo(a,h)anthracene	
Total HPAH	0.000	Yes	Yes	Total HPAH *	
Total PAH	0.000	Yes	Yes	Total PAH *	
SVOC - other					
Bis(2-Ethylhexyl)phthalate	0.000	Yes	No		Bis(2-Ethylhexyl)phthalate
Pentachlorophenol	0.000	Yes	No		Pentachlorophenol
Metals					
Antimony	0.344	No	No		Antimony
Arsenic	0.034	Yes	No		Arsenic *
Chromium	0.193	No	No		Chromium
Lead	0.005	Yes	No		Lead
Other					
Chlordane	0.009	Yes	No		Chlordane
Aroclor 1254	0.000	Yes	No		Aroclor 1254 *
Aroclor 1260	0.000	Yes	No		Aroclor 1260 *
Total PCBs	0.000	Yes	No		Total PCBs *
Tributyltin	0.007	Yes	No		Tributyltin *

Notes:

* Indicates risk driver.

Non-detects were set to one-half the reporting limit.

[1] COCs identified for further evaluation through the risk evaluations. All COCs have at least 20 ALU samples except antimony (19), chlordane (10), and tributyltin (14).

[2] Statistical analyses performed using SPSS 13.0. Mann-Whitney is a non-parametric 2-sample hypothesis test. SPSS runs a 2-sided test; the GWSA > ALU column indicates when the GWSA concentration is significantly higher than the ALU concentration.

Additional explanation of the results as presented for the Mann-Whitney test:

p-value: A p-value is a measure of the statistical test result. The lower the p-value the less likely is the result, and the more statistically significant it is. P-values less than 0.05 are identified as significant according to this test.

Significantly Different?: Statistical significance ($p < 0.05$) is indicated by a "Yes." Statistical insignificance ($p \geq 0.05$) is indicated by a "No."

GWSA > ALU: "Yes" if the GWSA concentrations are statistically significantly higher. "No" if the GWSA concentrations are significantly lower or the GWSA and ALU are statistically equivalent.

ALU: Ambient Lake Union

COC: Chemical of concern

GWSA: Gas Works Sediment Area

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

SVOC: Semivolatile organic compound

Table 5-5 COC Summary

GWSA COCs		ALU COCs	
Risk Driver[1]	**Non-Risk Driver[2]**	**Risk Driver[3]**	**Non-Risk Driver[4]**
SVOCs - PAHs			
	Benzo(a)anthracene		
	Chrysene		
	Benzo(b)fluoranthene		
	Benzo(k)fluoranthene		
Benzo(a)pyrene			
	Indeno(1,2,3-cd)pyrene		
	Dibenzo(a,h)anthracene		
Total HPAH			
Total PAH			
SVOC - other			
			Bis(2-Ethylhexyl)phthalate
			Pentachlorophenol
Metals			
			Antimony
		Arsenic	
			Chromium
			Lead
Other			
			Chlordane
		Aroclor 1254	
		Aroclor 1260	
		Total PCBs	
		Tributyltin	

Notes:

[1] Indicator COCs are those that are both statistically higher in the GWSA than in ALU and are identified as risk driver COCs.

[2] GWSA non-risk driver COCs are those that are statistically higher in the GWSA than in the ALU but are not identified as risk driver COCs.

[3] ALU risk driver COCs are those that are not statistically higher in the GWSA and are identified as risk driver COCs.

[4] ALU non-risk driver COCs are those that are not statistically higher in the GWSA than in the ALU but are not identified as risk driver COCs. These chemicals are not retained as COCs.

ALU: Ambient Lake Union

COC: Chemical of concern

GWSA: Gas Works Sediment Area

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

SVOC: Semivolatile organic compound

Table 5-6 GWSA Indicator COC Derivation Summary

COCs at Beginning of Section 5		Comparison to Ambient		GWSA Indicator COCs [1]
Non-Risk Driver COCs	Risk Driver COCs	COCs Compared to Ambient	GWSA COCs	
Table 4-31		*Table 5-5*		
SVOCs - PAHs				
Benzo(a)anthracene		Benzo(a)anthracene	Benzo(a)anthracene ^	
Chrysene		Chrysene	Chrysene ^	
Benzo(b)fluoranthene		Benzo(b)fluoranthene	Benzo(b)fluoranthene ^	
Benzo(k)fluoranthene		Benzo(k)fluoranthene	Benzo(k)fluoranthene ^	
	Benzo(a)pyrene	Benzo(a)pyrene	Benzo(a)pyrene	**Benzo(a)pyrene**
Indeno(1,2,3-cd)pyrene		Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene ^	
Dibenzo(a,h)anthracene		Dibenzo(a,h)anthracene	Dibenzo(a,h)anthracene ^	
	Total HPAH	Total HPAH	Total HPAH	**Total HPAH**
	Total PAH	Total PAH	Total PAH	**Total PAH**
SVOC - other				
Bis(2-Ethylhexyl)phthalate		Bis(2-Ethylhexyl)phthalate		
Pentachlorophenol		Pentachlorophenol		
Metals				
Antimony		Antimony		
	Arsenic	Arsenic		
Chromium		Chromium		
Lead [2]		Lead		
Vanadium [3]				
Other				
Chlordane		Chlordane		
	Aroclor 1254	Aroclor 1254		
	Aroclor 1260	Aroclor 1260		
	Total PCBs	Total PCBs		
	Tributyltin	Tributyltin		

Notes:

Bold Indcates GWSA COC risk drivers.

^ Non-risk driver COC.

[1] Indicator COCs are those that are both statistically higher in the GWSA than in ALU and are identified as a risk driver COC.

[2] Although lead is not able to be included in the risk driver analysis because standard risk calculations were not conducted, it was not determined to be a risk driver because although the maximum GWSA concentration exceeded the acceptable risk threshold for the adult tribal netfishing scenario, the more representative exposure conentration, the GWSA 90th percentile, is well below this threshold.

[3] Vanadium had insufficient ALU data for statistical comparison (less than 10 ALU samples). Qualitative assessment resulted in vanadium not being retained as a COC based on the following lines of evidence: only data is older 1995 data; not a risk-driver COC; similar concentrations between ALU and GWSA, and to natural soil background.

ALU: Ambient Lake Union

COC: Chemical of concern

GWSA: Gas Works Sediment Area

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

SVOC: Semivolatile organic compound

Table 6-1 Iterative Approach: Estimated Lateral Extent - Benzo(a)pyrene Summary Statistics

Iteration	Data Set [1]	Total #	Censored #	% Censored	Mean [2] (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)	Distribution	R Squared	Percentile [3]	MTCAStat Background Module Calculation [4] (mg/kg)
No Action [5]	R	—	—	—	—	—	—	—	—	—	—
	NA	128	0	0.00	43.30	0.35	1100	Lognormal	0.99	4 X 50th	40.07
	ALU [6]	49	1	2.04	4.33	0.14	25	Lognormal	0.92	90th	10.38
1	R	20	0	0.00	98.82	0.49	1100	Lognormal	0.99	4 X 50th	84.17
	NA	108	0	0.00	33.02	0.35	430	Lognormal	0.98	4 X 50th	34.92
	ALU [6]	49	1	2.04	4.33	0.14	25	Lognormal	0.92	90th	10.38
2	R	40	0	0.00	97.73	0.49	1100	Lognormal	0.98	4 X 50th	129.85
	NA	88	0	0.00	18.57	0.35	386	Lognormal	0.98	4 X 50th	23.48
	ALU [6]	49	1	2.04	4.33	0.14	25	Lognormal	0.92	90th	10.38
3	R	53	0	0.00	84.56	0.49	1100	Lognormal	1.00	4 X 50th	100.57
	NA	75	0	0.00	14.15	0.35	154	Lognormal	0.98	4 X 50th	20.91
	ALU [6]	49	1	2.04	4.33	0.14	25	Lognormal	0.92	90th	10.38
4	R	78	0	0.00	63.72	0.49	1100	Lognormal	0.99	4 X 50th	67.67
	NA	50	0	0.00	11.45	0.35	98	Lognormal	0.98	4 X 50th	17.69
	ALU [6]	49	1	2.04	4.33	0.14	25	Lognormal	0.92	90th	10.38
5	R	89	0	0.00	57.98	0.49	1100	Lognormal	0.99	4 X 50th	58.88
	NA	39	0	0.00	9.81	0.35	66	Lognormal	0.98	4 X 50th	16.64
	ALU [6]	49	1	2.04	4.33	0.14	25	Lognormal	0.92	90th	10.38

Notes:

[1] Only surface sediment samples were included.

[2] Arithmetic mean used for all distributions.

[3] Per Washington State Department of Ecology guidance, when the 90th percentile > (4 x 50th), use (4 x 50th).

[4] Calculations performed using Washington State Department of Ecology's Model Toxics Control Act statistical program - MTCAStat 97 Background Module.

[5] No Action iteration encompasses all applicable surface sediment locations within the Gas Works Sediment Area (GWSA), and is shown for reference.

[6] Nearshore samples were excluded (i.e., those within 300 feet of shore and/or near potential nearshore impacts).

ALU: Ambient Lake Union

NA: Possible No Action areas

R: Possible Remediation areas

Table 6-2 Iterative Approach: Estimated Lateral Extent - HPAH Summary Statistics

Iteration	Data Set [1]	Total #	Censored #	% Censored	Mean [2] (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)	Distribution	R Squared	Percentile [3]	MTCAStat Background Module Calculation [4] (mg/kg)
	R	—	—	—	—	—	—	—	—	—	—
No Action [5]	NA	127	0	0.00	412.39	3.12	10040	Lognormal	0.98	4 X 50th	346.72
	ALU [6]	49	0	0.00	38.85	1.24	211	Lognormal	0.94	90th	91.07
	R	19	0	0.00	991.87	6.24	10040	Lognormal	0.98	4 X 50th	949.61
1	NA	108	0	0.00	310.44	3.12	4735	Lognormal	0.98	4 X 50th	290.40
	ALU [6]	49	0	0.00	38.85	1.24	211	Lognormal	0.94	90th	91.07
	R	39	0	0.00	942.62	6.24	10040	Lognormal	0.98	4 X 50th	1306.05
2	NA	88	0	0.00	177.40	3.12	4735	Lognormal	0.97	4 X 50th	192.62
	ALU [6]	49	0	0.00	38.85	1.24	211	Lognormal	0.94	90th	91.07
	R	52	0	0.00	825.92	6.24	10040	Lognormal	1.00	4 X 50th	947.45
3	NA	75	0	0.00	125.67	3.12	1378	Lognormal	0.97	4 X 50th	172.70
	ALU [6]	49	0	0.00	38.85	1.24	211	Lognormal	0.94	90th	91.07
	R	77	0	0.00	615.73	6.24	10040	Lognormal	0.99	4 X 50th	618.98
4	NA	50	0	0.00	99.23	3.12	891	Lognormal	0.97	4 X 50th	142.02
	ALU [6]	49	0	0.00	38.85	1.24	211	Lognormal	0.94	90th	91.07
	R	88	0	0.00	558.57	6.24	10040	Lognormal	0.99	4 X 50th	531.55
5	NA	39	0	0.00	82.53	3.12	520	Lognormal	0.97	4 X 50th	132.21
	ALU [6]	49	0	0.00	38.85	1.24	211	Lognormal	0.94	90th	91.07

Notes:

[1] Only surface sediment samples were included.

[2] Arithmetic mean used for all distributions.

[3] Per Washington State Department of Ecology guidance, when the 90th percentile > (4 x 50th), use (4 x 50th).

[4] Calculations performed using Washington State Department of Ecology's Model Toxics Control Act statistical program - MTCAStat 97 Background Module.

[5] No Action iteration encompasses all applicable surface sediment locations within the Gas Works Sediment Area (GWSA), and is shown for reference.

[6] Nearshore samples were excluded (i.e., those within 300 feet of shore and/or near potential nearshore impacts).

ALU: Ambient Lake Union

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

NA: Possible No Action areas

R: Possible Remediation areas

Table 6-3 Iterative Approach: Estimated Lateral Extent - TPAH Summary Statistics

Iteration	Data Set [1]	Total #	Censored #	% Censored	Mean [2] (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)	Distribution	R Squared	Percentile [3]	MTCAStat Background Module Calculation [4] (mg/kg)
No Action [5]	R	—	—	—	—	—	—	—	—	—	—
	NA	128	0	0.00	502	3.37	11154	Lognormal	0.98	4 X 50th	403.59
	ALU [6]	49	0	0.00	45.52	1.39	253	Lognormal	0.93	90th	106.99
1	R	20	0	0.00	1096.80	7.47	11154	Lognormal	0.99	4 X 50th	1068.09
	NA	108	0	0.00	391.78	3.37	6847	Lognormal	0.98	4 X 50th	337.03
	ALU [6]	49	0	0.00	45.52	1.39	253	Lognormal	0.93	90th	106.99
2	R	40	0	0.00	1116.32	7.47	11154	Lognormal	0.99	4 X 50th	1545.94
	NA	88	0	0.00	222.68	3.37	6847	Lognormal	0.97	4 X 50th	219.19
	ALU [6]	49	0	0.00	45.52	1.39	253	Lognormal	0.93	90th	106.99
3	R	53	0	0.00	1004.19	7.47	11154	Lognormal	0.99	4 X 50th	1127.35
	NA	75	0	0.00	147.02	3.37	1546	Lognormal	0.97	4 X 50th	195.29
	ALU [6]	49	0	0.00	45.52	1.39	253	Lognormal	0.93	90th	106.99
4	R	78	0	0.00	749.47	6.79	11154	Lognormal	0.99	4 X 50th	731.89
	NA	50	0	0.00	115.81	3.37	1149	Lognormal	0.97	4 X 50th	159.46
	ALU [6]	49	0	0.00	45.52	1.39	253	Lognormal	0.93	90th	106.99
5	R	89	0	0.00	680.61	6.79	11154	Lognormal	0.98	4 X 50th	625.49
	NA	39	0	0.00	94.20	3.37	581	Lognormal	0.97	4 X 50th	148.49
	ALU [6]	49	0	0.00	45.52	1.39	253	Lognormal	0.93	90th	106.99

Notes:

[1] Only surface sediment samples were included.

[2] Arithmetic mean used for all distributions.

[3] Per Washington State Department of Ecology guidance, when the 90th percentile > (4 x 50th), use (4 x 50th).

[4] Calculations performed using Washington State Department of Ecology's Model Toxics Control Act statistical program - MTCAStat 97 Background Module.

[5] No Action iteration encompasses all applicable surface sediment locations within the Gas Works Sediment Area (GWSA), and is shown for reference.

[6] Nearshore samples were excluded (i.e., those within 300 feet of shore and/or near potential nearshore impacts).

ALU: Ambient Lake Union

TPAH: Total polycyclic aromatic hydrocarbons

NA: Possible No Action areas

R: Possible Remediation areas

Table 6-4 Iterative Approach: Estimated Lateral Extent - Summary of Significant Differences

GWSA Indicator COC	No Action*		Iteration 1 (Remediate Band 1)		Iteration 2 (Remediate Bands 1-2)		Iteration 3 (Remediate Bands 1-3)		Iteration 4 (Remediate Bands 1-4)		Iteration 5 (Remediate Bands 1-5)	
	p-value	GWSA > ALU? **	p-value	GWSA > ALU? **	p-value	GWSA > ALU? **	p-value	GWSA > ALU? **	p-value	GWSA > ALU? **	p-value	GWSA > ALU? **
Benzo(a)pyrene	0.000	Yes	0.000	Yes	0.003	Yes	0.020	Yes	0.098	No	0.109	No
HPAH	0.000	Yes	0.000	Yes	0.017	Yes	0.062	No	0.345	No	0.403	No
TPAH	0.000	Yes	0.000	Yes	0.016	Yes	0.065	No	0.363	No	0.399	No

Notes:

Hypothesis testing was done using the 2-sided Mann-Whitney test, α=0.05 (SPSS 13.0), comparing the possible No Action area to the ALU area.

Non-detects were set to one-half the reporting limit.

* No Action iteration encompasses all applicable surface sediment locations within the GWSA, and is shown for reference.

** A "Yes" indicates that the GWSA concentration is statistically significantly higher than the ALU concentration.

ALU: Ambient Lake Union

COC: Contaminant of concern

GWSA: Gas Works Sediment Area

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

TPAH: Total polycyclic aromatic hydrocarbons

Waterway #22
Waterway #21
Northlake Shipyard
Metro Lake Union (N. Yard)
Metro Lake Union (S. Yard)
Waterway #20
Woodlawn Ave N.
Densmore Ave N.
Former Nortar Facility
Wallingford Ave N.
Burke Ave N.
Meridian Ave N.
Burke Gilman Trail
N. Northlake Way
Gas Works Park Marina
Waterway #19
Gas Works Uplands
Harbor Patrol
Gas Works Park
"the prow"
Western Study Area
Eastern Study Area

- Area Boundary
- Area of Investigation (AOI)
- Uplands CD Boundary as depicted on Exibit A to the Consent Decree (December 1999)
- Division between Eastern and Western Study Areas
- Shipyard Consent Decree Boundary
- Harbor Patrol Boundary
- Gas Works Park Boundary

0 125 250 Feet
1 inch = 250 feet
N

Notes:
Aerial photograph provided by City of Seattle and dated 2005.

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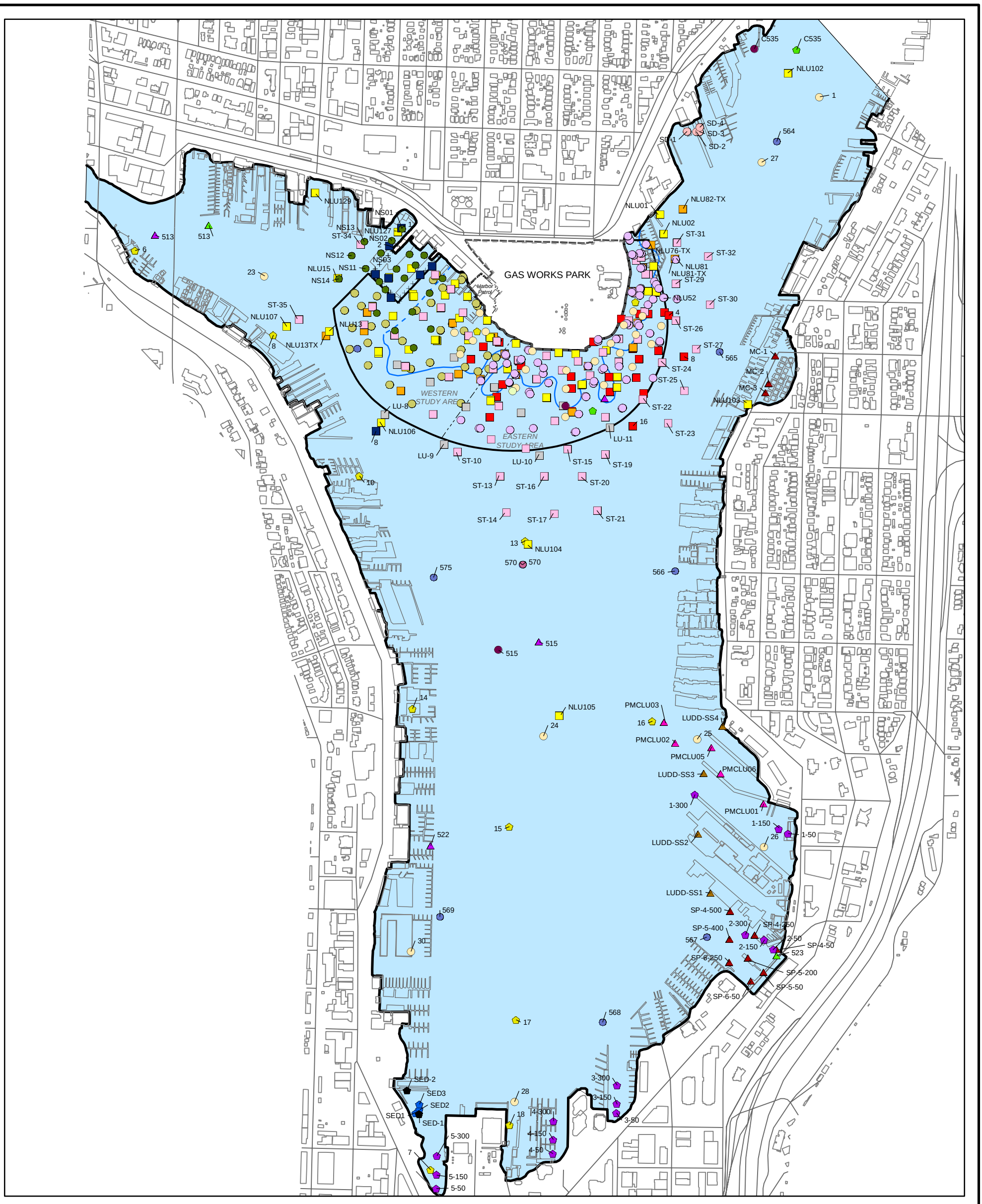
AECOM

SUPPLEMENT TO THE CLEANUP STANDARDS DOCUMENT GAS WORKS SEDIMENT AREA 60149262			**SITE MAP**
DATE: 09/06/2011	DRWN: RLB/ftc	Revision: 1	**FIGURE 1-1**



SEDQUAL Stations

Survey (Year)

- DUNATO96 (1996)
- EPAGAS84 (1984)
- GWPLKUN (1985)
- LUUCS097 (1996, 1997)
- FSnider_05 (2005)
- KC_LKUN01 (2001)
- KC_2008ww (2008)
- RIFSE (2004)
- NLSY09 (2009)
- LUUMON86 (1986)
- LUUMON95 (1995)
- NOAPMC94 (1994)
- SCLITE89 (1989)
- LKUNDRDK (1992)
- RETEC99 (1999)
- TAMU02 (2002)
- GWSA05 (2005)
- RETEC02 (2002)
- EPAGAS95 (1995)
- UNIMAR2 (1991)
- LKUNION (1990)
- LUUCSO00 (2000)
- SEACOM94 (1994)
- SLUPLT86 (1986)
- SLUPRK90 (1990)

- Area Boundary
- Area of Investigation (AOI)
- Uplands CD Boundary as depicted on Exibit A to the Consent Decree (December 1999)
- Division between Eastern and Western Study Areas
- Shipyard Consent Decree Boundary
- Harbor Patrol Boundary
- Gas Works Park Boundary

N

0 375 750 1,500 Feet

AECOM

SUPPLEMENT TO THE CLEANUP STANDARDS DOCUMENT GAS WORKS SEDIMENT AREA 60149262			**LAKE UNION SEDIMENT STUDIES AND LOCATIONS**
DATE: 09/06/2011	DWRN: CBB/ftc	Revision: 7	**FIGURE 2-1**

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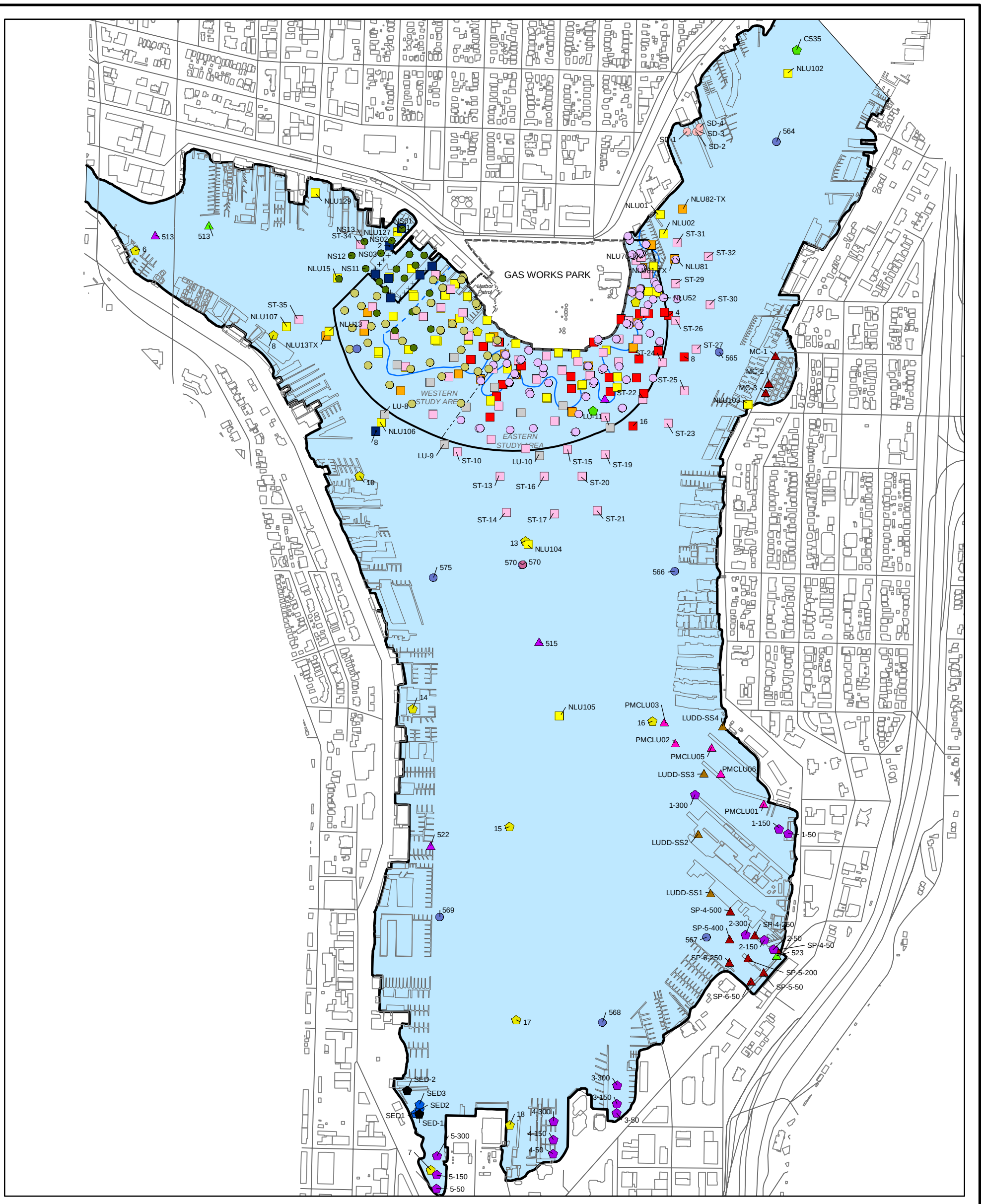

SEDQUAL Stations

Survey (Year)

- DUNATO96 (1996)
- FSnider_05 (2005)
- KC_LKUN01 (2001)
- KC_2008ww (2008)
- RIFSE (2004)
- NLSY09 (2009)
- LUUMON86 (1986)
- LUUMON95 (1995)
- NOAPMC94 (1994)
- SCLITE89 (1989)
- LKUNDRDK (1992)
- RETEC99 (1999)
- TAMU02 (2002)
- GWSA05 (2005)
- RETEC02 (2002)
- EPAGAS95 (1995)
- UNIMAR2 (1991)
- LKUNION (1990)
- LUUCSO00 (2000)
- SEACOM94 (1994)
- SLUPLT86 (1986)
- SLUPRK90 (1990)

- Area Boundary
- Area of Investigation (AOI)
- Uplands CD Boundary as depicted on Exibit A to the Consent Decree (December 1999)
- Division between Eastern and Western Study Areas
- Shipyard Consent Decree Boundary
- Harbor Patrol Boundary
- Gas Works Park Boundary

N

0 375 750 1,500 Feet

AECOM

SUPPLEMENT TO THE CLEANUP STANDARDS DOCUMENT
GAS WORKS SEDIMENT AREA
60149262

LAKE UNION SEDIMENT DATA SET

DATE: 09/06/2011 | DWRN: CBB/ftc | Revision: 7

FIGURE 2-2

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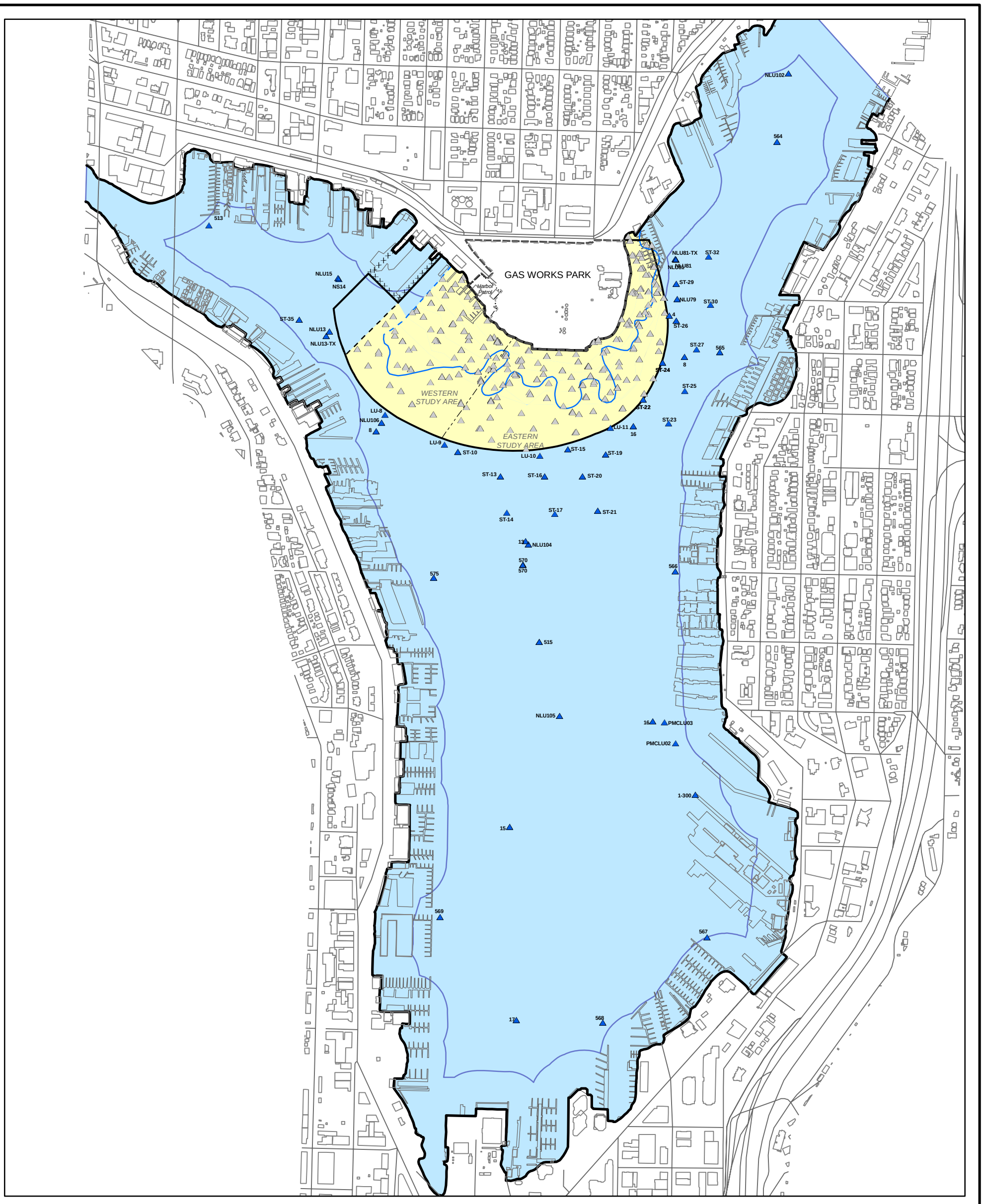

Surface and Subsurface Sample Locations

- GWSA Data Set
- Ambient Lake Union Data Set
- GWSA
- 300 ft. from Shoreline

- Area Boundary
- Area of Investigation (AOI)
- Uplands CD Boundary as depicted on Exibit A to the Consent Decree (December 1999)
- Division between Eastern and Western Study Areas
- Shipyard Consent Decree Boundary
- Harbor Patrol Boundary
- Gas Works Park Boundary

NOTES:

1. Sample dates range from November 1986 to September 2008. Only samples collected since 1995 are included in the GWSA Data Set.
2. Nearshore sample locations include those within 300 ft. of shore and/or those that are in proximity to over water structures or nearshore impacts (i.e., North Lake Shipyards). Nearshore samples are excluded from the final Lake Union sediment data set.

N

0 375 750 1,500 Feet

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SUPPLEMENT TO THE CLEANUP STANDARDS DOCUMENT GAS WORKS SEDIMENT AREA 60149262			**LAKE UNION SEDIMENT DATA SET - ALU**
DATE: 09/06/2011	DWRN: CBB/ftc	Revision: 7	**FIGURE 2-3**

0 150 300 Feet

N

GAS WORKS PARK

Harbor Patrol

Gas Works Park Marina

WESTERN STUDY AREA

EASTERN STUDY AREA

Surface and Subsurface Locations

- GWSA Data Set
- Ambient Lake Union Data Set
- GWSA
- 300 ft. from Shoreline

- Area Boundary
- Area of Investigation (AOI)
- Uplands CD Boundary as depicted on Exibit A to the Consent Decree (December 1999)
- Division between Eastern and Western Study Areas
- Shipyard Consent Decree Boundary
- Harbor Patrol Boundary
- Gas Works Park Boundary

NOTES:

1. Sample dates range from November 1986 to April 2009. Only samples collected since 1995 are included in the GWSA Data Set.
2. Nearshore sample locations include those within 300 ft. of shore and/or those that are in proximity to overwater structures or nearshore impacts (i.e., North Lake Shipyards). Nearshore samples are excluded from the final Lake Union sediment data set.

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SUPPLEMENT TO THE CLEANUP STANDARDS DOCUMENT
GAS WORKS SEDIMENT AREA
60149262

LAKE UNION SEDIMENT DATA SET - GWSA COPC SCREENING

DATE: 09/06/2011 | DRWN: CBB/ftc | Revision: 8 | **FIGURE 2-4**

0 150 300 Feet

N

GAS WORKS PARK

WESTERN STUDY AREA

EASTERN STUDY AREA

Harbor Patrol

Gas Works Park Marina

Surface Sample Locations

- GWSA Data Set
- Ambient Lake Union Data Set
- GWSA
- 300 ft. from Shoreline

- Area Boundary
- Area of Investigation (AOI)
- Uplands CD Boundary as depicted on Exibit A to the Consent Decree (December 1999)
- Division between Eastern and Western Study Areas
- Shipyard Consent Decree Boundary
- Harbor Patrol Boundary
- Gas Works Park Boundary

NOTES:

1. Sample dates range from November 1986 to September 2008. Only samples collected since 1995 are included in the GWSA Data Set.
2. The risk evaluations focused on surface sediment only.
3. Nearshore sample locations include those within 300 ft. of shore and/or those that are in proximity to overwater structures or nearshore impacts (i.e., North Lake Shipyards). Nearshore samples are excluded from the final Lake Union sediment data set.

AECOM

SUPPLEMENT TO THE CLEANUP STANDARDS DOCUMENT
GAS WORKS SEDIMENT AREA
60149262

LAKE UNION SEDIMENT DATA SET - GWSA RISK EVALUATION

DATE: 09/06/2011 | DRWN: CBB/ftc | Revision: 7 | **FIGURE 2-5**

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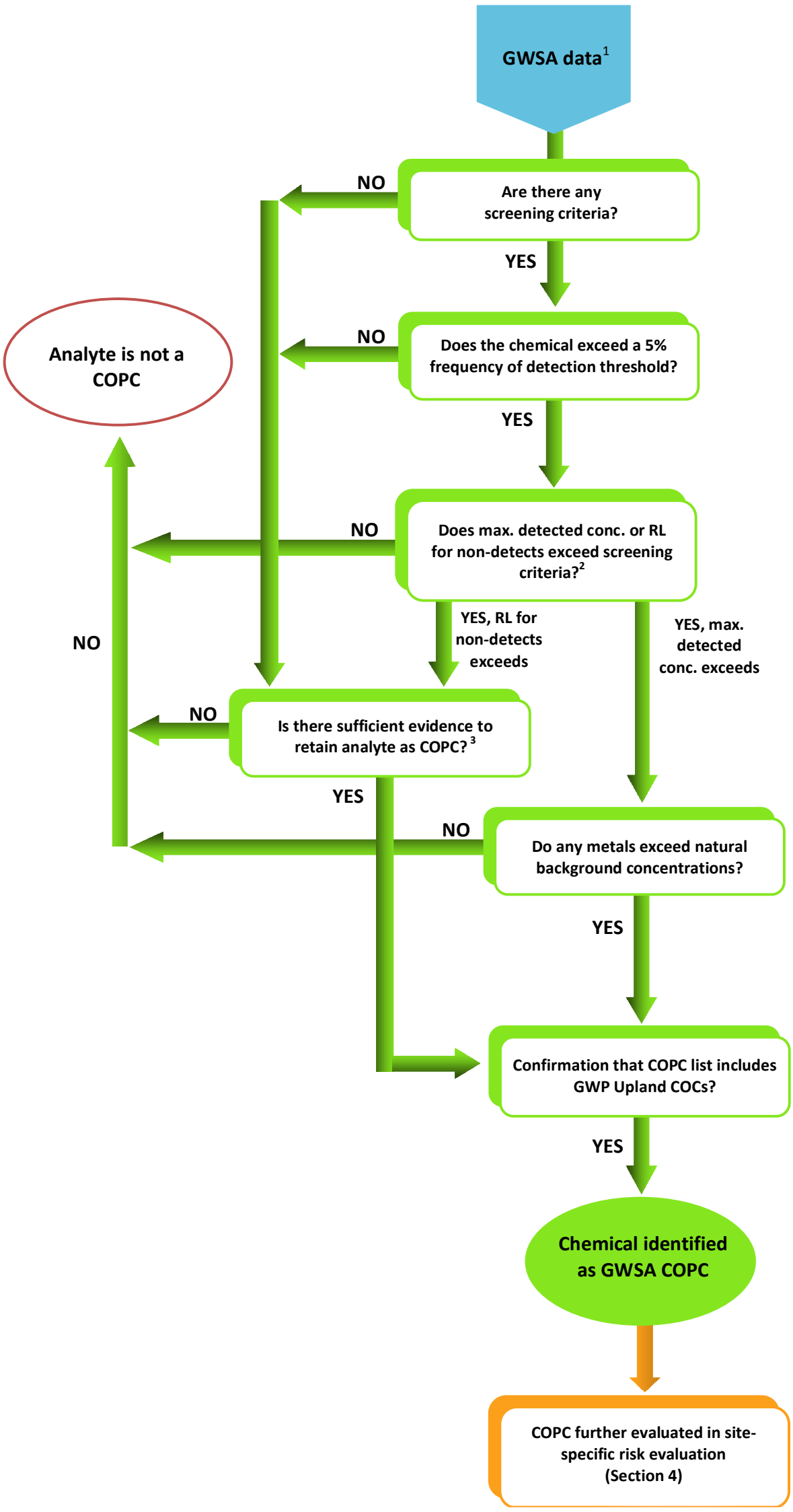

Abbreviations

ATL: Acceptable Tissue Levels
BTAG: Biological Technical Assessment Group
COPCs: Chemicals of Potential Concern
CTLs: Critical Tissue Levels
GWP: Gas Works Park
GWSA: Gas Works Sediment Area
MTCA: Model Toxics Control Act
ODEQ: Oregon Department of Environmental Quality
RL: Analytical Reporting Limit
RSET: Regional Sediment Evaluation Team
RSL: U.S. EPA Regional Screening Levels
SLV: Sediment Level Values
SQV: Sediment Quality Value
TTLs: Target Tissue Levels

Notes:

1. For sediment, analytes that were measured and validated in samples within the GWSA between 1995 and 2009; For tissue, analytes that were measured in finfish or crayfish tissue within the GWSA or vicinity between 1984 and 1999.
2. Screening criteria included:
   - Ecology SQVs (2003)
   - Ecology MTCA Method A or B soil cleanup standard
   - RSET Interim SLVs (2006) and tissue TTLs (2009)
   - USEPA R3 BTAG Screening Benchmarks (2006)
   - USEPA R3,R6 and R9 RSLs for soil total exposure includes: dermal, ingestion, and inhalation (12/2009)
   - EPA R3 RSLs for fish tissue (2009)
   - ODEQ bioaccumulative SLVs, and tissue ATLs, and CTLs (2007)

   For screening, all non-detects were set at a value equal to one-half the detection limit and the hazard index was adjusted downward to HI=0.1 for screening additive effects.
3. Analytes with no available screening criteria, infrequently detected analytes, and non-detected analytes with RLs > screening criteria, were further assessed to determine if there is evidence to retain them as COPCs (e.g. based on historical use, characteristics of reporting limits, analytical interference, representativeness of samples, distribution, etc.).

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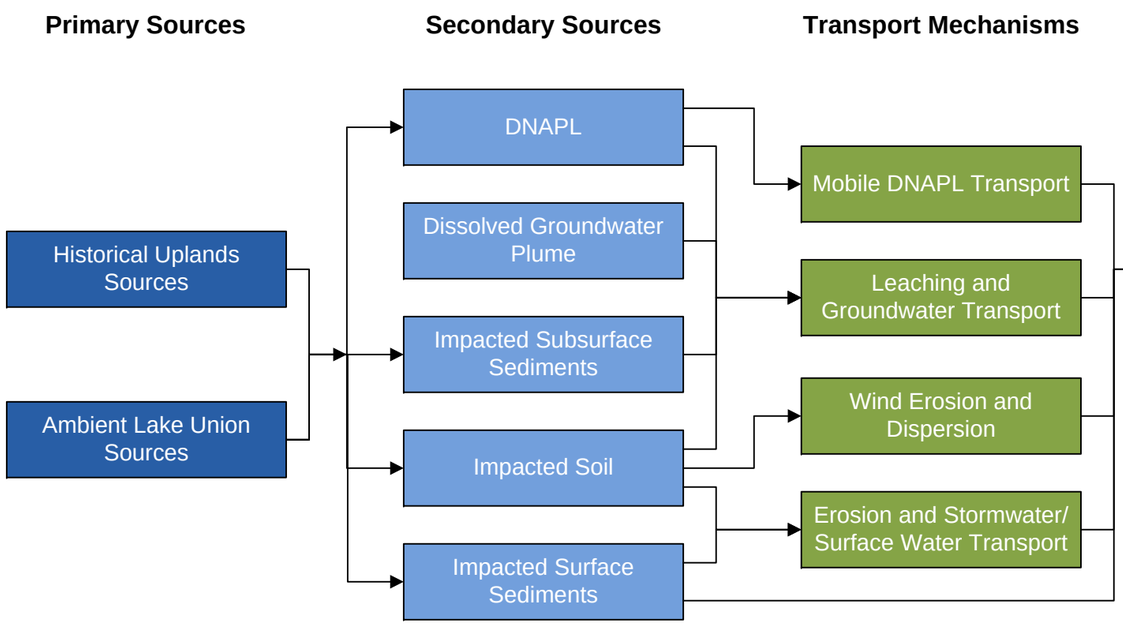
SUPPLEMENT TO THE CLEANUP STANDARDS DOCUMENT
GAS WORKS SEDIMENT AREA

GWSA DECISION FLOWCHART FOR IDENTIFYING COPCs

FIGURE 3-1



Exposure Route	Human: Beach Users	Human: Recreational Fishers	Human: Tribal Fishers	Ecological: Terrestrial (Otter, Heron, Mallard)	Ecological: Aquatic (Juvenile Salmon)	Ecological: Benthic Invertebrates
Ingestion of Sediments	X		X	X	X	X
Direct Contact with Sediments	X		X			X
Ingestion of Crayfish/Fish		X	X	X	X	

Note:
X Indicates that the exposure pathway is complete and was quantitatively evaluated in the Supplement to the Cleanup Standards Document.

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Supplement to the Cleanup Standards Document
Gas Works Sediment Area
Seattle, Washington

Figure 4.1
Conceptual Site Model for
Gas Works Sediment Area Sediments

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Supplement to the Cleanup Standards Document
Gas Works Sediment Area
City of Seattle

Figure 4-2
Beach Play/Wading Risk Sample Locations

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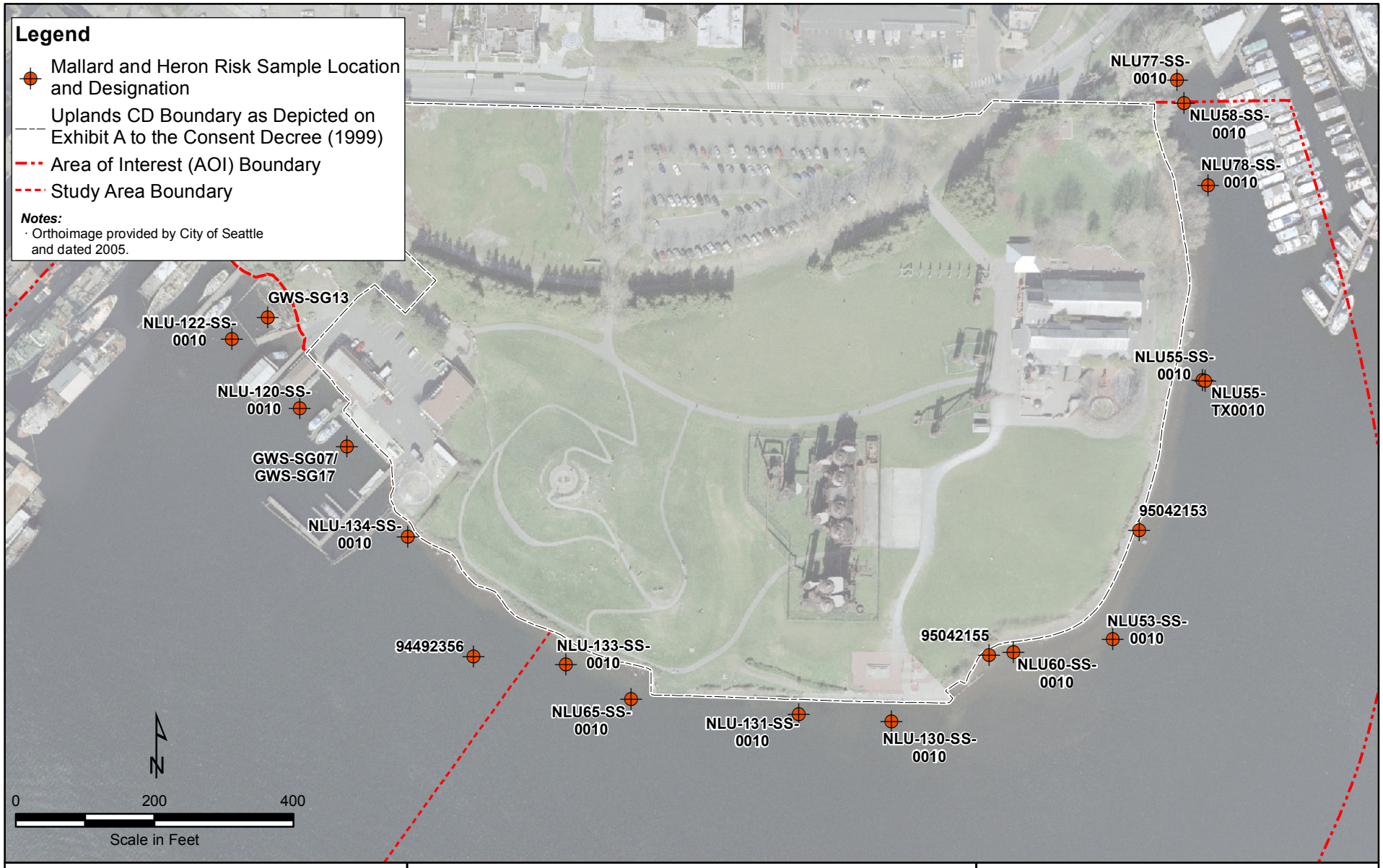
1/30/2012



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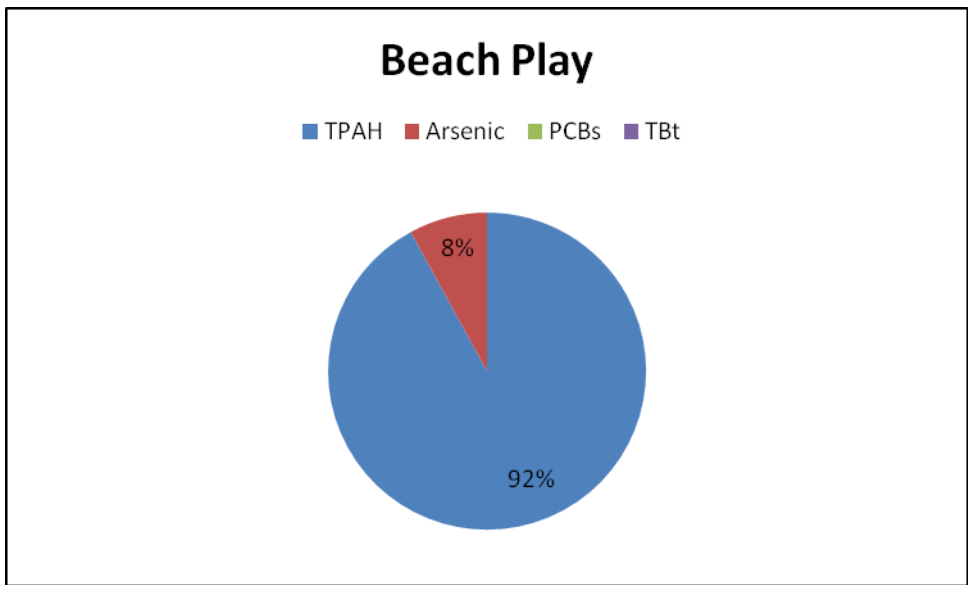
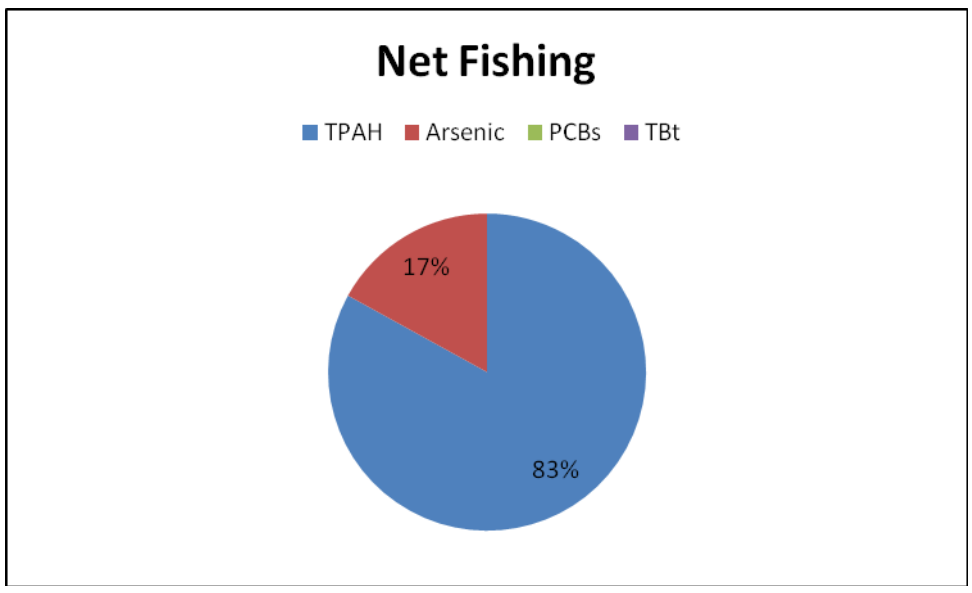
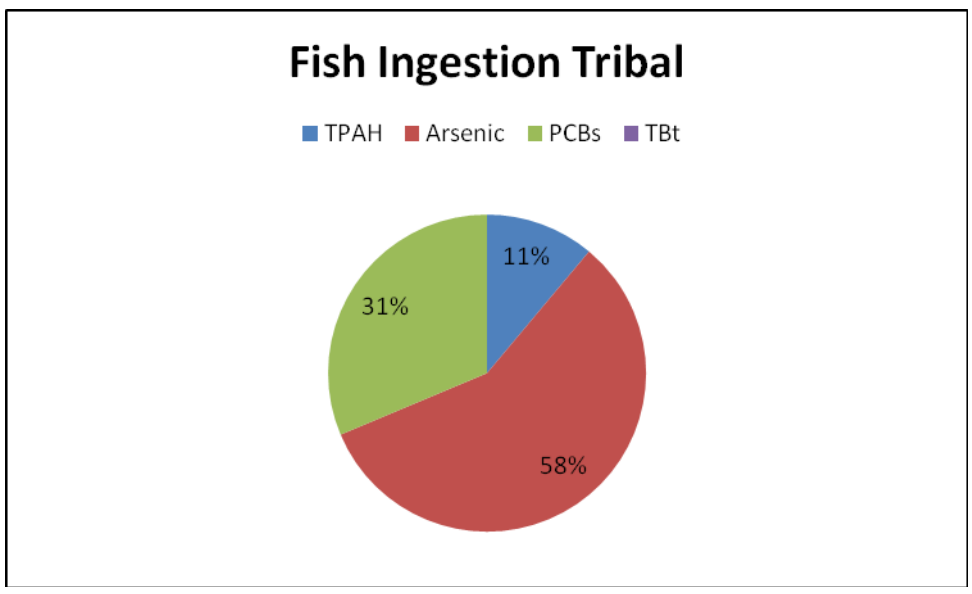
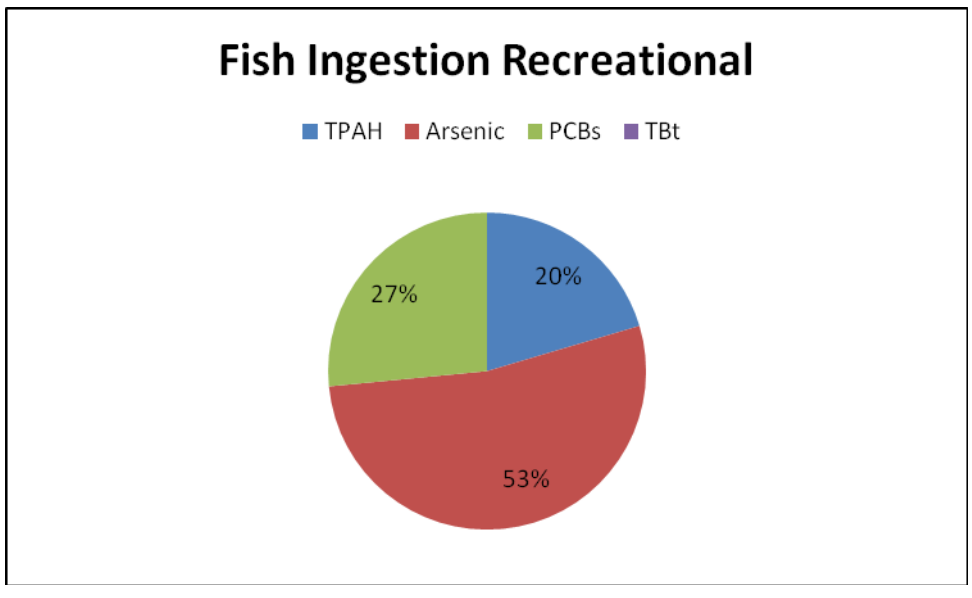
Supplement to the Cleanup Standards Document
Gas Works Sediment Area
City of Seattle

Figure 4-3
Mallard and Heron Ecological Risk Sample Locations









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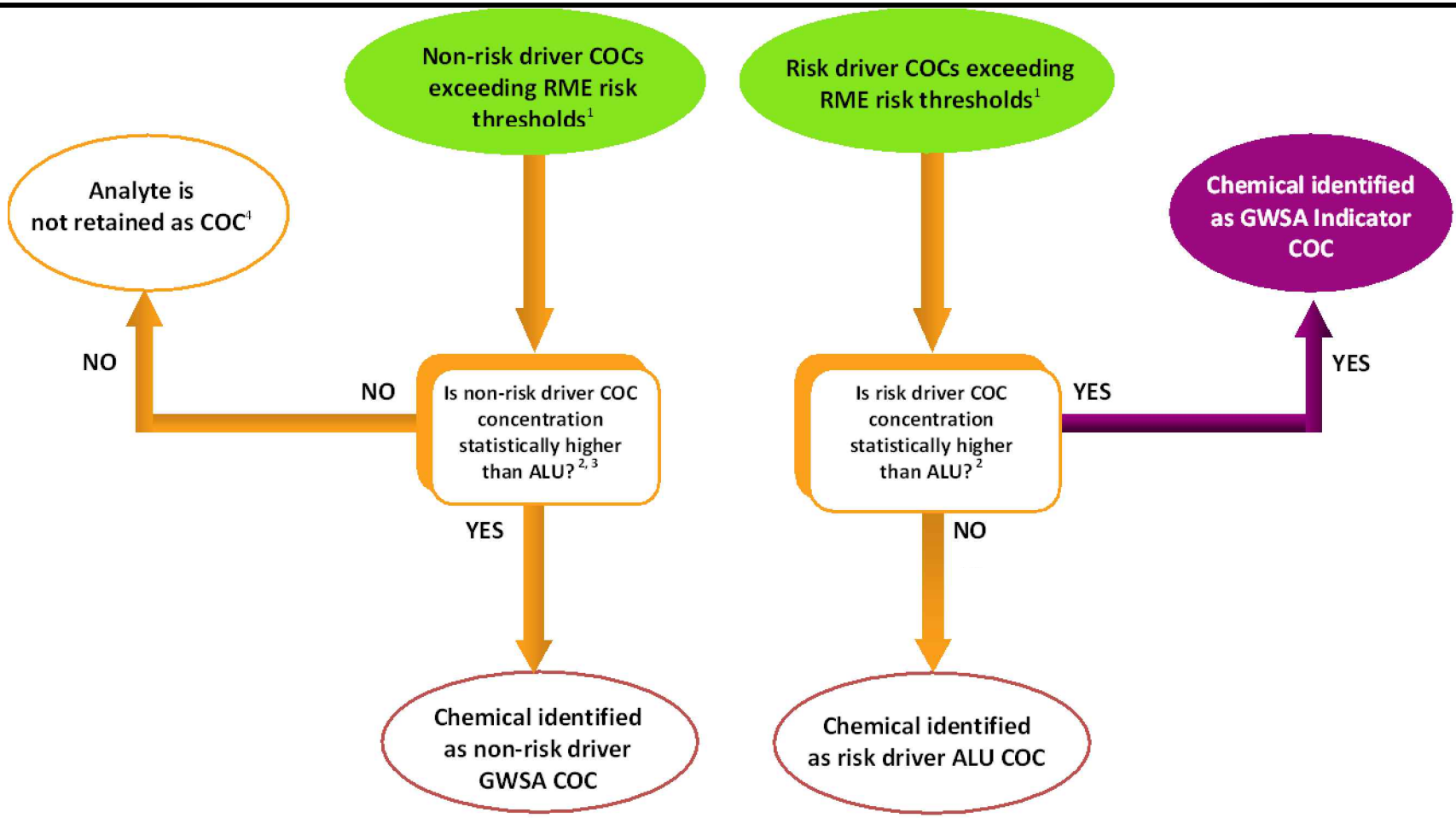
SUPPLEMENT TO THE CLEANUP STANDARDS DOCUMENT
GAS WORKS SEDIMENT AREA

Relative Contribution of COPCs to Cumulative GWSA Risk for Selected Exposure Scenarios
(Risk Driver Pie Charts)

Figure 4-4



Abbreviations

ALU:	Ambient Lake Union	GWSA:	Gas Works Sediment Area	RME:	Reasonable Maximum Exposure
COCs:	Chemicals of concern	HHRE:	Human health risk evaluation		
ERE:	Ecological risk evaluation	HQ:	Hazard Quotient		

Notes:

1. RME Risk driver COCs are those that comprise the majority of the RME risk defined as: >10% of the carcinogenic risk or HQ>5. COCs that exceed risk thresholds are defined for HHRE: $>10^{-6}$ or HQ>1 and for ERE: HQ>1 (see Section 4).
2. COC concentrations for the GWSA data set are compared to the chemical concentration for the same analyte in the ALU data set using a (non-parametric) two-sample hypothesis test to determine whether the two sample populations are significantly different. Statistical analyses were done for those chemicals having at least ten data points in the ALU data set.
3. In cases where there were less than ten ALU data points, COC is further evaluated qualitatively.
4. Analytes not retained as COCs for further assessment include all non-risk driver ALU COCs.

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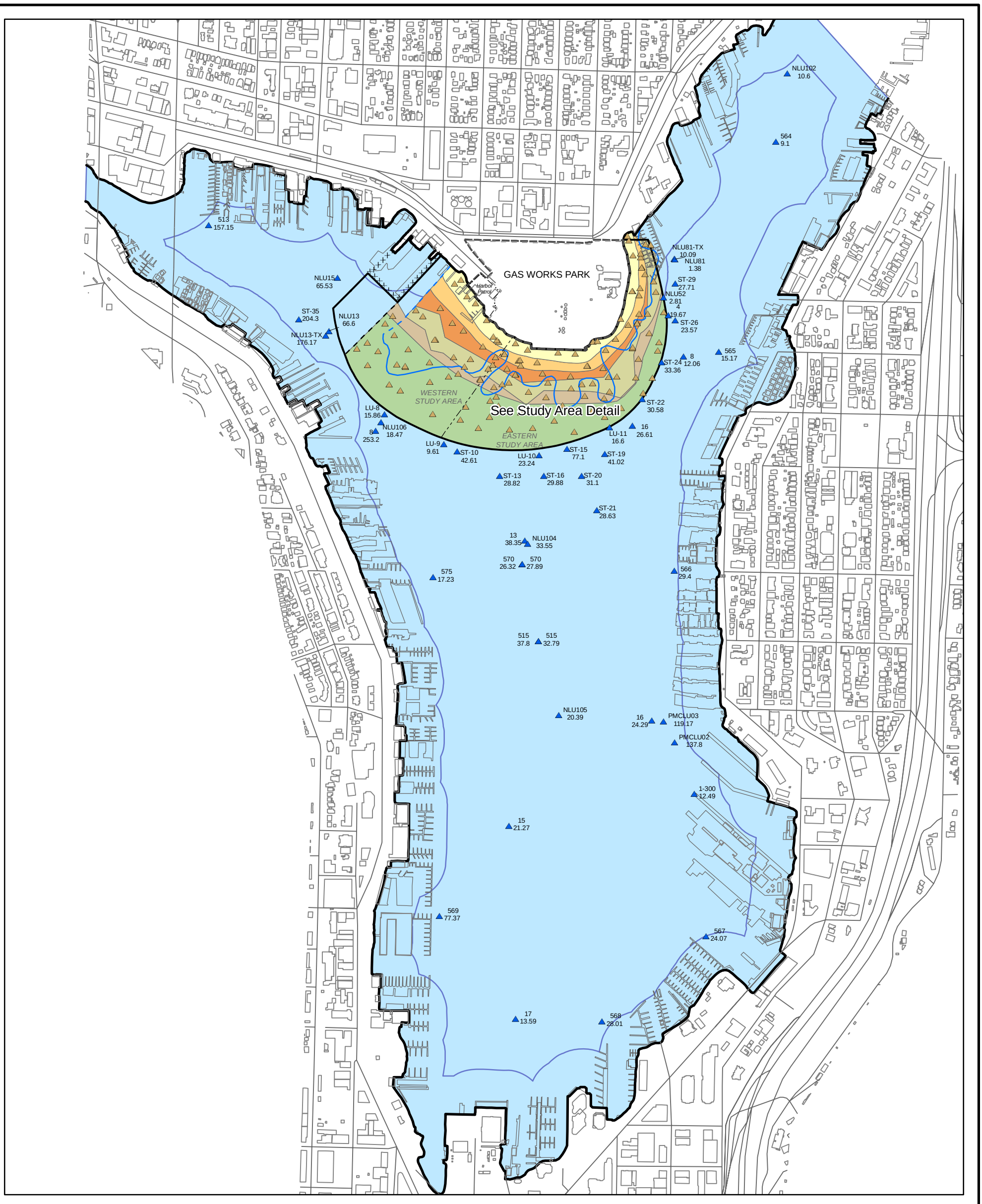
SUPPLEMENT TO THE CLEANUP STANDARDS DOCUMENT
GAS WORKS SEDIMENT AREA

DECISION FLOWCHART FOR IDENTIFYING GWSA INDICATOR COCs

FIGURE 5-1



Surface TPAH Sample Locations

- GWSA Data Set
- Ambient Lake Union Data Set

Statistical Analyses Areas

- Band 1
- Band 2
- Band 3
- Band 4
- Band 5
- No Action
- 300 ft. from shoreline

- Area Boundary
- Area of Investigation (AOI)
- Uplands CD Boundary as depicted on Exibit A to the Consent Decree (December 1999)
- Division between Eastern and Western Study Areas
- Shipyard Consent Decree Boundary
- Harbor Patrol Boundary
- Gas Works Park Boundary

NOTES:

1. Sample dates in ambient lake range from 1986 to 2005; samples dates within GWSA range from 1994 to 2005.
2. GWSA Indicator COCs include benzo(a)pyrene, HPAH, and TPAH.
3. Indicator COCs benzo(a)pyrene and HPAH have essentially identical data sets to TPAH, but different chemical concentrations at any given sample location.

N

0 375 750 1,500 Feet

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SUPPLEMENT TO THE CLEANUP STANDARDS DOCUMENT
GAS WORKS SEDIMENT AREA
60149262

DATE: 09/06/2011 | DWRN: RLB/ftc | Revision: 5

ITERATIVE APPROACH: ESTIMATED LATERAL EXTENT (LAKE WIDE VIEW) – INDICATOR COC – TPAH

FIGURE 6-1

T:\LakeUnion_N83\Projects\NLU\ESA_RI_Revision\Working\Report_Supp\CleanupStnds\Iterations\COCs\Fig_6-1_GWSA_Indicators_LW_ALT.mxd

0 150 300 Feet

N

Surface TPAH Sample Locations

- GWSA Data Set
- Ambient Lake Union Data Set

Statistical Analyses Areas

- Band 1
- Band 2
- Band 3
- Band 4
- Band 5
- No Action
- 300 ft. from shoreline

- Area Boundary
- Area of Investigation (AOI)
- Uplands CD Boundary as depicted on Exibit A to the Consent Decree (December 1999)
- Division between Eastern and Western Study Areas
- Shipyard Consent Decree Boundary
- Harbor Patrol Boundary
- Gas Works Park Boundary

GAS WORKS PARK

Harbor Patrol

Gas Works Park Marina

WESTERN STUDY AREA

EASTERN STUDY AREA

NOTES:

1. Sample dates in ambient lake range from 1986 to 2005; samples dates within GWSA range from 1994 to 2005.
2. GWSA Indicator COCs include benzo(a)pyrene, HPAH, and TPAH.
3. Indicator COCs benzo(a)pyrene and HPAH have essentially identical datasets to TPAH, but different chemical concentrations at any given sample location.

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SUPPLEMENT TO THE CLEANUP STANDARDS DOCUMENT GAS WORKS SEDIMENT AREA 60149262			**ITERATIVE APPROACH: ESTIMATED LATERAL EXTENT (GWSA DETAIL) – INDICATOR COC – TPAH**
DATE: 09/06/2011	DRWN: RLB/ftc	Revision:5	**FIGURE 6-2**

Appendix A

Evaluation of Infrequently Detected Chemicals and Chemicals Without Criteria

Table A-1 Evaluation of Infrequently Detected Chemicals, Including All Chemicals with Reporting Limits above the Lowest Screening Criteria

Parameter	CAS Number	No. of Samples	MTCA Ecology SMS	Uplands COC	No. of Detects	No. of Non-Detects	% Non-Detects	Max RL (mg/kg)	Lowest Criterion (mg/kg) *	RLs Above Lowest Criterion		Max RL >3x Lowest Criterion?	MTCA Soil PQL Evaluation					Date Assoc. w/ Elevated RLs	Elevated RLs Assoc. w/ Surface?	Further Evaluation of RLs Above Lowest Criterion	Retain? (Y/N)	Rationale for Retention/Elimination
										No.	%		MTCA Soil PQL (mg/kg)	Max RL <3x PQL? #	Lowest Criterion < PQL ^	# RLs > PQL	% RLs > PQL					
Metals																						
Thallium	7440-28-0	24		No	1	23	95.8	1.1	5.6	0	0.0	No	—	—	—	—	—	NA	NA	NA	No	Max RL < LC; detected concentration < LC
Phthalates																						
Di-n-octyl Phthalate	117-84-0	244	X	No	3	241	98.8	32	0.011	241	100.0	Yes	0.66	No	0.02	38	15.8	1995-2005	Yes	Surface and subsurface, ESA and WSA, 1995-2005	Yes	Elevated RLs distributed across the GWSA; detected concentrations also > LC
Phenols																						
2-Chlorophenol	95-57-8	104		No	0	104	100.0	43	0.0312	92	88.5	Yes	0.66	No	0.05	13	12.5	1995-2005	Yes	Surface and subsurface, ESA and WSA, 1995-2005	No	Limited RLs > PQL; LC is substantially lower than PQL
2,4-Dichlorophenol	120-83-2	104		No	0	104	100.0	210	0.117	92	88.5	Yes	0.66	No	0.18	55	52.9	1995-2005	Yes	Surface and subsurface, ESA and WSA, 1995-2005	No	LC is substantially lower than PQL
2,4,5-Trichlorophenol	95-95-4	104		No	0	104	100.0	210	611	0	0.0	No	0.66	No	NA	NA	NA	NA	NA	NA	No	Max RL < LC
2,4,6-Trichlorophenol	88-06-2	104		No	0	104	100.0	210	0.213	92	88.5	Yes	0.66	No	0.32	57	54.8	1995-2005	Yes	Surface and subsurface, ESA and WSA, 1995-2005	No	LC is substantially lower than PQL
4-Chloro-3-methylphenol	59-50-7	103		No	0	103	100.0	210	611	0	0.0	No	1.2	No	NA	NA	NA	NA	NA	NA	No	Max RL < LC
2-Methylphenol	95-48-7	267	X	No	8	259	97.0	43	306	0	0.0	No	0.66	No	NA	NA	NA	NA	NA	NA	No	Max RL < LC; detected concentrations also < LC
2,4-Dinitrophenol	51-28-5	103		No	0	103	100.0	430	12.2	9	8.7	Yes	3.3	No	NA	NA	NA	2005	No	All subsurface (including GWS-EC06, GWS-EC08, NLU67, NLU405)	No	RL > LC in <10% of samples; RL exceedances associated solely with subsurface samples at locations with interference from other elevated contaminants
4,6-Dinitro-2-Methylphenol	534-52-1	103		No	0	103	100.0	430	0.611	86	83.5	Yes	3.3	No	0.19	22	21.4	2005	Yes	Surface and subsurface, ESA and WSA, 2005: 19 cores (including GWS-EC06, GWS-EC08, NLU67, NLU405); 29 grabs	No	Elevated RLs due to interference from other contaminants
Pentachlorophenol	87-86-5	246	X	No	8	238	96.7	210	0.03	238	100.0	Yes	3.3	No	0.01	40	16.8	1995-2005	Yes	Surface and Subsurface, ESA and WSA, 1995-2005	Yes	Elevated RLs distributed across the GWSA; detected concentrations also > LC
Misc. Extractables																						
Benzidine	92-87-5	2		No	0	2	100.0	6	0.000501	2	100.0	Yes	29	Yes	0.00	0	0.0	1995-2000	Yes	Surface: 527 (1995 and 2000)	No	Elevated RLs associated with a large proportion of older data from a single location; no PQL exceedances
Benzyl Alcohol	100-51-6	244	X	No	8	236	96.7	32	611	0	0.0	No	1.3	No	NA	NA	NA	NA	NA	NA	No	Max RL < LC; detected concentrations also < LC
Hexachlorobenzene	118-74-1	286	X	No	2	284	99.3	32	0.0023	248	87.3	Yes	0.66	No	0.00	39	13.7	1999-2005	Yes	Predominantly subsurface (90%); highest exceedances at CR-10 and NLU119	No	Max RL elevated due to interference from other contaminants; detected only twice (2002, 2004)
Hexachlorobutadiene	87-68-3	286	X	No	0	286	100.0	32	6.11	4	1.4	Yes	0.66	No	NA	NA	NA	1999-2002	No	Subsurface: CR-10, CR-19, NLU119	No	RL > LC in <10% of samples; elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
Hexachlorocyclopentadiene	77-47-4	103		No	0	103	100.0	21	36.6	0	0.0	No	0.66	No	NA	NA	NA	NA	NA	NA	No	Max RL < LC
Hexachloroethane	67-72-1	104		No	0	104	100.0	4.3	1.027	10	9.6	Yes	0.66	No	NA	NA	NA	2005	No	Subsurface only (including GWS-EC06, GWS-EC08, NLU405)	No	RL > LC in <10% of samples; elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
Nitrobenzene	98-95-3	104		No	0	104	100.0	4.3	4.79	0	0.0	No	0.66	No	NA	NA	NA	NA	NA	NA	No	Max RL < LC
N-Nitrosodimethylamine	62-75-9	3		No	0	3	100.0	0.96	0.00226	3	100.0	Yes	1.3	Yes	0.00	0	0.0	1995-2001	Yes	Surface: 527 (1995, 2000); 572 (2001)	No	Elevated RLs associated with a large proportion of older data at just two locations; no PQL exceedances
N-Nitrosodiphenylamine	86-30-6	244	X	No	8	236	96.7	32	2.68	11	4.7	Yes	0.66	No	NA	NA	NA	1999-2005	No	All subsurface (including CR-10, CR-19, GWS-EC08, NLU109, NLU117, NLU119, NLU405)	No	RL > LC in <10% of samples; detected concentrations also < LC; elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
N-Nitroso-Di-N-Propylamine	621-64-7	104		No	0	104	100.0	21	0.0694	104	100.0	Yes	1.3	No	0.05	28	26.9	1995-2005	Yes	Surface and subsurface, ESA and WSA, 2005: 23 cores (including GWS-EC06, GWS-EC08, NLU405, NLU67); 32 grabs (including 527 [1995])	No	LC is substantially lower than PQL; elevated RLs due to interference from other contaminants; plus an older sample
4-Chloroaniline	106-47-8	122		No	0	122	100.0	21	2.43	14	11.5	Yes	0.33	No	NA	NA	NA	2005	Yes	Predominantly subsurface, ESA and WSA, 2005: 6 cores (including GWS-EC06, GWS-EC08, NLU405); 3 grabs	No	Elevated RLs due to interference from other contaminants
2-Nitroaniline	88-74-4	103		No	0	103	100.0	21	60.6	0	0.0	No	3.3	No	NA	NA	NA	NA	NA	NA	No	Max RL < LC
P-Nitroaniline	100-01-6	103		No	0	103	100.0	21	24.3	0	0.0	No	1.6	No	NA	NA	NA	NA	NA	NA	No	Max RL < LC
1,2-Dichlorobenzene	95-50-1	253	X	No	0	253	100.0	32	0.0165	242	95.7	Yes	0.66	No	0.03	39	15.4	1995-2005	Yes	Surface and subsurface, ESA and WSA, 1995-2005	No	Limited RLs > PQL; LC is substantially lower than PQL
1,3-Dichlorobenzene	541-73-1	183		No	0	183	100.0	61	4.43	12	6.6	Yes	0.66	No	NA	NA	NA	1999-2002	No	Subsurface: CR-10, CR-19, NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
1,4-Dichlorobenzene	106-46-7	253	X	No	0	253	100.0	32	0.599	41	16.2	Yes	0.66	No	0.91	39	15.4	1999-2005	Yes	Predominantly subsurface, ESA and WSA (including CR-10, CR-19, GWS-EC06, GWS-EC08, NLU109, NLU117, NLU119, NLU405)	No	Elevated RLs associated with samples at locations with interference from other elevated contaminants
1,2,3-Trichlorobenzene	87-61-6	9		No	0	9	100.0	310	0.858	9	100.0	Yes	—	—	—	—	—	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
1,2,4-Trichlorobenzene	120-82-1	253	X	No	0	253	100.0	32	2.1	13	5.1	Yes	0.66	No	NA	NA	NA	1999-2005	No	All subsurface (including CR-10, CR-19, GWS-EC08, NLU109, NLU117, NLU119, NLU405)	No	RL > LC in <10% of samples; elevated RLs associated solely with subsurface locations with interference from other contaminants
3,3'-Dichlorobenzidine	91-94-1	103		No	0	103	100.0	21	0.127	91	88.3	Yes	1.3	No	0.10	28	27.2	1995-2005	Yes	Surface and subsurface, ESA and WSA: 19 cores (including GWS-EC06, GWS-EC08, NLU67, NLU405); 31 grabs	No	Elevated RLs due to interference from other contaminants
Bis-(2-Chloroethyl) Ether	111-44-4	104		No	0	104	100.0	4.3	0.214	31	29.8	Yes	0.66	No	0.32	12	11.5	2001-2005	Yes	Surface and subsurface, ESA and WSA: 9 cores (including GWS-EC06, GWS-EC08, NLU67, NLU405); 9 grabs	No	Limited RLs > PQL; LC is substantially lower than PQL; elevated RLs due to interference from other contaminants

Table A-1 Evaluation of Infrequently Detected Chemicals, Including All Chemicals with Reporting Limits above the Lowest Screening Criteria

Parameter	CAS Number	No. of Samples	MTCA Ecology SMS	Uplands COC	No. of Detects	No. of Non-Detects	% Non-Detects	Max RL (mg/kg)	Lowest Criterion (mg/kg) *	RLs Above Lowest Criterion		Max RL >3x Lowest Criterion?	MTCA Soil PQL Evaluation					Date Assoc. w/ Elevated RLs	Elevated RLs Assoc. w/ Surface?	Further Evaluation of RLs Above Lowest Criterion	Retain? (Y/N)	Rationale for Retention/Elimination
										No.	%		MTCA Soil PQL (mg/kg)	Max RL <3x PQL? #	Lowest Criterion < PQL ^	# RLs > PQL	% RLs > PQL					
Misc. Extractables (continued)																						
Bis(2-chloroisopropyl)ether	39638-32-9	76		No	0	76	100.0	3.5	3200	0	0.0	No	0.66	No	NA	NA	NA	NA	NA	NA	No	Max RL < LC
bis(2-Chloroethoxy) Methane	111-91-1	104		No	0	104	100.0	4.3	18.3	0	0.0	No	0.66	No	NA	NA	NA	NA	NA	NA	No	Max RL < LC
2-Chloronaphthalene	91-58-7	104		No	0	104	100.0	4.3	626	0	0.0	No	0.66	No	NA	NA	NA	NA	NA	NA	No	Max RL < LC
4-Bromophenyl-phenylether	101-55-3	104		No	0	104	100.0	4.3	1.23	8	7.7	Yes	0.66	No	NA	NA	NA	2005	No	Subsurface only (including GWS-EC06, GWS-EC08, NLU405)	No	RL > LC in <10% of samples; RL exceedances associated solely with subsurface samples at locations with interference from other elevated contaminants
2,2'-Oxybis(1-Chloropropane)	108-60-1	28		No	0	28	100.0	4.3	4.57	0	0.0	No	—	—	—	—	—	NA	NA	NA	No	Max RL < LC
2,4-Dinitrotoluene	121-14-2	104		No	0	104	100.0	21	0.0416	104	100.0	Yes	0.66	No	0.06	55	52.9	1995-2005	Yes	Surface and subsurface, ESA and WSA: 23 cores (including GWS-EC06, GWS-EC08, NLU67, NLU405); 32 grabs (including 527 [1995])	No	LC is substantially lower than PQL; elevated RLs due to interference from other contaminants; plus an older sample
2,6-Dinitrotoluene	606-20-2	104		No	0	104	100.0	21	6.12	9	8.7	Yes	0.66	No	NA	NA	NA	2005	No	Subsurface only (including GWS-EC06, GWS-EC08, NLU405)	No	RL > LC in <10% of samples; elevated RLs associated solely with subsurface locations with interference from other contaminants
Volatile Organics																						
Acrolein	107-02-8	10		No	0	10	100.0	3100	0.0155	10	100.0	Yes	0.007	No	NA	NA	NA	1995-2002	Yes	All subsurface (NLU109, NLU117, NLU119), except one 1995 surface (527)	No	Elevated RLs associated almost exclusively with subsurface samples at locations with interference from other elevated contaminants; plus an older surface sample
Acrylonitrile	107-13-1	10		No	0	10	100.0	310	0.237	9	90.0	Yes	0.005	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
Aniline	62-53-3	3		No	0	3	100.0	0.5	42.8	0	0.0	No	0.66	Yes	NA	NA	NA	NA	NA	NA	No	Max RL < LC
Bromobenzene	108-86-1	9		No	0	9	100.0	61	29.7	4	44.4	No	—	—	—	—	—	2002	No	Subsurface: NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
Chlorobenzene	108-90-7	10		No	0	10	100.0	61	0.00842	10	100.0	Yes	0.005	No	NA	NA	NA	1995-2002	Yes	All subsurface (NLU109, NLU117, NLU119), except one 1995 surface (527)	No	Elevated RLs associated almost exclusively with subsurface samples at locations with interference from other elevated contaminants; plus an older surface sample
Isopropylbenzene	98-82-8	31		No	9	22	71.0	61	0.086	10	45.5	Yes	—	—	—	—	—	1995-2002	Yes	All subsurface (NLU109, NLU117, NLU119), except one 1995 surface (32)	No	Exceedances due only to elevated RLs associated almost exclusively with subsurface samples at locations with interference from other elevated contaminants; plus an older surface sample
Bromoform	75-25-2	10		No	0	10	100.0	61	0.654	9	90.0	Yes	0.005	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
trans-1,4-Dichloro-2-butene	110-57-6	9		No	0	9	100.0	310	0.00694	9	100.0	Yes	—	—	—	—	—	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
Carbon Disulfide	75-15-0	10		No	0	10	100.0	61	0.000851	10	100.0	Yes	0.1	No	0.01	9	90.0	1995-2002	Yes	All subsurface (NLU109, NLU117, NLU119), except one 1995 surface (527)	No	Elevated RLs associated almost exclusively with subsurface samples at locations with interference from other elevated contaminants; plus an older surface sample
Carbon Tetrachloride	56-23-5	10		No	0	10	100.0	61	0.0642	9	90.0	Yes	0.005	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
Chloroform	67-66-3	32		No	3	29	90.6	61	0.295	9	31.0	Yes	0.005	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Exceedances due only to elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
1,2-Dibromoethane	106-93-4	9		No	0	9	100.0	61	0.005	9	100.0	Yes	0.002	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
Chloroethane	75-00-3	10		No	0	10	100.0	61	345	0	0.0	No	0.01	No	NA	NA	NA	NA	NA	NA	No	Max RL < LC
1,1-Dichloroethane	75-34-3	10		No	0	10	100.0	61	3.31	9	90.0	Yes	0.005	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
1,2-Dichloroethane	107-06-2	31		No	1	30	96.8	61	0.432	9	30.0	Yes	0.005	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants; detected concentration < LC
1,1,1-Trichloroethane	71-55-6	11		No	1	10	90.9	61	0.0302	10	100.0	Yes	0.005	No	NA	NA	NA	1995-2002	Yes	All subsurface (NLU109, NLU117, NLU119), except one 1995 surface (527)	No	Exceedances due only to elevated RLs associated almost exclusively with subsurface samples at locations with interference from other elevated contaminants; plus an older surface sample
1,1,2-Trichloroethane	79-00-5	10		No	0	10	100.0	61	1.07	9	90.0	Yes	0.005	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
1,1,1,2-Tetrachloroethane	630-20-6	9		No	0	9	100.0	61	1.86	9	100.0	Yes	—	—	—	—	—	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
1,1,2,2-Tetrachloroethane	79-34-5	10		No	0	10	100.0	61	0.562	9	90.0	Yes	0.005	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	9		No	0	9	100.0	61	4250	0	0.0	No	—	—	—	—	—	NA	NA	NA	No	Max RL < LC
1,1-Dichloroethene	75-35-4	10		No	0	10	100.0	61	0.031	10	100.0	Yes	0.005	No	NA	NA	NA	1995-2002	Yes	All subsurface (NLU109, NLU117, NLU119), except one 1995 surface (527)	No	Elevated RLs associated almost exclusively with subsurface samples at locations with interference from other elevated contaminants; plus an older surface sample
cis-1,2-Dichloroethene	156-59-2	9		No	0	9	100.0	61	78.2	0	0.0	No	0.005	No	NA	NA	NA	NA	NA	NA	No	Max RL < LC
trans-1,2-Dichloroethene	156-60-5	10		No	0	10	100.0	61	1.05	9	90.0	Yes	0.005	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
Trichloroethene	79-01-6	10		No	0	10	100.0	61	0.03	10	100.0	Yes	0.001	No	NA	NA	NA	1995-2002	Yes	All subsurface (NLU109, NLU117, NLU119), except one 1995 surface (527)	No	Elevated RLs associated almost exclusively with subsurface samples at locations with interference from other elevated contaminants; plus an older surface sample
Tetrachloroethene	127-18-4	10		No	0	10	100.0	61	0.05	9	90.0	Yes	0.0003	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
1,2-Diphenylhydrazine	122-66-7	3		No	0	3	100.0	0.48	0.607	0	0.0	No	0.66	Yes	NA	NA	NA	NA	NA	NA	No	Max RL < LC

Table A-1 Evaluation of Infrequently Detected Chemicals, Including All Chemicals with Reporting Limits above the Lowest Screening Criteria

Parameter	CAS Number	No. of Samples	MTCA Ecology SMS	Uplands COC	No. of Detects	No. of Non-Detects	% Non-Detects	Max RL (mg/kg)	Lowest Criterion (mg/kg) *	RLs Above Lowest Criterion		Max RL >3x Lowest Criterion?	MTCA Soil PQL Evaluation					Date Assoc. w/ Elevated RLs	Elevated RLs Assoc. w/ Surface?	Further Evaluation of RLs Above Lowest Criterion	Retain? (Y/N)	Rationale for Retention/Elimination
										No.	%		MTCA Soil PQL (mg/kg)	Max RL <3x PQL? #	Lowest Criterion < PQL ^	# RLs > PQL	% RLs > PQL					
Volatile Organics cont'd																						
Bromomethane	74-83-9	10		No	0	10	100.0	61	0.732	9	90.0	Yes	0.01	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
Dibromomethane	74-95-3	9		No	0	9	100.0	61	2.46	9	100.0	Yes	—	—	—	—	—	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
Chloromethane	74-87-3	10		No	0	10	100.0	61	11.9	9	90.0	Yes	0.01	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
Bromodichloromethane	75-27-4	10		No	0	10	100.0	61	0.273	9	90.0	Yes	0.005	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
Dibromochloromethane	124-48-1	10		No	0	10	100.0	61	0.68	9	90.0	Yes	0.002	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
Trichlorofluoromethane	75-69-4	10		No	0	10	100.0	61	78.7	0	0.0	No	0.005	No	NA	NA	NA	NA	NA	NA	No	Max RL < LC
Methylene Chloride	75-09-2	32		No	1	31	96.9	120	0.02	23	74.2	Yes	0.005	No	NA	NA	NA	1995-2002	Yes	Subsurface (NLU109, NLU117, NLU119), and surface 1995 (including 527)	No	Elevated RLs associated with subsurface samples at locations with interference from other elevated contaminants; detected concentration < LC; only surface samples are from older data
2-Hexanone	591-78-6	31		No	3	28	90.3	310	20.9	9	32.1	Yes	0.05	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Exceedances due only to elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
1,2-Dichloropropane	78-87-5	10		No	0	10	100.0	61	0.895	9	90.0	Yes	0.005	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
1,3-Dichloropropane	142-28-9	9		No	0	9	100.0	61	156	0	0.0	No	—	—	—	—	—	NA	NA	NA	No	Max RL < LC
1,2,3-Trichloropropane	96-18-4	9		No	0	9	100.0	120	0.00497	9	100.0	Yes	—	—	—	—	—	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
1,2-Dibromo-3-chloropropane	96-12-8	9		No	0	9	100.0	310	0.00535	9	100.0	Yes	—	—	—	—	—	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
Styrene	100-42-5	31		No	1	30	96.8	61	0.559	9	30.0	Yes	0.005	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants; detected concentration < LC
2-Chlorotoluene	95-49-8	9		No	0	9	100.0	61	156	0	0.0	No	—	—	—	—	—	NA	NA	NA	No	Max RL < LC
4-Chlorotoluene	106-43-4	9		No	0	9	100.0	61	548	0	0.0	No	—	—	—	—	—	NA	NA	NA	No	Max RL < LC
Vinyl Acetate	108-05-4	10		No	0	10	100.0	310	97.5	5	50.0	Yes	0.05	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
Vinyl Chloride	75-01-4	10		No	0	10	100.0	61	0.0597	9	90.0	Yes	0.02	No	NA	NA	NA	2002	No	Subsurface: NLU109, NLU117, NLU119	No	Elevated RLs associated solely with subsurface samples at locations with interference from other elevated contaminants
Pesticides/PCBs																						
2,4,5-T	93-76-5	2		No	0	2	100.0	230	12.3	1	50.0	Yes	0.04	No	NA	NA	NA	1995	Yes	Surface: 527 (1995)	No	Elevated RL associated with older data from a single location; limited non-representative sample size
2,4,5-TP (Silvex)	93-72-1	2		No	0	2	100.0	280	0.675	1	50.0	Yes	0.034	No	NA	NA	NA	1995	Yes	Surface: 527 (1995)	No	Elevated RL associated with older data from a single location; limited non-representative sample size
2,4-D	94-75-7	2		No	0	2	100.0	180	68.6	1	50.0	No	0.24	No	NA	NA	NA	1995	Yes	Surface: 527 (1995)	No	Elevated RL associated with older data from a single location; limited non-representative sample size
2,4-DB	94-82-6	2		No	0	2	100.0	250	48.9	1	50.0	Yes	0.18	No	NA	NA	NA	1995	Yes	Surface: 527 (1995)	No	Elevated RL associated with older data from a single location; limited non-representative sample size
Aldrin	309-00-2	3		No	0	3	100.0	0.01	0.002	3	100.0	Yes	0.003	No	0.67	3	100.0	1995-2001	Yes	Surface: 527 (1995, 2000); 572 (2001)	No	Elevated RLs associated with a large proportion of older data; limited non-representative sample size
alpha-BHC	319-84-6	3		No	0	3	100.0	0.01	0.006	2	66.7	No	0.002	No	NA	NA	NA	1995-2000	Yes	Surface: 527 (1995, 2000)	No	Elevated RL associated with older data from a single location; limited non-representative sample size
beta-BHC	319-85-7	3		No	0	3	100.0	0.01	0.005	2	66.7	No	0.004	Yes	NA	NA	NA	1995-2000	Yes	Surface: 527 (1995, 2000)	No	Elevated RL associated with older data from a single location; limited non-representative sample size
delta-BHC	319-86-8	3		No	0	3	100.0	0.01	6.4	0	0.0	No	0.006	Yes	NA	NA	NA	NA	NA	NA	No	Max RL < LC
gamma-BHC (Lindane)	58-89-9	3		No	0	3	100.0	0.01	0.00237	3	100.0	Yes	0.003	No	0.79	2	66.7	1995-2001	Yes	Surface: 527 (1995, 2000); 572 (2001)	No	Elevated RLs associated with a large proportion of older data; limited non-representative sample size
Chlordane	12789-03-6	44		No	2	42	95.5	0.05	0.000046	42	100.0	Yes	0.009	No	0.01	5	11.9	2000-2005	Yes	Surface and subsurface, predominantly in the ESA	Yes	Elevated RLs distributed across the GWSA; detected concentrations also > LC
DDE	72-55-9	45		No	2	43	95.6	0.04	0.00316	14	32.6	Yes	0.003	No	NA	NA	NA	2000-2005	Yes	Surface and subsurface, predominantly ESA, 2005: 2 cores (including NLU58, NLU62); 12 grabs	No	Elevated RLs due to interference from other contaminants; detected only twice (1995, 2001)
DDT	50-29-3	45		No	2	43	95.6	0.04	0.00004	43	100.0	Yes	0.008	No	0.01	11	25.6	1995-2005	Yes	Surface and subsurface, predominantly ESA, 2005: 7 cores (including NLU58, NLU62); 29 grabs (including 527 (1995))	Yes	Elevated RLs distributed across the GWSA; detected concentrations also > LC; plus an older sample
Dicamba	1918-00-9	2		No	0	2	100.0	140	183	0	0.0	No	0.054	No	NA	NA	NA	NA	NA	NA	No	Max RL < LC
Dieldrin	60-57-1	3		No	0	3	100.0	0.01	0.000001	3	100.0	Yes	0.001	No	0.00	3	100.0	1995-2001	Yes	Surface: 527 (1995, 2000); 572 (2001)	No	Elevated RLs within 3x PQL; associated with a large proportion of older data from only 2 locations; limited non-representative sample size
Dinoseb	88-85-7	2		No	0	2	100.0	300	0.000611	2	100.0	Yes	0.014	No	0.04	1	50.0	1995-2001	Yes	Surface: 527 (1995); 572 (2001)	No	Elevated RLs associated with a large proportion of older data from only 2 locations; limited non-representative sample size
Endosulfan	115-29-7	3		No	0	3	100.0	0.01	0.00214	3	100.0	Yes	—	—	—	—	—	1995-2001	Yes	Surface: 527 (1995, 2000); 572 (2001)	No	Elevated RLs close to LC; associated with a large proportion of older data from only 2 locations; limited non-representative sample size
Endosulfan Sulfate	1031-07-8	3		No	0	3	100.0	0.021	0.0054	3	100.0	Yes	0.044	Yes	0.12	0	0.0	1995-2001	Yes	Surface: 527 (1995, 2000); 572 (2001)	No	No RLs > PQL; LC is substantially lower than PQL; elevated RLs associated with a large proportion of older data; limited non-representative sample size
Endrin	72-20-8	3		No	0	3	100.0	0.01	0.00222	3	100.0	Yes	0.004	Yes	0.56	3	100.0	1995-2001	Yes	Surface: 527 (1995, 2000); 572 (2001)	No	Elevated RLs within 3x PQL; associated with a large proportion of older data from only 2 locations; limited non-representative sample size

Table A-1 Evaluation of Infrequently Detected Chemicals, Including All Chemicals with Reporting Limits above the Lowest Screening Criteria

Parameter	CAS Number	No. of Samples	MTCA Ecology SMS	Uplands COC	No. of Detects	No. of Non-Detects	% Non-Detects	Max RL (mg/kg)	Lowest Criterion (mg/kg) *	RLs Above Lowest Criterion		Max RL >3x Lowest Criterion?	MTCA Soil PQL Evaluation					Date Assoc. w/ Elevated RLs	Elevated RLs Assoc. w/ Surface?	Further Evaluation of RLs Above Lowest Criterion	Retain? (Y/N)	Rationale for Retention/Elimination
										No.	%		MTCA Soil PQL (mg/kg)	Max RL <3x PQL? #	Lowest Criterion < PQL ^	# RLs > PQL	% RLs > PQL					
Pesticides/PCBs (continued)																						
Heptachlor	76-44-8	3		No	0	3	100.0	0.01	0.068	0	0.0	No	0.002	No	NA	NA	NA	NA	NA	NA	No	Max RL < LC
Heptachlor Epoxide	1024-57-3	3		No	0	3	100.0	0.0154	0.00247	3	100.0	Yes	0.056	Yes	0.04	0	0.0	1995-2001	Yes	Surface: 527 (1995, 2000); 572 (2001)	No	No RLs > PQL; elevated RLs associated with a large proportion of older data from only 2 locations; limited non-representative sample size
MCPA	94-74-6	2		No	0	2	100.0	310	3.06	1	50.0	Yes	50	No	0.06	1	50.0	1995	Yes	Surface: 527 (1995)	No	Elevated RL associated with older data from a single location; limited non-representative sample size
MCPP	93-65-2	2		No	0	2	100.0	280	6.11	1	50.0	Yes	38	No	0.16	1	50.0	1995	Yes	Surface: 527 (1995)	No	Elevated RL associated with older data from a single location; limited non-representative sample size
Methoxychlor	72-43-5	3		No	0	3	100.0	0.06	0.0187	3	100.0	Yes	0.12	Yes	0.16	0	0.0	1995-2001	Yes	Surface: 527 (1995, 2000); 572 (2001)	No	No RLs > PQL; elevated RLs associated with a large proportion of older data from only 2 locations; limited non-representative sample size
Toxaphene	8001-35-2	3		No	0	3	100.0	0.12	0.0001	3	100.0	Yes	0.16	Yes	0.00	0	0.0	1995-2001	Yes	Surface: 527 (1995, 2000); 572 (2001)	No	No RLs > PQL; elevated RLs associated with a large proportion of older data from only 2 locations; limited non-representative sample size
Aroclor 1016	12674-11-2	128		No	0	128	100.0	0.2	0.393	0	0.0	No	0.044	No	NA	NA	NA	NA	NA	NA	No	Max RL < LC
Aroclor 1221	11104-28-2	128		No	0	128	100.0	0.2	0.141	4	3.1	No	0.044	No	NA	NA	NA	2004-2005	Yes	Surface in WSA (including GWS-SG07), subsurface in ESA (including NLU58, NLU62)	No	RL > LC in <10% of samples; elevated RLs due to interference from other contaminants
Aroclor 1232	11141-16-5	128		No	0	128	100.0	0.3	0.141	4	3.1	No	0.044	No	NA	NA	NA	2004-2005	Yes	Surface in WSA (including GWS-SG07), subsurface in ESA (including NLU58, NLU62)	No	RL > LC in <10% of samples; elevated RLs due to interference from other contaminants
Aroclor 1242	53469-21-9	128		No	0	128	100.0	0.4	0.221	2	1.6	No	0.044	No	NA	NA	NA	2004-2005	Yes	Surface in WSA (GWS-SG07), subsurface in ESA (NLU62)	No	RL > LC in <10% of samples; elevated RLs due to interference from other contaminants
Aroclor 1248	12672-29-6	128		No	2	126	98.4	0.24	0.221	1	0.8	No	0.044	No	NA	NA	NA	2005	Yes	Surface in WSA (GWS-SG07)	No	RL > LC in <10% of samples; elevated RLs due to interference from other contaminants; detected concentrations < LC

Notes:

Yes = parameter retained as possible COPC

— = Not available

* From Table 3-3

If the RL > 3 times the PQL, then it is expected that the RL is elevated due to interference from other contaminants.

^ LC divided by the PQL. Values less than 1 indicate the degree to which the LC is less than the PQL.

Infrequently detected chemicals are those that were not detected at least 5% of the time.

Uplands COCs as defined in the Focused Feasibility Study (Parametrix 1998).

COC: Chemical of concern

COPC: Chemical of potential concern

DDT: Dichlorodiphenyltrichloroethane

Ecology: Washington State Department of Ecology

ESA: Eastern Study Area

GWSA: Gas Works Sediment Area

LC: Lowest criterion of all screening criteria used in this assessment (see Table 3-3)

Max: Maximum

MTCA: Washington State Model Toxics Control Act

NA: Not applicable

PCB: Polychlorinated biphenyl

PQL: Practical quantitation limit

RL: Reporting limit

SMS: Sediment Management Standards

WSA: Western Study Area

Table A-2 Evaluation of Chemicals Lacking Screening Criteria

Parameter	CAS Number	No. of Samples	MTCA Ecology SMS	Uplands COC	Proprotion of Data Older Than 1999	% Non-Detect	Further Details	Retain? (Y/N)	Rationale for Retention/Elimination
Metals									
Calcium	7440-70-2	24	No	No	95.8	0.0	Most samples from 1995; one from 2000	No	Not an Uplands COC; large proportion of older data
Magnesium	7439-95-4	24	No	No	95.8	0.0	Most samples from 1995; one from 2000	No	Not an Uplands COC; large proportion of older data
Potassium	9/7/7440	24	No	No	95.8	4.2	Most samples from 1995; one from 2000	No	Not an Uplands COC; large proportion of older data
Sodium	7440-23-5	23	No	No	100.0	0.0	All samples from 1995	No	Not an Uplands COC; large proportion of older data
Phenols									
2-Nitrophenol	88-75-5	125	No	No	16.8	100.0	Samples range from 1995-2005	No	Not an Uplands COC; never detected
4-Nitrophenol	100-02-7	103	No	No	1.0	99.0	Samples range from 1995-2005	No	Not an Uplands COC; never detected
Misc. Extractables									
Caffeine	58-08-2	2	No	No	0.0	100.0	Samples from 2000, 2001	No	Not an Uplands COC; limited (non-representative) sample size
B-Coprostanol	360-68-9	3	No	No	33.3	100.0	Samples range from 1995-2001	No	Not an Uplands COC; limited (non-representative) sample size
3-Nitroaniline	99-09-2	103	No	No	1.0	100.0	Samples range from 1995-2005	No	Not an Uplands COC; never detected
4-Chlorophenyl-phenylether	7005-72-3	104	No	No	1.0	100.0	Samples range from 1995-2005	No	Not an Uplands COC; never detected
Volatile Organics									
n-Butylbenzene	104-51-8	9	No	No	0.0	100.0	All from subsurface samples from 2002	No	Not an Uplands COC; never detected
sec-Butylbenzene	135-98-8	30	No	No	70.0	93.3	Most samples from 1995; remaining are subsurface samples from 2002	No	Not an Uplands COC; large proportion of older data
tert-Butylbenzene	98-06-6	9	No	No	0.0	100.0	All from subsurface samples from 2002	No	Not an Uplands COC; never detected
Bromoethane	74-96-4	9	No	No	11.1	100.0	All but one sample from subsurface samples from 2002	No	Not an Uplands COC; never detected
Bromochloromethane	74-97-5	9	No	No	0.0	100.0	All from subsurface samples from 2002	No	Not an Uplands COC; never detected
Methyl Iodide	74-88-4	9	No	No	0.0	100.0	All from subsurface samples from 2002	No	Not an Uplands COC; never detected
2,2-Dichloropropane	594-20-7	9	No	No	0.0	100.0	All from subsurface samples from 2002	No	Not an Uplands COC; never detected
1,1-Dichloropropene	563-58-6	9	No	No	0.0	100.0	All from subsurface samples from 2002	No	Not an Uplands COC; never detected
cis-1,3-Dichloropropene	10061-01-5	10	No	No	10.0	100.0	All but one sample from subsurface samples from 2002	No	Not an Uplands COC; never detected
trans-1,3-Dichloropropene	10061-02-6	10	No	No	10.0	100.0	All but one sample from subsurface samples from 2002	No	Not an Uplands COC; never detected
4-Isopropyltoluene	99-87-6	30	No	No	70.0	86.7	Samples range from 1995-2002	No	Not an Uplands COC; large proportion of older data
2-Chloroethylvinylether	110-75-8	10	No	No	10.0	100.0	All but one sample from subsurface samples from 2002	No	Not an Uplands COC; never detected
Pesticides/PCBs									
beta-Chlordane	5103-74-2	42	No	No	0.0	73.8	Surface and subsurface samples ranging from 2004-2005	No	Not an Uplands COC; rarely detected
Endrin Aldehyde	7421-93-4	3	No	No	33.3	100.0	Samples range from 1995-2001	No	Not an Uplands COC; limited (non-representative) sample size

Notes:

Uplands COCs as defined in the Focused Feasibility Study (Parametrix 1998).

COC: Chemical of concern

Ecology: Washington State Department of Ecology

MTCA: Washington State Model Toxics Control Act

PCB: Polychlorinated biphenyl

SMS: Sediment Management Standards

Appendix B

Fish Resources and Consumption in Lake Union

February 2012

Appendix B: Fish Resources and Consumption in Lake Union

Several types of fish resources are known to be present in Lake Union and, presumably, the Gas Works Sediment Area (GWSA) and potentially caught and consumed by humans. A review of all known literature available concerning possible fish resources in Lake Union has been performed and is summarized in this section. This review was carried out to assess information available on potential presence and abundance in Lake Union of fish resources including crayfish, shellfish, and several finfish. General information is presented regarding species characteristics and habitat.

The Lake Washington/Lake Union system hosts many native fish, including five salmonid species: Chinook salmon (*Oncorhynchus tshawytscha*), Coho salmon (*O. kisutch*), Sockeye/Kokanee salmon (*O. nerka*), coastal cutthroat (*O. clarki clarki*), and steelhead/rainbow trout (*O. mykiss*). Anadromous forms of some of these species are present; therefore, individuals are present in Lake Union both as adults during migrations to spawning grounds and as juveniles. Other fish native to the Lake Washington/Lake Union system include the northern pike minnow (*Ptychocheilus oregonensis*), peamouth (*Mylocheilus caurinus*), sculpins (*Cottus spp*.), and longfin smelt (*Spirinchus thaleichthys*) (Weitkamp et al. 2000).

Other fish present in Lake Union consist of common warm water fish species. The Washington Department of Fish and Wildlife (WDFW) lists large and smallmouth bass, yellow perch, and brown bullhead as present in Lake Union. Additionally, the National Oceanic and Atmospheric Administration (NOAA) has generated a long list of fish species found in Lake Union and Portage Bay (NOAA 1994). Approximately 24 non-native fish species have been introduced into the Lake Washington/Lake Union system, but only some of these species (such as bass) are a viable game fish or fish resource in the system.

Fish presence, life history, and importance as a game fish, when known, are discussed below. Importantly, the anadromous salmonid species are not discussed further in this section, but risk to the health of juvenile salmon is further evaluated in Section 4.0 of this Supplement to the Cleanup Standards Document. Resident fish and crayfish are the focus of the human health risk evaluations because they do not migrate and could be exposed to GWSA contamination year-round. This focus on resident fish is consistent with other regional human health risk evaluations that take into account fish consumption. In the risk assessment for the Lower Duwamish Waterway (LDW) (Windward 2007), the risk to human health posed by salmon was not evaluated as “their exposure to chemicals in LDW sediment is not anticipated to significantly influence the concentrations in their tissues, primarily because of the very small portion of their lives spent in the LDW.”

The potential exposure of the adult Tribal population to contaminated sediments while netfishing is also included in this Supplement to the Cleanup Standards Document. The Muckleshoot Indian Tribe (MIT) conducts commercial netfishing within the Puget Sound Region. Therefore, it is assumed that Muckleshoot Indians will continue to netfish within Lake Union and adjacent to the GWSA. The netfishing scenario assumes that people who engage in commercial netfishing could be exposed by both incidental sediment ingestion and dermal contact to surface sediments (from 0-10 cm) adhering to their nets, as gillnet lead lines used by the MIT for netfishing typically come in contact with sediments (Windward 2007).

B.1 Crayfish

B.1.1 Characteristics and Habitat

The indigenous crayfish in Lake Union is *Pacifastacus leniusculus*, known as the Pacific crayfish or signal crayfish. This freshwater crayfish is found in rivers and lakes west of the Rockies from British

Columbia to central California. The size at maturity is generally 6–9 cm in total length which occurs at age 2–3 years. They have a lifespan varying from 5 to 16 years (ISSG 2005). *P. leniusculus* is an introduced species in Europe and Japan, where it has shown a rapid spread. Studies in rivers in England have shown that individuals may travel up to 300 meters, suggesting that its home range is relatively large (Bubb et al. 2006).

A limiting factor in their movement is availability of appropriate habitat. A study in Lake Whatcom, Washington found that crayfish prefer a habitat of boulder/bedrock substrate, avoiding silt and sand substrates (Mueller and Rothaus 2001). Another study found that crayfish in streams are typically associated with vegetation patches or shallow rocky pools (Missouri Department of Conservation 2009). This substrate preference is most likely due to predator avoidance as they are a common prey item for fish such as smallmouth bass, an inhabitant of Lake Union. Generally, crayfish live at depths from 0.1 to 0.7 meters, but partition between shallower and deeper depths based on a variety of factors, including predator avoidance, food availability, body size, and substrate (Englund and Krupa 2000).

B.1.2 Presence and Abundance

Various crayfish tissue studies have been carried out, indicating the presence of crayfish in Lake Union. These studies have been previously discussed (refer to Section 2.4).

In the study *Analysis of Chemical Contaminants in Lake Union and Lake Washington Crayfish* (Frost and McCallum 1984), a total of 126 crayfish were captured near Gas Works Park.

Crayfish were collected for the University Regulator Pre- and Post-Separation Studies (King County 2009). Crayfish were collected from the canal between Lake Union and Portage Bay, near Ivar's restaurant. In the Pre-Separation Study, approximately 120 crayfish were collected over 5 days. Later, in the Post-Separation Study, 45 crayfish were collected from the same location.

As recently as 2006, there was a small active commercial and recreational fishery for crayfish in Lake Washington, but no specific data suggesting a crayfish fishery in Lake Union (Seattle Times October 10, 2006; Parametrix 2003). For recreational fishing, a permit is not required for crayfish and lakes are open year-round. WDFW does collect voluntary catch information on crayfish.

B.2 Shellfish

B.2.1 Presence and Abundance

The Lake Union benthic infaunal community was assessed in the following studies:

- The Metro database contains 1986 benthic community data from the top 5 cm of sediment (Hansen et al. 1993). They identified three species of mollusks in the Pelecypoda (bivalves) class including: *Sphaerium spp.*, *Pisidium spp.*, and *Gyraulus spp.* The *Gyraulus spp*. is a freshwater snail; the two remaining Pelecypoda are in the group commonly known as fingernail or pea clams due to their small size, generally less than 1 inch in length. The most abundant bivalve found in the 1986 data was the *Pisidium spp*.

- As part of the University Regulator CSO Control Project, a benthic infauna study was done on Lake Union in 1990 and 1991 (Houck 1992). Benthic samples were collected from six locations in and around north Lake Union: three near the Freeway Bridge location, one in Lake Washington, one off Gas Works Park, and one undetermined location. Sampling followed the Puget Sound Estuary Program Protocol (Tetra Tech 1987) and organisms were identified to the lowest practicable taxon. Bivalve mollusks identified included *Corbicula manilensis* (a freshwater Asian clam introduced into the

United States) and the two fingernail clams, *Sphaerium spp*. and *Pisidium spp*. The most abundant bivalve found in the 1990 and 1991 samples was *Sphaerium spp*.

Small bivalves, including *Sphaerium* and *Pisidium*, can be a major food source for aquatic predators such as fish and crayfish. Searches have turned up no studies or records showing any history of human use of these tiny clams.

None of the native freshwater mussels were found in any of the studies done in Lake Union. There are only two species of native freshwater mussels found in King County, the western pearlshell (*Margaritifera falcata*) and the Oregon floater (*Anodonta oregonensis*). Of these two, the western pearlshell is most commonly found. Historically, Native Americans harvested the large populations supported by Bear Creek (Wong 1993), although these populations have gone into decline in recent years (Thomas 2008). Populations of both the western pearlshell and the Oregon floater require streams or rivers with flowing water and sand/gravel substrates (Fevold and Vanderhoof 2002) and are therefore unlikely to be located in a lake environment.

According to information currently available, it does not appear that shellfish are an important food resource in Lake Union. Therefore, the use of shellfish as a diet fraction was not proposed for this risk evaluation.

B.3 Finfish

Lake Union finfish presence and abundance has been noted in several studies:

- An Ecology histopathology study (Landolt and Busch 1991) indicated that the greatest amount of fish caught during the two collection periods were yellow perch, followed by threespine stickleback, pumpkinseed, and sculpin. Threespine stickleback is a small, anadromous fish and is unlikely to form a large part of a fisher's diet. Pumpkinseed are closely related to bluegill and known to be a good food fish. Sculpin are small bottom-feeders and generally not considered suitable to eat, in part due to their small size.
- As part of the University Regulator CSO Control Project, contaminants were analyzed in several fish species collected from Lake Union over a period of 15 years (1984 1999), including perch, sculpin, bullhead, sucker, largemouth bass, catfish, pikeminnow, and crappie (unpublished data, King County 2009). The study indicated that the most abundant species collected were sculpin (56) and perch (29), with 6 or less fish captured for the remaining species indicated. Bullhead and sucker are not further discussed in this assessment as only 1 bullhead and 2 suckers were collected, indicating that they are not likely an important fish resource in Lake Union.
- Kerwin (2001) summarized the status of fish in the Lake Union/Lake Washington system. Yellow perch and pumpkinseed were noted by Kerwin (2001) to be "abundant," while smallmouth bass, largemouth bass, and bluegill were "common" in the Lake Union/Lake Washington system.
- Parametrix (2003) investigated, among other things, the types of fish caught and consumed in the lakes. Parametrix surveyed a total of 212 fishers regarding their fish caught and consumption patterns. Fishers were not surveyed in Lake Union but it can be assumed that fishers for Lakes Washington and Sammamish would exhibit similar fishing patterns as in Lake Union. The survey indicates that perch is the most caught fish in the lakes, followed by sockeye salmon, rainbow and cutthroat trout, and bluegill. The fishers indicated that all of the fish caught was consumed with the exception of perch that was consumed at a rate of 83 percent. Of these, only perch and bluegill are non-migratory and expected to reside in freshwater lakes year-round.

- The Washington State Department of Health (DOH 2004) examined contaminants in five fish species (refer to Section 2.4). It is noted that the greatest number of fish caught for the survey was yellow perch, at 29. Both northern pikeminnow and cutthroat trout had a sample size of 20; sample size was 10 for sockeye salmon, and 3 for smallmouth bass. Yellow perch, northern pikeminnow, and smallmouth bass are expected to reside in the lakes year-round.
- A study carried out in Lake Union by the U.S. Fish and Wildlife Service (USFWS) in 2003–2005 (Tabor 2006) indicated the presence of a large quantity of smallmouth bass. Tabor was able to tag and track 18 smallmouth bass in total between 2004 and 2005, including 6 from the GWSA. Smallmouth and largemouth are common in Lake Union, but only smallmouth bass were tagged in this study.
- A review of aquatic habitat in North Lake Union by Geomatrix suggests the northern pikeminnow is a non-migratory species endemic to the Lake Union/Lake Washington system (Geomatrix 2007). Geomatrix notes that there is anecdotal evidence suggesting pikeminnow are more numerous now than they were historically, "increasing 11–38 percent in population size between 1972 and 1997."

Based on apparent abundance and the availability of tissue data, the most appropriate fish to focus on are yellow perch, sculpin, largemouth bass, catfish, and crappie. Various studies have indicated the presence of these species in Lake Union, and tissue data is available from a sample size greater than three fish. Characteristics and habitat of these fish are described further below.

B.3.1 Characteristics and Habitat

B.3.1.1 Yellow Perch

Yellow perch (*Perca flavescens*) are non-migratory, with their home range generally spanning 0.5 to 2.2 hectare in size (Fish and Savitz 1983). Yellow perch feed on immature insects, plankton, larger invertebrates, small fish and fish eggs, and are preyed on by fish and birds (Froese and Pauly 2009). This indicates an intermediate trophic level in the food web. Yellow perch have been reported to live up to the age of 13 years, but their general life span is 9 to 12 years (Froese and Pauly 2009). Generally yellow perch prefer lake habitat to rivers and streams.

B.3.1.2 Largemouth Bass

The Tabor study (2006) indicated that smallmouth bass in Lake Union appeared to be associated with nearshore habitat, including overwater structures and riprap, which is also likely to be habitat for largemouth bass (*Micropterus salmoides*). Largemouth bass typically have a home range between 0.18 and 2.07 hectares (Fish and Savitz 1983).

Largemouth bass are carnivorous species and occupy a high trophic level in the food web, with their diet primarily consisting of crayfish, amphibians, insects, and smaller fish, including sunfish such as pumpkinseed and bluegill, and juvenile salmon (Geomatrix 2007). Largemouth bass have been reported to live up to 23 years (Froese and Pauly 2009).

B.3.1.3 Crappie

Crappie (*Pomoxis annulari, Pomoxis nigromaculatus*) has been shown to have a reasonably small home range. Crappie reside within 0.5 to 1.25 hectares (Fish and Savitz 1983). Catch and release studies suggest they have a home range, and if released in a different area of the lake, will return to their original point of capture (Downs et al. 2002). Sunfish including crappie generally have a lifespan of 4 to 6 years in the wild (Froese and Pauly 2009). Crappie are carnivorous, eating a variety of insects, small mollusks and crustaceans, and some smaller fish. They are known to be a fine food fish and are popular with fishermen.

B.3.1.4 Catfish

Several species of catfish may occur in the Lake Washington system, including Channel (*Ictalurus punctatus*), Flathead (*Pylodictis olivaris*), and Blue catfish (*Ictalurus furcatus*). Catfish are a benthic-feeding freshwater fish and prefer live prey. They are carnivorous and feed primarily on other fish, insects, annelid worms, and crustaceans. They range in size from as small as 5 cm to over several meters in length, depending on their habitat. Catfish prefer clear, slow-moving water, such as pools with submerged logs and rocks. Catfish tend to have a range within 5 miles from their general resting area. The lifespan for catfish is expected to be around 11 to 12 years (Wikipedia 2009).

B.3.1.5 Sculpin

Several species of sculpin occur in the Lake Washington system, including prickly sculpin (*Cottus asper*) and slimy sculpin (*Cottus cognatus*), among others. Sculpin are bottom-dwelling, inactive fish. The sculpin is a small fish averaging 3 inches in length. In part due to their size, sculpin are not generally considered gamefish and are of little value to humans. They are found in freshwater and sometimes brackish water in areas with rocky or gravel type bottoms. Sculpin feed primarily on insects, but also eat crustaceans, fish eggs, and small fish.

B.4 Summary

Potential risks to human health will be evaluated for those fish resources most likely to be caught and consumed by humans from the GWSA, and those resources for which there is available tissue data. Consumption of crayfish will be evaluated as crayfish are both present in the GWSA and known to be consumed by humans. Shellfish will not be evaluated as those present in Lake Union are not known to be consumed by humans. Finfish will be evaluated based on the available data. Data are available for perch, sculpin, largemouth bass, crappie, and catfish.

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Appendix C

Chronic Daily Intake Results Tables

Table C-1 Beach Play/Wading Chronic Daily Intake Results—Carcinogenic

Chemical of Potential Concern	CT Scenario			RME Scenario		
	Dermal CDI (mg/kg-day)	Oral CDI (mg/kg-day)	Total CDI (mg/kg-day)	Dermal CDI (mg/kg-day)	Oral CDI (mg/kg-day)	Total CDI (mg/kg-day)
Adult Cancer Risk Calculations						
Metals						
Arsenic	1.4E-09	4.0E-08	4.2E-08	1.1E-06	9.5E-06	1.1E-05
Chromium VI	—	1.1E-08	1.1E-08	—	1.2E-06	1.2E-06
HPAH						
Benzo[a]anthracene	5.4E-09	3.6E-08	4.2E-08	4.2E-06	8.2E-06	1.2E-05
Benzo[a]pyrene	7.2E-09	4.8E-08	5.5E-08	5.4E-06	1.0E-05	1.6E-05
Benzo[b]fluoranthene	5.7E-09	3.8E-08	4.4E-08	4.1E-06	7.9E-06	1.2E-05
Benzo[k]fluoranthene	5.1E-09	3.4E-08	3.9E-08	3.3E-06	6.4E-06	9.7E-06
Chrysene	6.0E-09	4.0E-08	4.6E-08	4.8E-06	9.2E-06	1.4E-05
Dibenzo[a,h]anthracene	9.8E-10	6.6E-09	7.6E-09	9.9E-07	1.9E-06	2.9E-06
Indeno[1,2,3-cd]pyrene	5.4E-09	3.6E-08	4.2E-08	4.2E-06	8.2E-06	1.2E-05
Total HPAH	—	—	—	—	—	—
Phthalates						
Bis(2-Ethylhexyl)phthalate	1.6E-10	1.4E-09	1.5E-09	8.7E-08	2.2E-07	3.0E-07
Butylbenzylphthalate	3.2E-11	1.4E-09	1.4E-09	1.0E-08	2.6E-08	3.6E-08
Phenols						
Pentachlorophenol	2.7E-10	9.5E-10	1.2E-09	1.2E-07	1.2E-07	2.4E-07
Misc. Extractables						
Carbazole	3.0E-10	2.6E-09	2.9E-09	3.0E-07	7.5E-07	1.0E-06
Volatile Organics						
Benzene	—	5.4E-12	5.4E-12	—	3.7E-10	3.7E-10
Ethylbenzene	—	5.4E-12	5.4E-12	—	2.7E-10	2.7E-10
Pesticides/PCBs						
Chlordane	3.6E-13	7.9E-12	8.2E-12	2.2E-10	1.4E-09	1.6E-09
DDD	5.6E-13	7.9E-12	8.4E-12	3.3E-10	2.7E-09	3.0E-09
DDT	6.6E-13	1.7E-11	1.7E-11	3.3E-10	2.7E-09	3.0E-09
PCB Aroclor 1254[1]	1.6E-11	1.9E-11	3.5E-11	3.6E-09	6.4E-09	1.0E-08
PCB Aroclor 1260[1]	6.7E-12	1.0E-10	1.1E-10	1.6E-09	2.9E-09	4.4E-09
Total PCBs	2.1E-11	4.2E-11	6.3E-11	6.5E-09	1.2E-08	1.8E-08
Child Cancer Risk Calculations						
Metals						
Arsenic	5.3E-09	1.6E-07	1.6E-07	1.2E-06	1.4E-05	1.5E-05
Chromium VI	—	1.6E-07	1.6E-07	—	1.8E-06	1.8E-06
HPAH						
Benzo[a]anthracene	2.1E-08	1.4E-07	1.6E-07	4.4E-06	1.2E-05	1.7E-05
Benzo[a]pyrene	2.7E-08	1.4E-07	1.7E-07	5.7E-06	1.6E-05	2.1E-05
Benzo[b]fluoranthene	2.2E-08	1.9E-07	2.1E-07	4.3E-06	1.2E-05	1.6E-05
Benzo[k]fluoranthene	1.9E-08	1.5E-07	1.7E-07	3.5E-06	9.6E-06	1.3E-05
Chrysene	2.3E-08	1.3E-07	1.6E-07	5.0E-06	1.4E-05	1.9E-05
Dibenzo[a,h]anthracene	3.8E-09	1.6E-07	1.6E-07	1.0E-06	2.8E-06	3.9E-06
Indeno[1,2,3-cd]pyrene	2.1E-08	2.6E-08	4.6E-08	4.4E-06	1.2E-05	1.7E-05
Total HPAH	—	—	—	—	—	—
Phthalates						
Bis(2-Ethylhexyl)phthalate	6.0E-10	5.3E-09	5.9E-09	9.1E-08	3.3E-07	4.2E-07
Butylbenzylphthalate	1.2E-10	5.3E-09	5.4E-09	1.1E-08	3.9E-08	4.9E-08
Phenols						
Pentachlorophenol	1.0E-09	3.7E-09	4.7E-09	1.3E-07	1.8E-07	3.1E-07
Misc. Extractables						
Carbazole	1.1E-09	1.0E-08	1.1E-08	3.1E-07	1.1E-06	1.4E-06
Volatile Organics						
Benzene	—	2.1E-11	2.1E-11	—	5.5E-10	5.5E-10
Ethylbenzene	—	2.1E-11	2.1E-11	—	4.1E-10	4.1E-10
Pesticides/PCBs						
Chlordane	1.4E-12	3.1E-11	3.2E-11	2.3E-10	2.0E-09	2.3E-09
DDD	2.2E-12	3.1E-11	3.3E-11	3.4E-10	4.1E-09	4.4E-09
DDT	2.5E-12	6.4E-11	6.7E-11	3.4E-10	4.1E-09	4.4E-09
PCB Aroclor 1254	6.1E-11	7.5E-11	1.4E-10	3.7E-09	9.6E-09	1.3E-08
PCB Aroclor 1260	2.6E-11	3.9E-10	4.2E-10	1.7E-09	4.3E-09	5.9E-09
Total PCBs	8.0E-11	1.6E-10	2.4E-10	6.9E-09	1.8E-08	2.4E-08

Notes:

— Dermal absorption factor was not available or chemical was not analyzed; calculations could not be completed.

CDI: Chronic Daily Intake

CT: Central Tendency

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

RME: Reasonable Maximum Exposure

Table C-2 Beach Play/Wading Chronic Daily Intake Results—Non-Carcinogenic

Chemical of Potential Concern	CT Scenario			RME Scenario		
	Dermal CDI (mg/kg-day)	Oral CDI (mg/kg-day)	Total CDI (mg/kg-day)	Dermal CDI (mg/kg-day)	Oral CDI (mg/kg-day)	Total CDI (mg/kg-day)
Adult Non-cancer Risk Calculations						
Conventionals/Misc.						
Total Cyanide	—	1.6E-07	1.6E-07	—	5.3E-05	5.3E-05
Metals						
Antimony	—	3.2E-08	3.2E-08	—	6.3E-06	6.3E-06
Arsenic	3.2E-09	9.4E-08	9.7E-08	2.7E-06	2.2E-05	2.5E-05
Cadmium	4.6E-12	4.0E-09	4.0E-09	3.8E-09	9.5E-07	9.5E-07
Chromium III	—	1.5E-07	1.5E-07	—	1.7E-05	1.7E-05
Chromium VI	—	2.5E-08	2.5E-08	—	2.9E-06	2.9E-06
Cobalt	—	3.5E-08	3.5E-08	—	2.3E-06	2.3E-06
Copper	—	6.0E-07	6.0E-07	—	1.3E-04	1.3E-04
Lead and Compounds[1]	—	4.2E-07	4.2E-07	—	7.6E-05	7.6E-05
Mercury	—	2.0E-09	2.0E-09	—	2.5E-07	2.5E-07
Nickel Soluble Salts	—	7.6E-07	7.6E-07	—	8.5E-05	8.5E-05
Selenium	—	1.2E-09	1.2E-09	—	7.9E-08	7.9E-08
Silver	—	3.0E-09	3.0E-09	—	6.3E-07	6.3E-07
Vanadium	—	6.2E-07	6.2E-07	—	4.2E-05	4.2E-05
Zinc	—	1.3E-06	1.3E-06	—	2.9E-04	2.9E-04
Butyltins						
Tributyltin	5.9E-11	5.2E-10	5.8E-10	3.2E-08	7.9E-08	1.1E-07
LPAH						
Acenaphthene	4.9E-09	3.3E-08	3.8E-08	6.6E-06	1.3E-05	1.9E-05
Acenaphthylene	3.6E-09	2.4E-08	2.8E-08	2.6E-06	5.1E-06	7.7E-06
Anthracene	6.5E-09	4.4E-08	5.0E-08	7.4E-06	1.4E-05	2.2E-05
Fluorene	3.8E-09	2.6E-08	3.0E-08	3.3E-06	6.3E-06	9.6E-06
2-Methylnaphthalene	4.4E-09	3.0E-08	3.4E-08	5.3E-06	1.0E-05	1.5E-05
Naphthalene	1.5E-08	9.9E-08	1.1E-07	1.6E-05	3.1E-05	4.7E-05
Phenanthrene	2.2E-08	1.5E-07	1.7E-07	2.0E-05	3.8E-05	5.8E-05
Total LPAH	—	—	—	—	—	—
HPAH						
Benzo(g,h,i)perylene	1.2E-08	8.0E-08	9.2E-08	9.4E-06	1.8E-05	2.7E-05
Fluoranthene	2.8E-08	1.9E-07	2.2E-07	2.3E-05	4.4E-05	6.7E-05
Pyrene	3.4E-08	2.3E-07	2.6E-07	2.5E-05	4.8E-05	7.2E-05
Retene	5.9E-10	5.2E-09	5.8E-09	2.3E-07	5.7E-07	8.0E-07
Total HPAH	—	—	—	—	—	—
Total PAH	—	—	—	—	—	—
Phthalates						
Bis(2-Ethylhexyl)phthalate	3.6E-10	3.2E-09	3.6E-09	2.0E-07	5.1E-07	7.1E-07
Butylbenzylphthalate	7.5E-11	6.6E-10	7.3E-10	2.4E-08	6.0E-08	8.4E-08
Di-n-butylpthalate	3.3E-10	2.9E-09	3.2E-09	3.4E-07	8.6E-07	1.2E-06
Diethylphthalate	7.5E-11	6.6E-10	7.3E-10	2.4E-08	6.0E-08	8.4E-08
Dimethylphthalate	7.5E-11	6.6E-10	7.3E-10	2.4E-08	6.0E-08	8.4E-08
Di-n-octylphthalate	7.5E-11	6.6E-10	7.3E-10	2.4E-08	6.0E-08	8.4E-08
Phenols						
2,4-Dimethylphenol	5.0E-11	4.4E-10	4.9E-10	2.4E-08	6.0E-08	8.4E-08
4-Methylphenol	6.4E-11	5.6E-10	6.3E-10	2.0E-08	5.1E-08	7.1E-08
Pentachlorophenol	6.3E-10	2.2E-09	2.8E-09	2.8E-07	2.9E-07	5.7E-07
Phenol	8.6E-11	7.5E-10	8.4E-10	8.2E-08	2.1E-07	2.9E-07
Misc. Extractables						
Benzoic Acid	8.6E-10	7.5E-09	8.4E-09	4.3E-07	1.1E-06	1.5E-06
Dibenzofuran	6.4E-10	5.6E-09	6.3E-09	5.9E-07	1.5E-06	2.1E-06
Volatile Organics						
Benzene	—	1.4E-11	1.4E-11	—	9.5E-10	9.5E-10
Ethylbenzene	—	9.4E-12	9.4E-12	—	6.3E-10	6.3E-10
Toluene	—	7.5E-11	7.5E-11	—	5.1E-09	5.1E-09
Total Xylenes	—	1.3E-11	1.3E-11	—	8.6E-10	8.6E-10
1,2,4-Trimethylbenzene	—	8.0E-08	8.0E-08	—	5.4E-06	5.4E-06
Pesticides/PCBs						
Chlordane	8.4E-13	1.8E-11	1.9E-11	5.1E-10	3.2E-09	3.7E-09
DDT	1.5E-12	4.5E-11	4.7E-11	7.6E-10	6.3E-09	7.1E-09
PCB Aroclor 1254	3.7E-11	2.4E-10	2.7E-10	8.9E-09	1.6E-08	2.5E-08
Child Non-cancer Risk Calculations						
Conventionals/Misc.						
Total Cyanide	—	3.1E-06	3.1E-06	—	4.0E-04	4.0E-04

Table C-2 Beach Play/Wading Chronic Daily Intake Results—Non-Carcinogenic

Chemical of Potential Concern	CT Scenario			RME Scenario		
	Dermal CDI (mg/kg-day)	Oral CDI (mg/kg-day)	Total CDI (mg/kg-day)	Dermal CDI (mg/kg-day)	Oral CDI (mg/kg-day)	Total CDI (mg/kg-day)
Metals						
Antimony	—	6.2E-07	6.2E-07	—	4.7E-05	4.7E-05
Arsenic	6.1E-08	1.8E-06	1.9E-06	1.4E-05	1.7E-04	1.8E-04
Cadmium	8.8E-11	7.9E-08	7.9E-08	2.0E-08	7.1E-06	7.1E-06
Chromium III	—	3.0E-06	3.0E-06	—	1.3E-04	1.3E-04
Chromium VI	—	4.9E-07	4.9E-07	—	2.1E-05	2.1E-05
Cobalt	—	6.8E-07	6.8E-07	—	1.8E-05	1.8E-05
Copper	—	1.2E-05	1.2E-05	—	9.7E-04	9.7E-04
Lead and Compounds[1]	—	8.1E-06	8.1E-06	—	5.7E-04	5.7E-04
Mercury	—	3.9E-08	3.9E-08	—	1.9E-06	1.9E-06
Nickel Soluble Salts	—	1.5E-05	1.5E-05	—	6.4E-04	6.4E-04
Selenium	—	2.3E-08	2.3E-08	—	5.9E-07	5.9E-07
Silver	—	5.8E-08	5.8E-08	—	4.7E-06	4.7E-06
Vanadium	—	1.2E-05	1.2E-05	—	3.1E-04	3.1E-04
Zinc	—	2.6E-05	2.6E-05	—	2.2E-03	2.2E-03
Butyltins						
Tributyltin	1.1E-09	1.0E-08	1.1E-08	1.7E-07	5.9E-07	7.6E-07
LPAH						
Acenaphthene	9.4E-08	6.5E-07	7.4E-07	3.5E-05	9.5E-05	1.3E-04
Acenaphthylene	6.9E-08	4.8E-07	5.4E-07	1.4E-05	3.8E-05	5.2E-05
Anthracene	1.2E-07	8.5E-07	9.7E-07	3.9E-05	1.1E-04	1.5E-04
Fluorene	7.3E-08	5.0E-07	5.8E-07	1.7E-05	4.7E-05	6.5E-05
2-Methylnaphthalene	8.4E-08	5.8E-07	6.6E-07	2.8E-05	7.6E-05	1.0E-04
Naphthalene	2.8E-07	1.9E-06	2.2E-06	8.5E-05	2.3E-04	3.2E-04
Phenanthrene	4.1E-07	2.8E-06	3.2E-06	1.0E-04	2.8E-04	3.9E-04
Total LPAH	—	—	—	—	—	—
HPAH						
Benzo(g,h,i)perylene	2.3E-07	1.6E-06	1.8E-06	4.9E-05	1.4E-04	1.8E-04
Fluoranthene	5.3E-07	3.7E-06	4.2E-06	1.2E-04	3.3E-04	4.5E-04
Pyrene	6.5E-07	4.5E-06	5.1E-06	1.3E-04	3.6E-04	4.9E-04
Retene	1.1E-08	1.0E-07	1.1E-07	1.2E-06	4.3E-06	5.5E-06
Total HPAH	—	—	—	—	—	—
Total PAH	—	—	—	—	—	—
Phthalates						
Bis(2-Ethylhexyl)phthalate	7.0E-09	6.2E-08	6.9E-08	1.1E-06	3.8E-06	4.9E-06
Butylbenzylphthalate	1.4E-09	1.3E-08	1.4E-08	1.3E-07	4.5E-07	5.8E-07
Di-n-butylpthalate	6.2E-09	5.6E-08	6.2E-08	1.8E-06	1.1E-05	1.3E-05
Diethylphthalate	1.4E-09	1.3E-08	1.4E-08	1.3E-07	4.5E-07	5.8E-07
Dimethylphthalate	1.4E-09	1.3E-08	1.4E-08	1.3E-07	4.5E-07	5.8E-07
Di-n-octylphthalate	1.4E-09	1.3E-08	1.4E-08	1.3E-07	4.5E-07	5.8E-07
Phenols						
2,4-Dimethylphenol	9.6E-10	8.6E-09	9.5E-09	1.3E-07	4.5E-07	5.8E-07
4-Methylphenol	1.2E-09	1.1E-08	1.2E-08	1.1E-07	3.8E-07	4.9E-07
Pentachlorophenol	1.2E-08	4.3E-08	5.5E-08	1.5E-06	2.1E-06	3.6E-06
Phenol	1.6E-09	1.5E-08	1.6E-08	4.3E-07	1.5E-06	2.0E-06
Misc. Extractables						
Benzoic Acid	1.6E-08	1.5E-07	1.6E-07	2.3E-06	8.1E-06	1.0E-05
Dibenzofuran	1.2E-08	1.1E-07	1.2E-07	3.1E-06	1.1E-05	1.4E-05
Volatile Organics						
Benzene	—	2.7E-10	2.7E-10	—	7.1E-09	7.1E-09
Ethylbenzene	—	1.8E-10	1.8E-10	—	4.7E-09	4.7E-09
Toluene	—	1.5E-09	1.5E-09	—	3.8E-08	3.8E-08
Total Xylenes	—	2.5E-10	2.5E-10	—	6.4E-09	6.4E-09
1,2,4-Trimethylbenzene	—	1.6E-06	1.6E-06	—	4.0E-05	4.0E-05
Pesticides/PCBs						
Chlordane	1.6E-11	3.6E-10	3.7E-10	2.7E-09	2.4E-08	2.6E-08
DDT	2.9E-11	8.8E-10	9.1E-10	4.0E-09	4.7E-08	5.1E-08
PCB Aroclor 1254	7.2E-10	4.6E-09	5.3E-09	4.7E-08	1.2E-07	1.7E-07

Notes:

— Dermal absorption factor was not available or chemical was not analyzed; calculations could not be completed.

CDI: Chronic Daily Intake

CT: Central Tendency

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

RME: Reasonable Maximum Exposure

Table C-3 Fish Ingestion Chronic Daily Intake Results—Carcinogenic

Chemical of Potential Concern	CT Scenario Oral CDI, Recreational			CT Scenario Oral CDI, Tribal			RME Scenario Oral CDI, Recreational			RME Scenario Oral CDI, Tribal		
	Crayfish (mg/kg-day)	Finfish (mg/kg-day)	Total CDI (mg/kg-day)	Crayfish (mg/kg-day)	Finfish (mg/kg-day)	Total CDI (mg/kg-day)	Crayfish (mg/kg-day)	Finfish (mg/kg-day)	Total CDI (mg/kg-day)	Crayfish (mg/kg-day)	Finfish (mg/kg-day)	Total CDI (mg/kg-day)
Adult Cancer Risk Calculations												
Metals												
Arsenic	5.2E-07	1.4E-07	6.7E-07	1.3E-05	7.2E-07	1.4E-05	4.4E-05	8.5E-06	5.2E-05	5.7E-04	2.1E-05	5.9E-04
Chromium VI	1.1E-08	2.6E-08	3.7E-08	2.6E-07	1.3E-07	3.9E-07	1.0E-06	3.7E-06	4.7E-06	1.3E-05	9.2E-06	2.2E-05
HPAH												
Benzo[a]anthracene	1.3E-08	5.9E-09	1.9E-08	3.3E-07	2.9E-08	3.6E-07	1.5E-06	6.2E-07	2.1E-06	1.9E-05	1.5E-06	2.1E-05
Benzo[a]pyrene	1.6E-08	1.1E-08	2.6E-08	3.9E-07	5.4E-08	4.4E-07	1.3E-06	1.1E-06	2.4E-06	1.7E-05	2.7E-06	2.0E-05
Benzo[b]fluoranthene	1.4E-08	1.7E-08	3.1E-08	3.6E-07	8.5E-08	4.5E-07	8.5E-07	1.7E-06	2.5E-06	1.1E-05	4.2E-06	1.5E-05
Benzo[k]fluoranthene	2.0E-08	1.7E-08	3.7E-08	4.9E-07	8.5E-08	5.8E-07	1.2E-06	1.7E-06	2.9E-06	1.5E-05	4.2E-06	1.9E-05
Chrysene	2.0E-08	5.9E-09	2.5E-08	4.9E-07	2.9E-08	5.2E-07	2.5E-06	6.2E-07	3.2E-06	3.3E-05	1.5E-06	3.5E-05
Dibenzo[a,h]anthracene	2.0E-08	1.7E-08	3.7E-08	4.9E-07	8.5E-08	5.8E-07	1.7E-06	1.7E-06	3.4E-06	2.2E-05	4.2E-06	2.6E-05
Indeno[1,2,3-cd]pyrene	1.2E-08	1.1E-08	2.3E-08	3.1E-07	5.4E-08	3.6E-07	1.1E-06	1.1E-06	2.2E-06	1.4E-05	2.7E-06	1.7E-05
Total HPAH	—	—	—	—	—	—	—	—	—	—	—	—
Phthalates												
Bis(2-Ethylhexyl)phthalate	1.7E-08	5.9E-09	2.3E-08	4.3E-07	2.9E-08	4.6E-07	1.7E-06	6.2E-07	2.3E-06	2.2E-05	1.5E-06	2.4E-05
Butylbenzylphthalate	7.2E-09	5.9E-09	1.3E-08	1.8E-07	2.9E-08	2.1E-07	6.2E-07	6.2E-07	1.2E-06	8.0E-06	1.5E-06	9.5E-06
Phenols												
Pentachlorophenol	1.2E-08	1.1E-08	2.3E-08	3.1E-07	5.4E-08	3.6E-07	1.1E-06	1.1E-06	2.2E-06	1.4E-05	2.7E-06	1.7E-05
Misc. Extractables												
Carbazole	1.2E-08	1.1E-08	2.3E-08	3.1E-07	5.4E-08	3.6E-07	1.1E-06	1.1E-06	2.2E-06	1.4E-05	2.7E-06	1.7E-05
Volatile Organics												
Benzene	—	—	—	—	—	—	—	—	—	—	—	—
Ethylbenzene	—	—	—	—	—	—	—	—	—	—	—	—
Pesticides/PCBs												
Chlordane	3.0E-09	4.3E-09	7.3E-09	7.5E-08	2.2E-08	9.7E-08	3.1E-07	3.1E-07	6.2E-07	4.0E-06	7.6E-07	4.8E-06
DDD	4.6E-10	6.5E-10	1.1E-09	1.1E-08	3.3E-09	1.4E-08	3.9E-08	3.9E-08	7.7E-08	5.0E-07	9.5E-08	6.0E-07
DDT	4.6E-10	6.5E-10	1.1E-09	1.1E-08	3.3E-09	1.4E-08	3.9E-08	3.9E-08	7.7E-08	5.0E-07	9.5E-08	6.0E-07
PCB Aroclor 1254	5.2E-08	9.3E-09	6.2E-08	1.3E-06	4.6E-08	1.3E-06	8.5E-06	6.9E-07	9.2E-06	1.1E-04	1.7E-06	1.1E-04
PCB Aroclor 1260	5.5E-08	5.8E-09	6.1E-08	1.4E-06	2.9E-08	1.4E-06	9.1E-06	5.4E-07	9.6E-06	1.2E-04	1.3E-06	1.2E-04
Total PCBs	9.2E-08	9.3E-09	1.0E-07	2.3E-06	4.6E-08	2.3E-06	2.0E-05	6.9E-07	2.1E-05	2.6E-04	1.7E-06	2.6E-04
Child Cancer Risk Calculations												
Metals												
Arsenic	3.3E-07	9.0E-08	4.2E-07	5.7E-06	3.1E-07	6.0E-06	1.6E-05	3.2E-06	2.0E-05	1.1E-04	3.9E-06	1.1E-04
Chromium VI	6.5E-09	1.6E-08	2.3E-08	1.1E-07	5.7E-08	1.7E-07	3.7E-07	1.4E-06	1.8E-06	2.4E-06	1.7E-06	4.1E-06
HPAH												
Benzo[a]anthracene	8.1E-09	3.7E-09	1.2E-08	1.4E-07	1.3E-08	1.5E-07	5.5E-07	2.3E-07	7.8E-07	3.6E-06	2.9E-07	3.8E-06
Benzo[a]pyrene	9.8E-09	6.7E-09	1.6E-08	1.7E-07	2.3E-08	1.9E-07	4.9E-07	4.0E-07	8.9E-07	3.2E-06	5.0E-07	3.7E-06
Benzo[b]fluoranthene	9.0E-09	1.1E-08	2.0E-08	1.6E-07	3.7E-08	2.0E-07	3.2E-07	6.3E-07	9.5E-07	2.1E-06	7.8E-07	2.8E-06
Benzo[k]fluoranthene	1.2E-08	1.1E-08	2.3E-08	2.1E-07	3.7E-08	2.5E-07	4.3E-07	6.3E-07	1.1E-06	2.8E-06	7.8E-07	3.6E-06
Chrysene	1.2E-08	3.7E-09	1.6E-08	2.1E-07	1.3E-08	2.2E-07	9.5E-07	2.3E-07	1.2E-06	6.2E-06	2.9E-07	6.5E-06
Dibenzo[a,h]anthracene	1.2E-08	1.1E-08	2.3E-08	2.1E-07	3.7E-08	2.5E-07	6.3E-07	6.3E-07	1.3E-06	4.1E-06	7.8E-07	4.9E-06
Indeno[1,2,3-cd]pyrene	7.7E-09	6.7E-09	1.4E-08	1.4E-07	2.3E-08	1.6E-07	4.0E-07	4.0E-07	8.1E-07	2.6E-06	5.0E-07	3.1E-06
Total HPAH	—	—	—	—	—	—	—	—	—	—	—	—
Phthalates												
Bis(2-Ethylhexyl)phthalate	1.1E-08	3.7E-09	1.4E-08	1.9E-07	1.3E-08	2.0E-07	6.3E-07	2.3E-07	8.6E-07	4.1E-06	2.9E-07	4.4E-06
Butylbenzylphthalate	4.5E-09	3.7E-09	8.1E-09	7.9E-08	1.3E-08	9.2E-08	2.3E-07	2.3E-07	4.6E-07	1.5E-06	2.9E-07	1.8E-06
Phenols												
Pentachlorophenol	7.7E-09	6.7E-09	1.4E-08	1.4E-07	2.3E-08	1.6E-07	4.0E-07	4.0E-07	8.1E-07	2.6E-06	5.0E-07	3.1E-06
Misc. Extractables												
Carbazole	7.7E-09	6.7E-09	1.4E-08	1.4E-07	2.3E-08	1.6E-07	4.0E-07	4.0E-07	8.1E-07	2.6E-06	5.0E-07	3.1E-06
Volatile Organics												
Benzene	—	—	—	—	—	—	—	—	—	—	—	—
Ethylbenzene	—	—	—	—	—	—	—	—	—	—	—	—
Pesticides/PCBs												
Chlordane	1.9E-09	2.7E-09	4.6E-09	3.3E-08	9.4E-09	4.2E-08	1.2E-07	1.2E-07	2.3E-07	7.5E-07	1.4E-07	8.9E-07
DDD	2.9E-10	4.1E-10	6.9E-10	5.0E-09	1.4E-09	6.4E-09	1.4E-08	1.4E-08	2.9E-08	9.4E-08	1.8E-08	1.1E-07
DDT	2.9E-10	4.1E-10	6.9E-10	5.0E-09	1.4E-09	6.4E-09	1.4E-08	1.4E-08	2.9E-08	9.4E-08	1.8E-08	1.1E-07
PCB Aroclor 1254	3.3E-08	5.8E-09	3.8E-08	5.7E-07	2.0E-08	5.9E-07	3.2E-06	2.6E-07	3.4E-06	2.1E-05	3.2E-07	2.1E-05
PCB Aroclor 1260	3.4E-08	3.6E-09	3.8E-08	6.0E-07	1.3E-08	6.1E-07	3.4E-06	2.0E-07	3.6E-06	2.2E-05	2.5E-07	2.2E-05
Total PCBs	5.7E-08	5.8E-09	6.3E-08	1.0E-06	2.0E-08	1.0E-06	7.5E-06	2.6E-07	7.8E-06	4.9E-05	3.2E-07	4.9E-05

Notes:

— Chemical was not analyzed; calculations could not be completed.

CDI: Chronic Daily Intake

CT: Central Tendency

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

RME: Reasonable Maximum Exposure

Table C-4 Fish Ingestion Chronic Daily Intake Results—Non-Carcinogenic

Chemical of Potential Concern	CT Scenario Oral CDI, Recreational			CT Scenario Oral CDI, Tribal			RME Scenario Oral CDI, Recreational			RME Scenario Oral CDI, Tribal		
	Crayfish (mg/kg-day)	Finfish (mg/kg-day)	Total CDI (mg/kg-day)	Crayfish (mg/kg-day)	Finfish (mg/kg-day)	Total CDI (mg/kg-day)	Crayfish (mg/kg-day)	Finfish (mg/kg-day)	Total CDI (mg/kg-day)	Crayfish (mg/kg-day)	Finfish (mg/kg-day)	Total CDI (mg/kg-day)
Adult Non-cancer Risk Calculations												
Conventionals/Misc.												
Total Cyanide	—	—	—	—	—	—	—	—	—	—	—	—
Metals												
Antimony	4.9E-07	3.1E-07	7.9E-07	5.2E-06	6.6E-07	5.9E-06	5.8E-05	2.9E-05	8.7E-05	3.0E-04	2.9E-05	3.3E-04
Arsenic	1.2E-06	3.4E-07	1.6E-06	1.3E-05	7.2E-07	1.4E-05	1.1E-04	2.1E-05	1.3E-04	5.7E-04	2.1E-05	5.9E-04
Cadmium	4.0E-07	8.6E-09	4.1E-07	4.3E-06	1.8E-08	4.3E-06	7.1E-05	7.7E-07	7.2E-05	3.7E-04	7.6E-07	3.7E-04
Chromium III	1.4E-07	4.5E-07	5.9E-07	1.5E-06	9.6E-07	2.5E-06	1.5E-05	5.6E-05	7.1E-05	7.7E-05	5.5E-05	1.3E-04
Chromium VI	2.4E-08	7.3E-08	9.8E-08	2.6E-07	1.6E-07	4.2E-07	2.5E-06	9.3E-06	1.2E-05	1.3E-05	9.2E-06	2.2E-05
Cobalt	—	—	—	—	—		—	—	—	—	—	—
Copper	2.4E-05	9.8E-07		2.6E-04	2.1E-06	2.6E-04	2.7E-03	7.5E-05		1.4E-02	7.4E-05	1.4E-02
Lead and Compounds	3.4E-06	9.8E-08	3.5E-06	3.6E-05	2.1E-07	3.6E-05	6.1E-04	1.9E-05	6.3E-04	3.2E-03	1.9E-05	3.2E-03
Mercury	3.0E-07	3.7E-07	6.6E-07	3.2E-06	7.9E-07	4.0E-06	2.9E-05	3.5E-05	6.4E-05	1.5E-04	3.4E-05	1.8E-04
Nickel Soluble Salts	1.3E-07	1.1E-07	2.4E-07	1.4E-06	2.4E-07	1.6E-06	8.1E-06	9.6E-06	1.8E-05	4.2E-05	9.5E-06	5.2E-05
Selenium	5.5E-07	9.5E-07	1.5E-06	5.9E-06	2.0E-06	7.9E-06	3.5E-05	1.2E-04	1.5E-04	1.8E-04	1.1E-04	2.9E-04
Silver	2.8E-08	7.0E-09	3.5E-08	3.0E-07	1.5E-08	3.1E-07	1.7E-06	7.7E-07	2.5E-06	9.0E-06	7.6E-07	9.8E-06
Vanadium	—	—	—	—	—		—	—	—	—	—	—
Zinc	4.0E-05	2.0E-05	6.0E-05	4.3E-04	4.3E-05	4.7E-04	2.7E-03	1.9E-03	4.6E-03	1.4E-02	1.9E-03	1.6E-02
Butyltins												
Tributyltin	9.2E-09	2.8E-07	2.9E-07	9.8E-08	6.1E-07	7.1E-07	5.8E-07	1.8E-05	1.9E-05	3.0E-06	1.8E-05	2.1E-05
LPAHs												
Acenaphthene	1.2E-08	1.0E-08	2.2E-08	1.2E-07	2.2E-08	1.5E-07	1.2E-06	1.2E-06	2.3E-06	6.0E-06	1.1E-06	7.2E-06
Acenaphthylene	1.7E-08	1.4E-08	3.1E-08	1.8E-07	3.0E-08	2.1E-07	1.5E-06	1.5E-06	3.1E-06	8.0E-06	1.5E-06	9.5E-06
Anthracene	9.2E-09	1.4E-08	2.3E-08	9.8E-08	3.0E-08	1.3E-07	5.8E-07	1.5E-06	2.1E-06	3.0E-06	1.5E-06	4.5E-06
Fluorene	1.7E-08	1.4E-08	3.1E-08	1.8E-07	3.0E-08	2.1E-07	1.5E-06	1.5E-06	3.1E-06	8.0E-06	1.5E-06	9.5E-06
2-Methylnaphthalene	4.6E-08	4.0E-08	8.6E-08	4.9E-07	8.5E-08	5.8E-07	5.4E-06	1.5E-06	6.9E-06	2.2E-05	4.2E-06	2.6E-05
Naphthalene	4.6E-08	4.0E-08	8.6E-08	4.9E-07	8.5E-08	5.8E-07	4.2E-06	4.2E-06	8.5E-06	2.2E-05	4.2E-06	2.6E-05
Phenanthrene	4.0E-08	1.4E-08	5.3E-08	4.3E-07	3.0E-08	4.6E-07	4.2E-06	4.2E-06	8.5E-06	2.8E-05	1.5E-06	3.0E-05
Total LPAH	—	—	—	—	—	—	—	—	—	—	—	—
HPAH												
Benzo(g,h,i)perylene	2.9E-08	2.5E-08	5.4E-08	3.1E-07	5.4E-08	3.6E-07	2.7E-06	2.7E-06	5.4E-06	1.4E-05	2.7E-06	1.7E-05
Fluoranthene	2.2E-08	1.5E-08	3.7E-08	2.4E-07	3.1E-08	2.7E-07	1.9E-06	1.5E-06	3.5E-06	1.0E-05	1.5E-06	1.2E-05
Pyrene	1.3E-07	1.4E-08	1.4E-07	1.3E-06	3.0E-08	1.4E-06	2.1E-05	1.5E-06	2.3E-05	1.1E-04	1.5E-06	1.1E-04
Retene	—	—	—	—	—	—	—	—	—	—	—	—
Total HPAH	—	—	—	—	—	—	—	—	—	—	—	—
Total PAH	—	—	—	—	—	—	—	—	—	—	—	—
Phthalates												
Bis(2-Ethylhexyl)phthalate	4.0E-08	1.4E-08	5.3E-08	4.3E-07	3.0E-08	4.6E-07	4.2E-06	1.5E-06	5.8E-06	2.2E-05	1.5E-06	2.4E-05
Butylbenzylphthalate	1.7E-08	1.4E-08	3.1E-08	1.8E-07	3.0E-08	2.1E-07	1.5E-06	1.5E-06	3.1E-06	8.0E-06	1.5E-06	9.5E-06
Di-n-butylphthalate	2.9E-08	2.5E-08	5.4E-08	3.1E-07	5.4E-08	3.6E-07	2.7E-06	2.7E-06	5.4E-06	1.4E-05	2.7E-06	1.7E-05
Diethylphthalate	2.9E-08	2.5E-08	5.4E-08	3.1E-07	5.4E-08	3.6E-07	2.7E-06	2.7E-06	5.4E-06	1.4E-05	2.7E-06	1.7E-05
Dimethylphthalate	1.1E-08	8.6E-09	1.9E-08	1.2E-07	1.8E-08	1.3E-07	1.2E-06	1.2E-06	2.3E-06	6.0E-06	1.1E-06	7.2E-06
Di-n-octylphthalate	1.7E-08	1.4E-08	3.1E-08	1.8E-07	3.0E-08	2.1E-07	1.5E-06	1.5E-06	3.1E-06	8.0E-06	1.5E-06	9.5E-06
Phenols												
2,4-Dimethylphenol	2.9E-08	2.5E-08	5.4E-08	3.1E-07	5.4E-08	3.6E-07	2.7E-06	2.7E-06	5.4E-06	1.4E-05	2.7E-06	1.7E-05
4-Methylphenol	2.9E-08	2.5E-08	5.4E-08	3.1E-07	5.4E-08	3.6E-07	2.7E-06	2.7E-06	5.4E-06	1.4E-05	2.7E-06	1.7E-05
Pentachlorophenol	2.9E-08	2.5E-08	5.4E-08	3.1E-07	5.4E-08	3.6E-07	2.7E-06	2.7E-06	5.4E-06	1.4E-05	2.7E-06	1.7E-05
Phenol	1.2E-05	8.9E-08	1.2E-05	1.3E-04	1.9E-07	1.3E-04	1.5E-03	1.1E-05	1.5E-03	7.9E-03	1.0E-05	7.9E-03
Misc. Extractables												
Benzoic Acid	5.5E-07	2.7E-07	8.2E-07	5.9E-06	5.8E-07	6.5E-06	5.8E-05	2.7E-05	8.5E-05	3.0E-04	2.7E-05	3.3E-04
Dibenzofuran	2.9E-08	2.5E-08	5.4E-08	3.1E-07	5.4E-08	3.6E-07	2.7E-06	2.7E-06	5.4E-06	1.4E-05	2.7E-06	1.7E-05
Volatile Organics												
Benzene	—	—	—	—	—	—	—	—	—	—	—	—
Ethylbenzene	—	—	—	—	—	—	—	—	—	—	—	—
Toluene	—	—	—	—	—	—	—	—	—	—	—	—
Total Xylenes	—	—	—	—	—	—	—	—	—	—	—	—
1,2,4-Trimethylbenzene	—	—	—	—	—	—	—	—	—	—	—	—
Pesticides/PCBs												
Chlordane	7.0E-09	1.0E-08	1.7E-08	7.5E-08	2.2E-08	9.7E-08	7.7E-07	7.7E-07	1.5E-06	4.0E-06	7.6E-07	4.8E-06
DDT	1.1E-09	1.5E-09	2.6E-09	1.2E-08	3.3E-09	1.5E-08	9.6E-08	9.6E-08	1.9E-07	5.0E-07	9.5E-08	6.0E-07
Aroclor 1254	1.2E-07	2.2E-08	1.4E-07	1.3E-06	4.7E-08	1.4E-06	2.1E-05	1.7E-06	2.3E-05	1.1E-04	1.7E-06	1.1E-04

Table C-4 Fish Ingestion Chronic Daily Intake Results—Non-Carcinogenic

Chemical of Potential Concern	CT Scenario Oral CDI, Recreational			CT Scenario Oral CDI, Tribal			RME Scenario Oral CDI, Recreational			RME Scenario Oral CDI, Tribal		
	Crayfish (mg/kg-day)	Finfish (mg/kg-day)	Total CDI (mg/kg-day)	Crayfish (mg/kg-day)	Finfish (mg/kg-day)	Total CDI (mg/kg-day)	Crayfish (mg/kg-day)	Finfish (mg/kg-day)	Total CDI (mg/kg-day)	Crayfish (mg/kg-day)	Finfish (mg/kg-day)	Total CDI (mg/kg-day)
Child Non-cancer Risk Calculations												
Conventionals/Misc.												
Total Cyanide	—	—	—	—	—	—	—	—	—	—	—	—
Metals												
Antimony	1.5E-06	9.5E-07	2.5E-06	2.7E-05	3.3E-06	3.0E-05	1.1E-04	5.4E-05	1.6E-04	6.6E-04	6.2E-05	7.2E-04
Arsenic	3.8E-06	1.1E-06	4.9E-06	6.7E-05	3.7E-06	7.0E-05	2.1E-04	4.0E-05	2.4E-04	1.2E-03	4.6E-05	1.3E-03
Cadmium	1.2E-06	2.7E-08	1.3E-06	2.2E-05	9.3E-08	2.2E-05	1.3E-04	1.4E-06	1.3E-04	8.1E-04	1.7E-06	8.1E-04
Chromium III	4.5E-07	1.4E-06	1.8E-06	7.8E-06	4.9E-06	1.3E-05	2.8E-05	1.0E-04	1.3E-04	1.7E-04	1.2E-04	2.9E-04
Chromium VI	7.6E-08	2.3E-07	3.0E-07	1.3E-06	8.0E-07	2.1E-06	4.7E-06	1.7E-05	2.2E-05	2.8E-05	2.0E-05	4.8E-05
Cobalt	—	—	—	—	—	—	—	—	—	—	—	—
Copper	7.4E-05	3.0E-06	7.7E-05	1.3E-03	1.1E-05	1.3E-03	5.0E-03	1.4E-04	5.2E-03	3.1E-02	1.6E-04	3.1E-02
Lead and Compounds	1.1E-05	3.0E-07	1.1E-05	1.8E-04	1.1E-06	1.8E-04	1.1E-03	3.6E-05	1.2E-03	6.9E-03	4.2E-05	6.9E-03
Mercury	9.2E-07	1.1E-06	2.1E-06	1.6E-05	4.0E-06	2.0E-05	5.4E-05	6.5E-05	1.2E-04	3.3E-04	7.5E-05	4.0E-04
Nickel Soluble Salts	4.0E-07	3.5E-07	7.5E-07	7.0E-06	1.2E-06	8.2E-06	1.5E-05	1.8E-05	3.3E-05	9.2E-05	2.1E-05	1.1E-04
Selenium	1.7E-06	3.0E-06	4.7E-06	3.0E-05	1.0E-05	4.0E-05	6.5E-05	2.2E-04	2.8E-04	3.9E-04	2.5E-04	6.4E-04
Silver	8.6E-08	2.2E-08	1.1E-07	1.5E-06	7.7E-08	1.6E-06	3.2E-06	1.4E-06	4.7E-06	2.0E-05	1.7E-06	2.1E-05
Vanadium	—	—	—	—	—	—	—	—	—	—	—	—
Zinc	1.2E-04	6.3E-05	1.9E-04	2.2E-03	2.2E-04	2.4E-03	5.0E-03	3.6E-03	8.6E-03	3.1E-02	4.1E-03	3.5E-02
Butyltins												
Tributyltin	2.9E-08	8.8E-07	9.1E-07	5.0E-07	3.1E-06	3.6E-06	1.1E-06	3.3E-05	3.5E-05	6.6E-06	3.9E-05	4.5E-05
LPAHs												
Acenaphthene	3.6E-08	3.1E-08	6.8E-08	6.3E-07	1.1E-07	7.4E-07	2.2E-06	2.2E-06	4.3E-06	1.3E-05	2.5E-06	1.6E-05
Acenaphthylene	5.2E-08	4.3E-08	9.5E-08	9.2E-07	1.5E-07	1.1E-06	2.9E-06	2.9E-06	5.8E-06	1.7E-05	3.3E-06	2.1E-05
Anthracene	2.9E-08	4.3E-08	7.1E-08	5.0E-07	1.5E-07	6.5E-07	1.1E-06	2.9E-06	4.0E-06	6.6E-06	3.3E-06	9.9E-06
Fluorene	5.2E-08	4.3E-08	9.5E-08	9.2E-07	1.5E-07	1.1E-06	2.9E-06	2.9E-06	5.8E-06	1.7E-05	3.3E-06	2.1E-05
2-Methylnaphthalene	1.4E-07	1.2E-07	2.7E-07	2.5E-06	4.3E-07	2.9E-06	7.9E-06	2.9E-06	1.1E-05	6.1E-05	3.3E-06	6.4E-05
Naphthalene	1.4E-07	1.2E-07	2.7E-07	2.5E-06	4.3E-07	2.9E-06	7.9E-06	7.9E-06	1.6E-05	4.8E-05	9.2E-06	5.7E-05
Phenanthrene	1.2E-07	4.3E-08	1.7E-07	2.2E-06	1.5E-07	2.3E-06	1.0E-05	7.9E-06	1.8E-05	4.8E-05	9.2E-06	5.7E-05
Total LPAH	—	—	—	—	—	—	—	—	—	—	—	—
HPAH												
Benzo(g,h,i)perylene	9.0E-08	7.8E-08	1.7E-07	1.6E-06	2.7E-07	1.9E-06	5.0E-06	5.0E-06	1.0E-05	3.1E-05	5.8E-06	3.6E-05
Fluoranthene	6.8E-08	4.6E-08	1.1E-07	1.2E-06	1.6E-07	1.4E-06	3.6E-06	2.9E-06	6.5E-06	2.2E-05	3.3E-06	2.5E-05
Pyrene	3.9E-07	4.3E-08	4.3E-07	6.8E-06	1.5E-07	7.0E-06	4.0E-05	2.9E-06	4.3E-05	2.4E-04	3.3E-06	2.5E-04
Retene	—	—		—	—	—	—	—		—	—	—
Total HPAH	—	—	—	—	—	—	—	—	—	—	—	—
Total PAH	—	—	—	—	—	—	—	—	—	—	—	—
Phthalates												
Bis(2-Ethylhexyl)phthalate	1.2E-07	4.3E-08	1.7E-07	2.2E-06	1.5E-07	2.3E-06	7.9E-06	2.9E-06	1.1E-05	4.8E-05	3.3E-06	5.1E-05
Butylbenzylphthalate	5.2E-08	4.3E-08	9.5E-08	9.2E-07	1.5E-07	1.1E-06	2.9E-06	2.9E-06	5.8E-06	1.7E-05	3.3E-06	2.1E-05
Di-n-butylphthalate	9.0E-08	7.8E-08	1.7E-07	1.6E-06	2.7E-07	1.9E-06	5.0E-06	5.0E-06	1.0E-05	3.1E-05	5.8E-06	3.6E-05
Diethylphthalate	9.0E-08	7.8E-08	1.7E-07	1.6E-06	2.7E-07	1.9E-06	5.0E-06	5.0E-06	1.0E-05	3.1E-05	5.8E-06	3.6E-05
Dimethylphthalate	3.3E-08	2.7E-08	6.0E-08	5.8E-07	9.3E-08	6.8E-07	2.2E-06	2.2E-06	4.3E-06	1.3E-05	2.5E-06	1.6E-05
Di-n-octylphthalate	5.2E-08	4.3E-08	9.5E-08	9.2E-07	1.5E-07	1.1E-06	2.9E-06	2.9E-06	5.8E-06	1.7E-05	3.3E-06	2.1E-05
Phenols												
2,4-Dimethylphenol	9.0E-08	7.8E-08	1.7E-07	1.6E-06	2.7E-07	1.9E-06	5.0E-06	5.0E-06	1.0E-05	3.1E-05	5.8E-06	3.6E-05
4-Methylphenol	9.0E-08	7.8E-08	1.7E-07	1.6E-06	2.7E-07	1.9E-06	5.0E-06	5.0E-06	1.0E-05	3.1E-05	5.8E-06	3.6E-05
Pentachlorophenol	9.0E-08	7.8E-08	1.7E-07	1.6E-06	2.7E-07	1.9E-06	5.0E-06	5.0E-06	1.0E-05	3.1E-05	5.8E-06	3.6E-05
Phenol	3.7E-05	2.8E-07	3.7E-05	6.5E-04	9.7E-07	6.5E-04	2.8E-03	2.0E-05	2.9E-03	1.7E-02	2.3E-05	1.7E-02
Misc. Extractables												
Benzoic Acid	1.7E-06	8.4E-07	2.5E-06	3.0E-05	2.9E-06	3.3E-05	1.1E-04	5.0E-05	1.6E-04	6.6E-04	5.8E-05	7.1E-04
Dibenzofuran	9.0E-08	7.8E-08	1.7E-07	1.6E-06	2.7E-07	1.9E-06	5.0E-06	5.0E-06	1.0E-05	3.1E-05	5.8E-06	3.6E-05
Volatile Organics												
Benzene	—	—	—	—	—	—	—	—	—	—	—	—
Ethylbenzene	—	—	—	—	—	—	—	—	—	—	—	—
Toluene	—	—	—	—	—	—	—	—	—	—	—	—
Total Xylenes	—	—	—	—	—	—	—	—	—	—	—	—
1,2,4-Trimethylbenzene	—	—	—	—	—	—	—	—	—	—	—	—
Pesticides/PCBs												
Chlordane	2.2E-08	3.1E-08	5.3E-08	3.8E-07	1.1E-07	4.9E-07	1.4E-06	1.4E-06	2.9E-06	8.7E-06	1.7E-06	1.0E-05
DDT	3.3E-09	4.8E-09	8.1E-09	5.8E-08	1.7E-08	7.5E-08	1.8E-07	1.8E-07	3.6E-07	1.1E-06	2.1E-07	1.3E-06
Aroclor 1254	3.8E-07	6.8E-08	4.5E-07	6.7E-06	2.4E-07	6.9E-06	4.0E-05	3.2E-06	4.3E-05	2.4E-04	3.7E-06	2.4E-04

Notes:

— Chemical was not analyzed; calculations could not be completed.
CDI: Chronic Daily Intake
CT: Central Tendency
DDT: Dichlorodiphenyltrichloroethane
HPAH: High-molecular weight polycyclic aromatic hydrocarbon
LPAH: Low-molecular weight polycyclic aromatic hydrocarbon
PAH: Polycyclic aromatic hydrocarbon
PCB: Polychlorinated biphenyl
RME: Reasonable Maximum Exposure

Table C-5 Netfishing Chronic Daily Intake Results—Carcinogenic

Chemical of Potential Concern	CT Scenario			RME Scenario		
	Dermal CDI (mg/kg-day)	Oral CDI (mg/kg-day)	Total CDI (mg/kg-day)	Dermal CDI (mg/kg-day)	Oral CDI (mg/kg-day)	Total CDI (mg/kg-day)
Adult Cancer Risk Calculations						
Metals						
Arsenic	3.9E-08	1.3E-06	1.3E-06	3.2E-05	7.5E-05	1.1E-04
Chromium VI	—	1.4E-07	1.4E-07	—	1.1E-06	1.1E-06
HPAH						
Benzo[a]anthracene	5.9E-08	4.4E-07	5.0E-07	4.1E-05	2.2E-05	6.3E-05
Benzo[a]pyrene	8.9E-08	6.6E-07	7.5E-07	6.4E-05	3.4E-05	9.9E-05
Benzo[b]fluoranthene	6.7E-08	5.0E-07	5.7E-07	4.7E-05	2.5E-05	7.2E-05
Benzo[k]fluoranthene	4.2E-08	3.1E-07	3.5E-07	2.5E-05	1.3E-05	3.9E-05
Chrysene	6.5E-08	4.9E-07	5.5E-07	4.5E-05	2.4E-05	6.9E-05
Dibenzo[a,h]anthracene	1.1E-08	8.4E-08	9.6E-08	8.8E-06	4.7E-06	1.3E-05
Indeno[1,2,3-cd]pyrene	5.8E-08	4.3E-07	4.9E-07	5.2E-05	2.8E-05	8.0E-05
Total HPAH	—	—	—	—	—	—
Phthalates						
Bis(2-Ethylhexyl)phthalate	2.6E-09	2.6E-08	2.8E-08	2.9E-07	2.0E-07	5.0E-07
Butylbenzylphthalate	4.9E-10	4.7E-09	5.2E-09	3.2E-08	2.2E-08	5.3E-08
Phenols						
Pentaclorophenol	9.0E-10	3.5E-09	4.4E-09	5.2E-08	1.4E-08	6.6E-08
Misc. Extractables						
Carbazole	1.8E-09	1.8E-08	1.9E-08	2.8E-07	1.9E-07	4.7E-07
Volatile Organics						
Benzene	—	4.7E-08	4.7E-08	—	1.1E-06	1.1E-06
Ethylbenzene	—	6.4E-09	6.4E-09	—	1.8E-07	1.8E-07
Pesticides/PCBs						
Chlordane	6.9E-11	1.7E-09	1.8E-09	2.2E-09	3.8E-09	5.9E-09
DDD	9.4E-12	3.1E-10	3.2E-10	1.2E-09	2.8E-09	4.0E-09
DDT	9.4E-12	3.1E-10	3.2E-10	2.7E-10	6.3E-10	9.0E-10
PCB Aroclor 1254	2.4E-10	1.7E-09	1.9E-09	3.0E-08	1.5E-08	4.5E-08
PCB Aroclor 1260	1.8E-10	1.2E-09	1.4E-09	1.9E-08	9.4E-09	2.8E-08
Total PCBs	3.7E-10	2.6E-09	3.0E-09	4.4E-08	2.2E-08	6.6E-08

Notes:

— Dermal absorption factor was not available; calculations could not be completed.

CDI: Chronic Daily Intake

CT: Central Tendency

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

RME: Reasonable Maximum Exposure

Table C-6 Netfishing Chronic Daily Intake Results—Non-Carcinogenic

Chemical of Potential Concern	CT Scenario			RME Scenario		
	Dermal CDI (mg/kg-day)	Oral CDI (mg/kg-day)	Total CDI (mg/kg-day)	Dermal CDI (mg/kg-day)	Oral CDI (mg/kg-day)	Total CDI (mg/kg-day)
Adult Non-cancer Risk Calculations						
Conventionals/Misc.						
Total Cyanide	—	3.5E-07	3.5E-07	—	8.4E-06	8.4E-06
Metals						
Antimony	—	1.4E-07	1.4E-07	—	9.5E-07	9.5E-07
Arsenic	9.4E-08	2.2E-06	2.3E-06	5.1E-05	1.2E-04	1.7E-04
Cadmium	7.1E-11	4.9E-08	4.9E-08	2.9E-09	2.0E-07	2.0E-07
Chromium III	—	1.4E-06	1.4E-06	—	1.1E-05	1.1E-05
Chromium VI	—	2.4E-07	2.4E-07	—	1.8E-06	1.8E-06
Cobalt	—	1.4E-06	1.4E-06	—	1.2E-05	1.2E-05
Copper	—	7.7E-06	7.7E-06	—	5.2E-05	5.2E-05
Lead and Compounds[1]	—	8.4E-06	8.4E-06	—	5.6E-05	5.6E-05
Mercury	—	2.4E-08	2.4E-08	—	1.1E-07	1.1E-07
Nickel Soluble Salts	—	2.6E-06	2.6E-06	—	3.2E-05	3.2E-05
Selenium	—	2.2E-08	2.2E-08	—	1.1E-07	1.1E-07
Silver	—	5.0E-08	5.0E-08	—	2.3E-07	2.3E-07
Vanadium	—	1.7E-06	1.7E-06	—	6.6E-06	6.6E-06
Zinc	—	1.1E-05	1.1E-05	—	4.8E-05	4.8E-05
Butyltins						
Tributyltin	2.9E-09	2.0E-08	2.3E-08	5.1E-07	3.5E-07	8.6E-07
LPAH						
Acenaphthene	6.7E-08	3.6E-07	4.3E-07	2.1E-05	1.1E-05	3.3E-05
Acenaphthylene	2.1E-08	1.1E-07	1.3E-07	7.4E-06	3.9E-06	1.1E-05
Anthracene	7.4E-08	4.0E-07	4.7E-07	3.0E-05	1.6E-05	4.6E-05
Fluorene	4.1E-08	2.2E-07	2.6E-07	1.2E-05	6.3E-06	1.8E-05
2-methylnaphthalene	2.3E-08	1.2E-07	1.4E-07	5.4E-06	2.9E-06	8.3E-06
Naphthalene	4.2E-08	2.2E-07	2.7E-07	1.1E-05	6.0E-06	1.7E-05
Phenanthrene	2.3E-07	1.3E-06	1.5E-06	1.2E-04	6.6E-05	1.9E-04
Total LPAH	—	—	—	—	—	—
HPAH						
Benzo[g,h,i]perylene	1.5E-07	8.2E-07	9.8E-07	1.0E-04	5.5E-05	1.6E-04
Fluoranthene	4.3E-07	2.3E-06	2.7E-06	1.8E-04	9.5E-05	2.7E-04
Pyrene	5.0E-07	2.7E-06	3.2E-06	2.1E-04	1.1E-04	3.1E-04
Retene	7.7E-09	5.3E-08	6.1E-08	8.6E-07	6.0E-07	1.5E-06
Total HPAH	—	—	—	—	—	—
Total PAH	—	—	—	—	—	—
Phthalates						
Bis(2-Ethylhexyl)phthalate	6.4E-09	4.4E-08	5.1E-08	4.7E-07	3.2E-07	7.9E-07
Butylbenzylphthalate	1.2E-09	8.2E-09	9.4E-09	5.0E-08	3.5E-08	8.5E-08
Di-n-butylpthalate	1.7E-08	1.2E-07	1.4E-07	2.7E-06	1.9E-06	4.5E-06
Diethylphthalate	9.7E-09	6.7E-08	7.7E-08	3.2E-07	2.2E-07	5.5E-07
Dimethylphthalate	7.2E-10	5.0E-09	5.7E-09	3.0E-08	2.1E-08	5.1E-08
Di-n-octylphthalate	1.8E-09	1.3E-08	1.4E-08	3.4E-08	2.4E-08	5.8E-08
Phenols						
2,4-Dimethylphenol	4.6E-10	3.2E-09	3.6E-09	1.2E-08	8.5E-09	2.1E-08
4-Methylphenol	1.7E-09	1.2E-08	1.4E-08	1.1E-07	7.5E-08	1.8E-07
Pentachlorophenol	2.2E-09	6.1E-09	8.3E-09	8.3E-08	2.3E-08	1.1E-07
Phenol	2.4E-09	1.6E-08	1.9E-08	1.4E-07	9.5E-08	2.3E-07
Misc. Extractables						
Benzoic Acid	8.2E-09	5.7E-08	6.5E-08	2.9E-07	2.0E-07	4.9E-07
Dibenzofuran	8.1E-09	5.6E-08	6.4E-08	2.4E-06	1.7E-06	4.1E-06
Volatile Organics						
Benzene	—	8.2E-08	8.2E-08	—	1.7E-06	1.7E-06
Ethylbenzene	—	1.1E-08	1.1E-08	—	2.9E-07	2.9E-07
Toluene	—	1.6E-10	1.6E-10	—	8.0E-10	8.0E-10
Total Xylenes	—	3.7E-09	3.7E-09	—	1.1E-07	1.1E-07
1,2,4-Trimethylbenzene	—	4.5E-07	4.5E-07	—	8.5E-07	8.5E-07
Pesticides/PCBs						
Chlordane	1.7E-10	2.9E-09	3.1E-09	3.4E-09	6.0E-09	9.4E-09
DDT	2.3E-11	5.3E-10	5.5E-10	4.3E-10	1.0E-09	1.4E-09
PCB Aroclor 1254	5.8E-10	2.9E-09	3.5E-09	4.8E-08	2.4E-08	7.2E-08

Notes:

— Dermal absorption factor was not available; calculations could not be completed.

CDI: Chronic Daily Intake

CT: Central Tendency

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbon

LPAH: Low-molecular weight polycyclic aromatic hydrocarbon

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

RME: Reasonable Maximum Exposure

Appendix D

Risk Driver Evaluation

Table D-1 Risk Driver Assessment

Chemical of Potential Concern	Beach Play/Wading (Oral and Dermal summed) Adult			Beach Play/Wading (Oral and Dermal summed) Child			Fish Consumption General Adult			Fish Consumption General Child			Fish Consumption Tribal Adult			Fish Consumption Tribal Child			Netfishing (Oral and Dermal Summed) Tribal Adult			Ecological Risk			
	Cancer Risk	Percent of Cumulative Cancer Risk	HQ	Cancer Risk	Percent of Cumulative Cancer Risk	HQ	Cancer Risk	Percent of Cumulative Cancer Risk	HQ	Cancer Risk	Percent of Cumulative Cancer Risk	HQ	Cancer Risk	Percent of Cumulative Cancer Risk	HQ	Cancer Risk	Percent of Cumulative Cancer Risk	HQ	Cancer Risk	Percent of Cumulative Cancer Risk	HQ	HQ LOAEL Heron	HQ LOAEL Mallard	HQ LOAEL Otter	HQ NOAEL Salmonid
Conventionals/Misc.																									
Total Cyanide	—		0.00	—		0.02	—		—	—		—	—		—	—		—	—		0.00	—	—	0.00	—
Metals																									
Antimony	—		0.10	—		0.80	—		0.20	—		0.40	—		0.80	—		**2.00**	—		0.00	—	—	0.00	—
Arsenic	**2.E-05**	12.68	0.08	**2.E-05**	7.55	0.57	**8.E-05**	52.35	0.40	**3.E-05**	53.75	0.80	**9.E-04**	56.68	**2.00**	**2.E-04**	59.28	**4.00**	**2.E-04**	18.09	0.60	0.00	0.02	0.25	**2.56**
Cadmium	—		0.00	—		0.01	—		0.07	—		0.10	—		0.40	—		0.80	—		0.00	0.00	0.01	0.00	0.00
Chromium III	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	0.00	0.01	0.01	—
Chromium VI	6.E-07	0.38	0.00	9.E-07	0.34	0.01	**2.E-06**	1.31	0.00	9.E-07	1.61	0.01	**1.E-05**	0.63	0.01	**2.E-06**	0.59	0.02	6.E-07	0.05	0.00	—	—	0.00	—
Cobalt	—		0.01	—		0.06	—		—	—		—	—		—	—		—	—		0.04	0.00	0.01	0.00	—
Copper			0.00	—		0.02	—		0.07	—		0.10	—		0.40	—		0.77	—		0.00	0.01	0.03	0.02	0.31
Lead[1]	—		—	—		—	—		—	—		—	—		—	—		—	—		—	0.02	0.10	0.03	0.02
Mercury	—		0.01	—		0.09	—		0.20	—		0.40	—		0.60	—		1.00	—		0.00	0.19	0.42	0.22	0.16
Nickel	—		0.00	—		0.03	—		0.00	—		0.00	—		0.00	—		0.01	—		0.00	0.00	0.00	0.02	—
Selenium	—		0.00	—		0.00	—		0.03	—		0.06	—		0.06	—		0.10	—		0.00	0.01	0.01	0.02	0.36
Silver	—		0.00	—		0.02	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	0.00	0.00	0.00	—
Vanadium	—		0.60	—		**4.00**	—		—	—		—	—		—	—		—	—		0.00	0.09	0.37	0.01	**1.36**
Zinc	—		0.00	—		0.01	—		0.02	—		0.03	—		0.05	—		0.10	—		0.00	0.01	0.02	0.00	0.11
Butyltins																									
Tributyltin	—		0.00	—		0.00	—		0.06	—		0.10	—		0.07	—		0.20	—		0.00	0.00	0.00	0.00	**32.40**
LPAH																									
Acenaphthene	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—	—	0.00	—
Acenaphthylene	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—	—	0.00	—
Anthracene	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—	—	0.00	—
Fluorene	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—	—	0.00	—
2-Methylnaphthalene	—		0.00	—		0.03	—		0.00	—		0.00	—		0.01	—		0.02	—		0.00	—	—	0.00	—
Naphthalene	—		0.00	—		0.02	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—	—	0.00	—
Phenanthrene	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—	—	0.00	—
Total LPAH[2]			0.01			0.06			0.00			0.00			0.01			0.02			0.00	—	0.01	0.00	—
HPAH																									
Benzo(a)anthracene	**9.E-06**	5.71	—	**1.E-05**	3.77	—	**2.E-06**	1.31	—	6.E-07	1.07	—	**2.E-05**	1.26	—	**3.E-06**	0.89	—	**5.E-05**	4.52	—	—	—	0.04	—
Benzo(a)pyrene	**1.E-04**	63.41	—	**2.E-04**	75.46	—	**2.E-05**	13.09	—	**7.E-06**	12.54	—	**1.E-04**	6.30	—	**3.E-05**	8.89	—	**7.E-04**	63.30	—	0.38	**1.53**	0.06	**1.11**
Benzo(b)fluoranthene	**9.E-06**	5.71	—	**1.E-05**	3.77	—	**2.E-06**	1.31	—	7.E-07	1.25	—	**1.E-05**	0.63	—	**2.E-06**	0.59	—	**5.E-05**	4.52	—	—	—	0.04	—
Benzo(k)fluoranthene	**7.E-06**	4.44	—	**1.E-05**	3.77	—	**2.E-06**	1.31	—	8.E-07	1.43	—	**1.E-05**	0.63	—	**3.E-06**	0.89	—	**3.E-05**	2.71	—	—	—	0.02	—
Benzo(g,h,i)perylene	—		0.00	—		0.01	—		0.00		-	0.00	—		0.00	—		0.00	—		0.01	—	—	0.06	—
Chrysene	1.E-06	0.63	—	1.E-06	0.38	—	2.E-07	0.13	—	9.E-08	0.16	—	**3.E-06**	0.19	—	5.E-07	0.15	—	**5.E-06**	0.45	—	—	—	0.01	—
Dibenzo(a,h)anthracene	**2.E-06**	1.27	—	**3.E-06**	1.13	—	**2.E-06**	1.31	—	9.E-07	1.61	—	**2.E-05**	1.26	—	**4.E-06**	1.19	—	**1.E-05**	0.90	—	—	—	0.01	—
Indeno(1,2,3-cd)pyrene	**9.E-06**	5.71	—	**1.E-05**	3.77	—	**2.E-06**	1.31	—	6.E-07	1.07	—	**1.E-05**	0.63	—	**2.E-06**	0.59	—	**6.E-05**	5.43	—	—	—	0.33	—
Fluoranthene	—		0.00	—		0.01	—		0.00	—		0.00	—		0.00	—		0.00	—		0.01	—	—	0.05	—
Pyrene	—		0.00	—		0.02	—		0.00	—		0.00	—		0.00	—		0.01	—		0.01	—	—	0.39	—
Retene	—		0.00	—		0.00	—		—	—		—	—		—	—		—	—		0.00	—	—	0.00	—
Total HPAH[2]	**1.E-04**	86.88	0.00	**2.E-04**	92.07	0.04	**3.E-05**	19.76	0.00	**1.E-05**	19.15	0.00	**2.E-04**	10.89	0.00	**4.E-05**	13.19	0.01	**9.E-04**	81.84	0.02	—	—	**1.73**	—
Total PAH[2]	**1.E-04**	86.88	0.01	**2.E-04**	92.07	0.09	**3.E-05**	19.76	0.00	**1.E-05**	19.15	0.01	**2.E-04**	10.89	0.01	**4.E-05**	13.19	0.03	**9.E-04**	81.84	0.03	0.03	0.11	—	**3.52**

Table D-1 Risk Driver Assessment

Chemical of Potential Concern	Beach Play/Wading (Oral and Dermal summed) Adult			Beach Play/Wading (Oral and Dermal summed) Child			Fish Consumption General Adult			Fish Consumption General Child			Fish Consumption Tribal Adult			Fish Consumption Tribal Child			Netfishing (Oral and Dermal Summed) Tribal Adult			Ecological Risk			
	Cancer Risk	Percent of Cumulative Cancer Risk	HQ	Cancer Risk	Percent of Cumulative Cancer Risk	HQ	Cancer Risk	Percent of Cumulative Cancer Risk	HQ	Cancer Risk	Percent of Cumulative Cancer Risk	HQ	Cancer Risk	Percent of Cumulative Cancer Risk	HQ	Cancer Risk	Percent of Cumulative Cancer Risk	HQ	Cancer Risk	Percent of Cumulative Cancer Risk	HQ	HQ LOAEL Heron	HQ LOAEL Mallard	HQ LOAEL Otter	HQ NOAEL Salmonid
Phthalates																									
Bis(2-Ethylhexylphthalate	4.E-09	0.00	0.00	6.E-09	0.00	0.00	3.E-08	0.02	0.00	1.E-08	0.02	0.00	3.E-07	0.02	0.00	6.E-08	0.02	0.00	7.E-09	0.00	0.00	0.00	0.00	0.00	**1.82**
Butylbenzylphthalate	7.E-11	0.00	0.00	9.E-11	0.00	0.00	2.E-09	0.00	0.00	9.E-10	0.00	0.00	2.E-08	0.00	0.00	3.E-09	0.00	0.00	1.E-10	0.00	0.00	0.00	0.00	0.00	—
Di-n-butylphthalate	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	0.00	0.00	0.00	—
Diethylphthalate	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	0.00	0.00	0.00	—
Dimethylphthalate	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	0.00	0.00	0.00	—
Di-n-octylphthalate	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	0.00	0.00	0.00	—
Phenols																									
2,4-Dimethylphenol	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—	—	0.00	—
4-Methylphenol	—		0.00	—		0.00	—		0.00	—		0.00	—		0.00	—		0.01	—		0.00	—	—	0.00	—
Pentachlorophenol	3.E-08	0.02	0.00	4.E-08	0.02	0.00	3.E-07	0.20	0.00	1.E-07	0.18	0.00	**2.E-06**	0.13	0.00	4.E-07	0.12	0.00	8.E-09	0.00	0.00	0.00	0.00	0.00	—
Phenol	—		0.00	—		0.00	—		0.01	—		0.01	—		0.03	—		0.06	—		0.00	—	—	0.00	—
Misc. Extractables																									
Benzoic Acid	—		0.00	—		0.00	—		0.00	—		0.00			0.00	—		0.00	—		0.00	—	—	0.00	—
Carbazole	2.E-08	0.01	—	3.E-08	0.01	—	4.E-08	0.03	—	2.E-08	0.04	—	3.E-07	0.02	—	6.E-08	0.02	—	9.E-09	0.00	—	—	—	—	—
Dibenzofuran	—		0.00	—		0.01	—		0.01	—		0.01	—		0.02	—		0.04	—		0.00	—	—	—	—
Volatile Organic Compounds																									
Benzene	2.E-11	0.00	0.00	3.E-11	0.00	0.00	—		—	—		—	—		—	—		—	6.E-08	0.01	0.00	—	—	0.00	0.01
Ethylbenzene	3.E-12	0.00	0.00	4.E-12	0.00	0.00	—		—	—		—	—		—	—		—	2.E-09	0.00	0.00	—	—	—	—
Toluene	—		0.00	—		0.00	—		—	—		—	—		—	—		—	—		0.00	—	—	—	—
Total Xylenes	—		0.00	—		0.00	—		—	—		—	—		—	—		—	—		0.00	—	—	—	—
1,2,4-Trimethylbenzene	—		0.00	—		0.00	—		—	—		—	—		—	—		—	—		0.00	—	—	—	—
Pesticides/PCBs																									
Chlordane	6.E-10	0.00	0.00	8.E-10	0.00	0.00	2.E-07	0.13	0.00	8.E-08	0.14	0.01	**2.E-06**	0.13	0.01	3.E-07	0.09	0.02	2.E-09	0.00	0.00	0.00	0.00	0.00	0.01
DDD	7.E-10	0.00	—	1.E-09	0.00	—	2.E-08	0.01	—	7.E-09	0.01	—	1.E-07	0.01	—	3.E-08	0.01	—	1.E-09	0.00	—	0.00	0.00	0.00	0.01
DDT	1.E-09	0.00	0.00	2.E-09	0.00	0.00	3.E-08	0.02	0.00	1.E-08	0.02	0.00	2.E-07	0.01	0.00	4.E-08	0.01	0.00	3.E-10	0.00	0.00	0.00	0.00	0.00	0.01
PCB Aroclor 1254	2.E-08	0.01	0.00	3.E-08	0.01	0.01	**2.E-05**	13.09	1.00	**7.E-06**	12.54	**2.00**	**2.E-04**	12.60	**6.00**	**4.E-05**	11.86	**11.00**	9.E-08	0.01	0.00	—	—	—	0.01
PCB Aroclor 1260	9.E-09	0.01	—	1.E-08	0.00	—	**2.E-05**	13.09	—	**7.E-06**	12.54	—	**2.E-04**	12.60	—	**4.E-05**	11.86	—	6.E-08	0.01	—	—	—	—	—
Total PCBs	4.E-08	0.03	0.00	5.E-08	0.02	0.01	**4.E-05**	26.17	1.00	**1.E-05**	25.08	**2.00**	**5.E-04**	31.49	**6.00**	**9.E-05**	26.68	**11.00**	1.E-07	0.01	0.00	0.00	0.03	0.01	—
Cumulative Risk	**2.E-04**	100.00	0.8	**3.E-04**	100.00	**5.7**	**2.E-04**	100.00	**2.1**	**6.E-05**	100.00	**4.0**	**2.E-03**	100.00	**10.5**	**3.E-04**	100.00	**20.2**	**1.E-03**	100.00	0.7	0.4	**2.6**	**2.3**	**42.7**

Notes:

Risk Driver defined as (1) any individual carcinogenic chemical that contributes at least 10% of total cumulative risk and the individual chemical risk exceeds acceptable risk thresholds or (2) non-carcinogenic or ecological hazard quotient >5.

Signifies a COPC identified to be further evaluated in Section 5.

BLUE Signifies a hazard quotient greater than 1.0 for individual COPCs.

GREEN Signifies a lifetime carcinogenic risk greater than 10^{-6} for individual COPCs.

— Toxicological information was not available or chemical was not analyzed; calculations could not be completed.

[1] Human health risk evaluation of lead has been presented primarily in the text, as risk calculations were not conducted.

[2] These results represent the sums of individual PAH results.

COPC: Chemical of potential concern

DDD: Dichlorodiphenyldichloroethane

DDT: Dichlorodiphenyltrichloroethane

HPAH: High-molecular weight polycyclic aromatic hydrocarbons

HQ: Hazard Quotient

LOAEL: Lowest Observed Adverse Effect Level

LPAH: Low-molecular weight polycyclic aromatic hydrocarbons

NOAEL: No Observed Adverse Effect Level

PAH: Polycyclic aromatic hydrocarbon

PCB: Polychlorinated biphenyl

Appendix E

Dietary Dose Values

Table E-1 Great Blue Heron Dietary Dose Values

Chemical of Potential Concern	Dietary Dose			
	Crayfish (dw mg/kg-day)	Finfish (dw mg/kg-day)	Sediment (dw mg/kg-day)	Total (dw mg/kg-day)
Conventionals/Misc.				
Total Cyanide	na	na	8.2E-02	8.2E-02
Metals				
Antimony	3.7E-04	3.5E-03	4.4E-03	8.2E-03
Arsenic	6.9E-04	2.5E-03	3.4E-02	3.7E-02
Cadmium	4.5E-04	9.3E-05	1.5E-03	2.0E-03
Chromium III	9.4E-05	6.7E-03	4.2E-02	4.9E-02
Chromium VI	1.6E-05	1.1E-03	7.0E-03	8.1E-03
Cobalt	na	na	4.9E-02	4.9E-02
Copper	1.7E-02	9.0E-03	3.4E-01	3.6E-01
Lead	3.9E-03	2.3E-03	1.6E-01	1.7E-01
Mercury	1.8E-04	4.2E-03	5.2E-04	4.9E-03
Nickel	5.1E-05	1.2E-03	1.3E-01	1.3E-01
Selenium	2.2E-04	1.4E-02	2.5E-04	1.4E-02
Silver	1.1E-05	9.3E-05	1.5E-03	1.6E-03
Vanadium	na	na	6.4E-02	6.4E-02
Zinc	1.7E-02	2.3E-01	4.4E-01	6.9E-01
Butyltins				
Tributyltin	3.7E-06	2.2E-03	2.0E-04	2.4E-03
LPAH				
Acenaphthene	7.3E-06	1.4E-04	1.0E-01	1.0E-01
Acenaphthylene	9.8E-06	1.9E-04	3.9E-02	3.9E-02
Anthracene	3.7E-06	1.9E-04	7.8E-02	7.8E-02
Flourene	9.8E-06	1.9E-04	3.6E-02	3.6E-02
2-Methylnaphthalene	2.7E-05	5.1E-04	2.2E-02	2.3E-02
Naphthalene	2.7E-05	5.1E-04	4.8E-02	4.8E-02
Phenanthrene	3.4E-05	1.9E-04	2.5E-01	2.5E-01
Total LPAH	3.8E-05	5.1E-04	5.4E-01	5.4E-01
HPAH				
Benzo(a)anthracene	2.3E-05	1.9E-04	3.4E-01	3.4E-01
Benzo(a)pyrene	2.1E-05	3.2E-04	5.4E-01	5.4E-01
Benzo(b)fluoranthene	1.3E-05	5.1E-04	3.9E-01	3.9E-01
Benzo(k)fluoranthene	1.8E-05	5.1E-04	2.1E-01	2.1E-01
Benzo(g,h,i)perylene	1.7E-05	3.2E-04	5.4E-01	5.4E-01
Chrysene	4.0E-05	1.9E-04	3.8E-01	3.8E-01
Dibenzo(a,h)anthracene	2.7E-05	5.1E-04	7.3E-02	7.4E-02
Fluoranthene	1.2E-05	1.9E-04	9.3E-01	9.3E-01
Indeno(1,2,3-cd)pyrene	1.7E-05	3.2E-04	4.3E-01	4.3E-01
Pyrene	1.4E-04	1.9E-04	1.1E+00	1.1E+00
Retene	na	na	1.8E-03	1.8E-03
Total HPAH	2.6E-04	5.1E-04	4.9E+00	4.9E+00
Total PAH	3.0E-04	5.1E-04	5.4E+00	5.4E+00
Phthalates				
Bis(2-Ethylhexyl)phthalate	2.7E-05	1.9E-04	1.3E-03	1.5E-03
Butylbenzylphthalate	9.8E-06	1.9E-04	1.2E-03	1.4E-03
Di-n-butylphthalate	1.7E-05	3.2E-04	3.2E-03	3.6E-03
Diethylphthalate	1.7E-05	3.2E-04	2.7E-04	6.1E-04
Dimethylphthalate	7.3E-06	1.4E-04	1.1E-04	2.5E-04
Di-n-octylphthalate	9.8E-06	1.9E-04	2.7E-04	4.6E-04
Phenols				
2,4-Dimethylphenol	1.7E-05	3.2E-04	2.7E-04	6.1E-04
4-Methylphenol	1.7E-05	3.2E-04	8.3E-05	4.2E-04
Pentachlorophenol	1.7E-05	3.2E-04	1.4E-03	1.7E-03
Phenol	9.6E-03	1.3E-03	3.2E-04	1.1E-02
Misc. Extractables				
Benzoic Acid	3.7E-04	3.2E-03	1.7E-03	5.3E-03
Carbazole	1.7E-05	3.2E-04	2.7E-03	3.0E-03
Dibenzofuran	1.7E-05	3.2E-04	6.8E-03	7.2E-03
Volatile Organic Compounds				
Benzene	na	na	2.4E-06	2.4E-06
Ethylbenzene	na	na	9.8E-07	9.8E-07
Toluene	na	na	7.8E-06	7.8E-06
Total Xylenes	na	na	6.3E-06	6.3E-06
1,2,4-Trimethylbenzene	na	na	8.3E-03	8.3E-03
Pesticides/PCBs				
Chlordane	4.9E-06	9.3E-05	4.9E-06	1.0E-04
DDD	6.1E-07	1.2E-05	9.8E-06	2.2E-05
DDT	6.1E-07	1.2E-05	9.8E-06	2.2E-05
PCB Aroclor 1254	1.3E-04	2.1E-04	2.3E-04	5.8E-04
PCB Aroclor 1260	1.4E-04	1.6E-04	8.3E-05	3.9E-04
Total PCBs	3.2E-04	2.1E-04	2.3E-04	7.6E-04

Notes:

DDD: Dichlorodiphenyldichloroethane
DDT: Dichlorodiphenyltrichloroethane
dw: Dry weight
HPAH: High-molecular weight polycyclic aromatic hydrocarbon
LPAH: Low-molecular weight polycyclic aromatic hydrocarbon
na: Not analyzed
PAH: Polycyclic aromatic hydrocarbon
PCB: Polychlorinated biphenyl

Table E-2 American Mallard Dietary Dose Values

Chemical of Potential Concern	Dietary Dose			
	Crayfish (dw mg/kg-day)	Finfish (dw mg/kg-day)	Sediment (dw mg/kg-day)	Total (dw mg/kg-day)
Conventionals/Misc.				
Total Cyanide	na	na	3.3E-01	3.3E-01
Metals				
Antimony	1.8E-02	na	1.8E-02	3.5E-02
Arsenic	3.4E-02	na	1.4E-01	1.7E-01
Cadmium	2.2E-02	na	5.9E-03	2.8E-02
Chromium III	4.6E-03	na	1.7E-01	1.7E-01
Chromium VI	7.7E-04	na	2.8E-02	2.9E-02
Cobalt	na	na	2.0E-01	2.0E-01
Copper	8.3E-01	na	1.3E+00	2.2E+00
Lead	1.9E-01	na	6.4E-01	8.3E-01
Mercury	8.9E-03	na	2.1E-03	1.1E-02
Nickel	2.5E-03	na	5.2E-01	5.3E-01
Selenium	1.1E-02	na	1.0E-03	1.2E-02
Silver	5.3E-04	na	5.9E-03	6.5E-03
Vanadium	na	na	2.6E-01	2.6E-01
Zinc	8.3E-01	na	1.8E+00	2.6E+00
Butyltins				
Tributyltin	1.8E-04	na	8.0E-04	9.8E-04
LPAH				
Acenaphthene	3.5E-04	na	4.1E-01	4.1E-01
Acenaphthylene	4.7E-04	na	1.5E-01	1.5E-01
Anthracene	1.8E-04	na	3.1E-01	3.1E-01
Flourene	4.7E-04	na	1.4E-01	1.4E-01
2-Methylnaphthalene	1.3E-03	na	9.0E-02	9.1E-02
Naphthalene	1.3E-03	na	1.9E-01	1.9E-01
Phenanthrene	1.7E-03	na	9.9E-01	1.0E+00
Total LPAH	1.8E-03	na	2.1E+00	2.1E+00
HPAH				
Benzo(a)anthracene	1.1E-03	na	1.4E+00	1.4E+00
Benzo(a)pyrene	1.0E-03	na	2.1E+00	2.1E+00
Benzo(b)fluoranthene	6.5E-04	na	1.6E+00	1.6E+00
Benzo(k)fluoranthene	8.9E-04	na	8.4E-01	8.4E-01
Benzo(g,h,i)perylene	8.3E-04	na	2.1E+00	2.1E+00
Chrysene	2.0E-03	na	1.5E+00	1.5E+00
Dibenzo(a,h)anthracene	1.3E-03	na	2.9E-01	2.9E-01
Fluoranthene	5.9E-04	na	3.7E+00	3.7E+00
Indeno(1,2,3-cd)pyrene	8.3E-04	na	1.7E+00	1.7E+00
Pyrene	6.6E-03	na	4.3E+00	4.3E+00
Retene	na	na	7.2E-03	7.2E-03
Total HPAH	1.3E-02	na	2.0E+01	2.0E+01
Total PAH	1.5E-02	na	2.2E+01	2.2E+01
Phthalates				
Bis(2-Ethylhexyl)phthalate	1.3E-03	na	5.3E-03	6.6E-03
Butylbenzylphthalate	4.7E-04	na	4.7E-03	5.2E-03
Di-n-butylphthalate	8.3E-04	na	1.3E-02	1.4E-02
Diethylphthalate	8.3E-04	na	1.1E-03	1.9E-03
Dimethylphthalate	3.5E-04	na	4.3E-04	7.8E-04
Di-n-octylphthalate	4.7E-04	na	1.1E-03	1.5E-03
Phenols				
2,4-Dimethylphenol	8.3E-04	na	1.1E-03	1.9E-03
4-Methylphenol	8.3E-04	na	3.3E-04	1.2E-03
Pentachlorophenol	8.3E-04	na	5.5E-03	6.3E-03
Phenol	4.7E-01	na	1.3E-03	4.7E-01
Misc. Extractables				
Benzoic Acid	1.8E-02	na	6.7E-03	2.4E-02
Carbazole	8.3E-04	na	1.1E-02	1.2E-02
Dibenzofuran	8.3E-04	na	2.7E-02	2.8E-02
Volatile Organic Compounds				
Benzene	na	na	9.8E-06	9.8E-06
Ethylbenzene	na	na	3.9E-06	3.9E-06
Toluene	na	na	3.1E-05	3.1E-05
Total Xylenes	na	na	2.5E-05	2.5E-05
1,2,4-Trimethylbenzene	na	na	3.3E-02	3.3E-02
Pesticides/PCBs				
Chlordane	2.4E-04	na	2.0E-05	2.6E-04
DDD	3.0E-05	na	3.9E-05	6.9E-05
DDT	3.0E-05	na	3.9E-05	6.9E-05
PCB Aroclor 1254	6.5E-03	na	9.4E-04	7.4E-03
PCB Aroclor 1260	7.0E-03	na	3.3E-04	7.3E-03
Total PCBs	1.5E-02	na	9.4E-04	1.6E-02

Notes:

DDD: Dichlorodiphenyldichloroethane
DDT: Dichlorodiphenyltrichloroethane
dw: Dry weight
HPAH: High-molecular weight polycyclic aromatic hydrocarbon
LPAH: Low-molecular weight polycyclic aromatic hydrocarbon
na: Not analyzed
PAH: Polycyclic aromatic hydrocarbon
PCB: Polychlorinated biphenyl

Table E-3 Northern River Otter Dietary Dose Values

Chemical of Potential Concern	Dietary Dose			
	Crayfish (dw mg/kg-day)	Finfish (dw mg/kg-day)	Sediment (dw mg/kg-day)	Total (dw mg/kg-day)
Conventionals/Misc.				
Total Cyanide	na	na	9.0E-02	9.0E-02
Metals				
Antimony	9.6E-04	3.5E-03	1.0E-02	1.5E-02
Arsenic	1.8E-03	2.6E-03	1.3E+00	1.3E+00
Cadmium	1.2E-03	9.4E-05	2.1E-03	3.4E-03
Chromium III	2.5E-04	6.8E-03	1.2E-01	1.2E-01
Chromium VI	4.2E-05	1.1E-03	1.9E-02	2.0E-02
Cobalt	na	na	1.3E-01	1.3E-01
Copper	4.5E-02	9.2E-03	5.6E-01	6.2E-01
Lead	1.0E-02	2.4E-03	6.0E-01	6.1E-01
Mercury	4.8E-04	4.2E-03	1.2E-03	6.0E-03
Nickel	1.3E-04	1.2E-03	3.4E-01	3.4E-01
Selenium	5.8E-04	1.4E-02	1.2E-03	1.6E-02
Silver	2.9E-05	9.4E-05	2.4E-03	2.5E-03
Vanadium	na	na	7.1E-02	7.1E-02
Zinc	4.5E-02	2.3E-01	5.1E-01	7.9E-01
Butyltins				
Tributyltin	9.6E-06	2.2E-03	3.8E-03	6.0E-03
LPAH				
Acenaphthene	1.9E-05	1.4E-04	1.2E-01	1.2E-01
Acenaphthylene	2.6E-05	1.9E-04	4.2E-02	4.3E-02
Anthracene	9.6E-06	1.9E-04	1.7E-01	1.7E-01
Flourene	2.6E-05	1.9E-04	6.8E-02	6.8E-02
2-Methylnaphthalene	7.1E-05	5.2E-04	3.1E-02	3.2E-02
Naphthalene	7.1E-05	5.2E-04	6.4E-02	6.5E-02
Phenanthrene	9.0E-05	1.9E-04	7.1E-01	7.1E-01
Total LPAH	1.0E-04	5.2E-04	1.1E+00	1.1E+00
HPAH				
Benzo(a)anthracene	6.1E-05	1.9E-04	3.7E-01	3.8E-01
Benzo(a)pyrene	5.5E-05	3.3E-04	5.9E-01	5.9E-01
Benzo(b)fluoranthene	3.5E-05	5.2E-04	4.3E-01	4.3E-01
Benzo(k)fluoranthene	4.8E-05	5.2E-04	2.3E-01	2.3E-01
Benzo(g,h,i)perylene	4.5E-05	3.3E-04	5.9E-01	5.9E-01
Chrysene	1.1E-04	1.9E-04	4.1E-01	4.1E-01
Dibenzo(a,h)anthracene	7.1E-05	5.2E-04	8.0E-02	8.1E-02
Fluoranthene	3.2E-05	1.9E-04	1.0E+00	1.0E+00
Indeno(1,2,3-cd)pyrene	4.5E-05	3.3E-04	4.8E-01	4.8E-01
Pyrene	3.6E-04	1.9E-04	1.2E+00	1.2E+00
Retene	na	na	6.4E-03	6.4E-03
Total HPAH	6.9E-04	5.2E-04	5.4E+00	5.4E+00
Total PAH	7.9E-04	5.2E-04	6.0E+00	6.0E+00
Phthalates				
Bis(2-Ethylhexyl)phthalate	7.1E-05	1.9E-04	3.5E-03	3.7E-03
Butylbenzylphthalate	2.6E-05	1.9E-04	3.5E-04	5.7E-04
Di-n-butylphthalate	4.5E-05	3.3E-04	2.0E-02	2.0E-02
Diethylphthalate	4.5E-05	3.3E-04	2.4E-03	2.8E-03
Dimethylphthalate	1.9E-05	1.4E-04	2.2E-04	3.9E-04
Di-n-octylphthalate	2.6E-05	1.9E-04	2.6E-04	4.7E-04
Phenols				
2,4-Dimethylphenol	4.5E-05	3.3E-04	9.1E-05	4.7E-04
4-Methylphenol	4.5E-05	3.3E-04	8.0E-04	1.2E-03
Pentachlorophenol	4.5E-05	3.3E-04	2.5E-04	6.2E-04
Phenol	2.5E-02	1.3E-03	1.0E-03	2.8E-02
Misc. Extractables				
Benzoic Acid	9.6E-04	3.3E-03	2.1E-03	6.4E-03
Carbazole	4.5E-05	3.3E-04	3.3E-03	3.6E-03
Dibenzofuran	4.5E-05	3.3E-04	1.8E-02	1.9E-02
Volatile Organic Compounds				
Benzene	na	na	1.8E-02	1.8E-02
Ethylbenzene	na	na	3.1E-03	3.1E-03
Toluene	na	na	8.6E-06	8.6E-06
Total Xylenes	na	na	1.2E-03	1.2E-03
1,2,4-Trimethylbenzene	na	na	9.1E-03	9.1E-03
Pesticides/PCBs				
Chlordane	1.3E-05	9.4E-05	6.4E-05	1.7E-04
DDD	1.6E-06	1.2E-05	4.8E-05	6.1E-05
DDT	1.6E-06	1.2E-05	1.1E-05	2.4E-05
PCB Aroclor 1254	3.5E-04	2.1E-04	2.6E-04	8.2E-04
PCB Aroclor 1260	3.8E-04	1.6E-04	1.6E-04	7.0E-04
Total PCBs	8.4E-04	2.1E-04	3.7E-04	1.4E-03

Notes:

DDD: Dichlorodiphenyldichloroethane
DDT: Dichlorodiphenyltrichloroethane
dw: Dry weight
HPAH: High-molecular weight polycyclic aromatic hydrocarbon
LPAH: Low-molecular weight polycyclic aromatic hydrocarbon
na: Not analyzed
PAH: Polycyclic aromatic hydrocarbon
PCB: Polychlorinated biphenyl

Table E-4 Juvenile Chinook Salmon Dietary Dose Values

Chemical of Potential Concern	Dietary Dose			
	Crayfish (dw mg/kg-day)	Finfish (dw mg/kg-day)	Sediment (dw mg/kg-day)	Total (dw mg/kg-day)
Conventionals/Misc.				
Total Cyanide	na	na	na	na
Metals				
Antimony	5.8E-03	na	7.3E-02	7.9E-02
Arsenic	1.1E-02	na	4.6E+00	4.6E+00
Cadmium	7.1E-03	na	7.7E-03	1.5E-02
Chromium III	1.5E-03	na	4.2E-01	4.2E-01
Chromium VI	2.5E-04	na	6.9E-02	7.0E-02
Cobalt	--	na	4.7E-01	4.7E-01
Copper	2.7E-01	na	2.0E+00	2.3E+00
Lead	6.1E-02	na	2.2E+00	2.2E+00
Mercury	2.9E-03	na	4.4E-03	7.3E-03
Nickel	8.1E-04	na	1.2E+00	1.2E+00
Selenium	3.5E-03	na	4.4E-03	7.8E-03
Silver	1.7E-04	na	8.7E-03	8.9E-03
Vanadium	na	na	2.5E-01	2.5E-01
Zinc	2.7E-01	na	1.8E+00	2.1E+00
Butyltins				
Tributyltin	5.8E-05	na	1.4E-02	1.4E-02
LPAH				
Acenaphthene	1.2E-04	na	4.4E-01	4.4E-01
Acenaphthylene	1.5E-04	na	1.5E-01	1.5E-01
Anthracene	5.8E-05	na	6.2E-01	6.2E-01
Flourene	1.5E-04	na	2.4E-01	2.4E-01
2-Methylnaphthalene	4.2E-04	na	1.1E-01	1.1E-01
Naphthalene	4.2E-04	na	2.3E-01	2.3E-01
Phenanthrene	5.4E-04	na	2.5E+00	2.5E+00
Total LPAH	6.0E-04	na	4.1E+00	4.1E+00
HPAH				
Benzo(a)anthracene	3.7E-04	na	1.3E+00	1.3E+00
Benzo(a)pyrene	3.3E-04	na	2.1E+00	2.1E+00
Benzo(b)fluoranthene	2.1E-04	na	1.5E+00	1.5E+00
Benzo(k)fluoranthene	2.9E-04	na	8.3E-01	8.3E-01
Benzo(g,h,i)perylene	2.7E-04	na	2.1E+00	2.1E+00
Chrysene	6.4E-04	na	1.5E+00	1.5E+00
Dibenzo(a,h)anthracene	4.2E-04	na	2.9E-01	2.9E-01
Fluoranthene	1.9E-04	na	3.7E+00	3.7E+00
Indeno(1,2,3-cd)pyrene	2.7E-04	na	1.7E+00	1.7E+00
Pyrene	2.1E-03	na	4.2E+00	4.2E+00
Retene	0.0E+00	na	2.3E-02	2.3E-02
Total HPAH	4.2E-03	na	1.9E+01	1.9E+01
Total PAH	4.8E-03	na	2.1E+01	2.1E+01
Phthalates				
Bis(2-Ethylhexyl)phthalate	4.2E-04	na	1.3E-02	1.3E-02
Butylbenzylphthalate	1.5E-04	na	1.3E-03	1.4E-03
Di-n-butylphthalate	2.7E-04	na	7.2E-02	7.2E-02
Diethylphthalate	2.7E-04	na	8.7E-03	8.9E-03
Dimethylphthalate	1.2E-04	na	8.1E-04	9.2E-04
Di-n-octylphthalate	1.5E-04	na	9.2E-04	1.1E-03
Phenols				
2,4-Dimethylphenol	2.7E-04	na	3.3E-04	6.0E-04
4-Methylphenol	2.7E-04	na	2.9E-03	3.2E-03
Pentachlorophenol	2.7E-04	na	8.9E-04	1.2E-03
Phenol	1.5E-01	na	3.7E-03	1.6E-01
Misc. Extractables				
Benzoic Acid	5.8E-03	na	7.7E-03	1.3E-02
Carbazole	2.7E-04	na	1.2E-02	1.2E-02
Dibenzofuran	2.7E-04	na	6.5E-02	6.6E-02
Volatile Organic Compounds				
Benzene	na	na	6.5E-02	6.5E-02
Ethylbenzene	na	na	1.1E-02	1.1E-02
Toluene	na	na	3.1E-05	3.1E-05
Total Xylenes	na	na	4.4E-03	4.4E-03
1,2,4-Trimethylbenzene	na	na	3.3E-02	3.3E-02
Pesticides/PCBs				
Chlordane	7.7E-05	na	2.3E-04	3.1E-04
DDD	9.6E-06	na	1.7E-04	1.8E-04
DDT	9.6E-06	na	3.9E-05	4.8E-05
PCB Aroclor 1254	2.1E-03	na	9.2E-04	3.0E-03
PCB Aroclor 1260	2.3E-03	na	5.8E-04	2.8E-03
Total PCBs	5.0E-03	na	1.3E-03	6.4E-03

Notes:

DDD: Dichlorodiphenyldichloroethane
DDT: Dichlorodiphenyltrichloroethane
dw: Dry weight
HPAH: High-molecular weight polycyclic aromatic hydrocarbon
LPAH: Low-molecular weight polycyclic aromatic hydrocarbon
na: Not analyzed
PAH: Polycyclic aromatic hydrocarbon
PCB: Polychlorinated biphenyl

Appendix F

Qualitative Evaluation of COPCs with Limited Toxicity Data

Appendix F: Qualitative Evaluation of COPCs with Limited Toxicity Data

For each of the six possible chemicals of potential concern (COPCs) that did not exceed human health risk thresholds, but had limited ecotoxicity data, further evaluation was conducted using a qualitative approach. The physical characteristics, fate, toxicity, and Gas Works Sediment Area (GWSA) distribution for these possible COPCs are discussed below to determine whether they should be retained for the comparison to ambient concentrations step (Section 5.1).

F.1 Dibenzofuran

F.1.1 Physical

Dibenzofuran is a heterocyclic PAH compound (non-substituted), and is similar in this respect to other non-substituted polynuclear aromatics such as PAHs. It is an aromatic compound that has two benzene rings fused to one furan ring in the middle.

It is important to distinguish the difference between dibenzofuran (an unsubstituted PAH compound) and polychlorinated dibenzofurans (PCDFs), which refer to a family of organic compounds that has two benzene rings fused to one furan ring in the middle, and chlorine atoms instead of hydrogen atoms attached to the carbon atoms. PCDFs are toxic chemicals with properties and chemical structures similar to polychlorinated dibenzodioxins, or dioxins. This family of compounds has distinctly different chemical behavior and toxicity than the unsubstituted dibenzofuran PAH (EPA 2000).

Sorptive interaction is expected to dominate the fate of dibenzofuran in aquatic environments and dibenzofuran is expected to adsorb to suspended solids and sediment based on its K_{oc}, which ranges from 4200 (Syracuse Research Corporation [SRC] as cited in HSDB 2010) to 9160 L/kg (EPA Regions 3, 6, and 9 2009). Correspondingly, the aqueous solubility of dibenzofuran is approximately 4 mg/L. Based on these properties, dibenzofuran is expected to be found associated with sediment and suspended solids and transported accordingly. Little or no dissolved phase transport is expected. These properties combined indicate that dibenzofuran will be predominantly sequestered or tightly bound to the organic carbon in the sediment environment and not bioavailable.

F.1.2 Fate

Dibenzofuran may be degraded by biotic and abiotic processes, although abiotic processes are minor. Sediment laboratory studies indicate that dibenzofuran is readily biodegradable under aerobic conditions (Mueller et al. 1991, Wilson et al. 1985). A similar pattern of biodegradation is noted in surface water and groundwater under analogous (aerobic/acclimated) conditions as reported in HSDB (2010).

Bioconcentration factor (BCF) values for fish range from 524 to 2,420. However, over 97 percent of the accumulated dibenzofuran was eliminated in two days during depuration tests in fathead minnow (HSDB 2010). Therefore, rapid elimination of dibenzofuran via metabolic processes significantly reduces its bioconcentration potential.

F.1.3 Toxicity

Dibenzofuran was evaluated for all the GWSA human health pathways and resulted in no human health risk threshold exceedances. However, dibenzofuran was not evaluated for ecological risk due to the lack of toxicity reference value (TRV) data. Limited or no information is available on the acute (short-term), chronic (long-term), reproductive, developmental, and carcinogenic effects of

dibenzofuran in humans or animals. Health effects information is available on the PCDFs; however, EPA (2000) has noted that the biological activity of various chlorinated dibenzofurans varies greatly, thus does not recommend the use of the toxicity of these more widely studied compounds to represent that of the non-chlorinated dibenzofuran. EPA has classified dibenzofuran as Group D—not classifiable as to human carcinogenicity. Dibenzofuran is an inducer of liver microsomal enzymes. Dibenzofuran is not mutagenic with or without metabolic activation in several strains of *Salmonella typhimurium* assay (Schoeny 1982). Dibenzofuran was compared with the polychlorinated dibenzodioxins and furans and was assigned a toxicity equivalence factor (TEF) of 0, indicating no dioxin-like toxicity (HSDB 2010). An estimate of relative toxicity can be based on a 10th percentile LC50 value (concentration that is lethal to 50 percent of the test animals) of 1,204 µg/L.

F.1.4 Distribution

Fifty-nine percent of the dibenzofuran surface sediment sample results in the GWSA had detected concentrations. Forty-three of the 75 detected surface sediment dibenzofuran concentrations exceeded screening criteria (provided in Section 3). Dibenzofuran surface sediment concentrations in the GWSA range from 0.0135 to 34 mg/kg. Concentrations tend to be highest nearer the shore, with scattered locally high concentrations off the prow, near the play barn, and in the vicinity of Northlake Shipyards (NLSY).

Dibenzofuran was also analyzed for in two of the four crayfish tissue samples (Table 2-5); it was not detected in either sample. Although it was not detected, concentrations used in the risk evaluation described in this Supplement were set to the method detection limit which ranged from 0.011 to 0.027 mg/kg wet weight (ww). Dibenzofuran was analyzed for in three of the six finfish tissue samples (Table 2-6); it was not detected in any sample. Although it was not detected, concentrations used in the risk evaluation described in this Supplement were set to the method detection limit which ranged from 0.007 to 0.027 mg/kg ww.

F.1.5 Summary

Dibenzofuran is not retained as a COPC based on the following lines of evidence: no human health risk threshold exceedances; physical structure and environmental behavior similar to that of low-molecular weight PAHs (LPAHs) which had no human health or ecological risk evaluation threshold exceedances; limited toxicity and generally adsorbs to sediments; and no detections in GWSA-vicinity tissue samples.

F.2 Carbazole

F.2.1 Physical

Carbazole is a heterocyclic organic compound that is insoluble in water. Carbazole has been detected in rain and snow samples, which demonstrates that physical removal via wet deposition occurs. Dry deposition may also occur (HSDB 2010). Once released to the environment, as suggested by the soil organic carbon-water partitioning coefficient, K_{oc} of 637, carbazole is expected to moderately adsorb to organic solids. Sorption of carbazole to sediments has been shown to be nonlinear and highly correlated with organic carbon content (Ainsworth et al. 1989).

F.2.2 Fate

Carbazole may be degraded by biotic and abiotic processes. In sediment, biodegradation is the dominant process, with biodegradation half-life ranges from 4 minutes to approximately 6 hours in batch fermentation screening studies (Eisenreich et al. 1981). Biodegradation appears to be dependent on the presence of certain microflora that is known to enhance biotic degradation (e.g., *Xanthamonas spp*.) (Grosser et al. 1991).

A BCF ranging from 48–500 in aquatic plants, invertebrates, and fish suggests that potential bioconcentration in aquatic organisms is moderate, with the highest values reported in invertebrates and fish (DeVoogt et al. 1991; Lu 1974). However, carbazole is known to be metabolized in vivo to N-methyl and N-acetyl derivatives (DeVoogt et al. 1991), thereby attenuating accumulation of carbazole and its derivatives in tissues.

F.2.3 Toxicity

Carbazole was evaluated for all the GWSA human health pathways and resulted in no human health risk threshold exceedances. However, carbazole was not evaluated for ecological risk due to the lack of TRV data. Toxicity data for carbazole obtained from EPA's EcoTox Database (EPA 2009) are limited to a few studies with defined toxicological endpoints. An estimate of relative toxicity can be based on a 10th percentile LC50 value of 958 µg/L.

F.2.4 Distribution

Fifty-eight percent of the carbazole surface sediment sample results in the GWSA had detected concentrations. Seventeen of the 53 detected surface sediment carbazole concentrations exceeded screening criteria (provided in Section 3). Carbazole surface sediment concentrations in the GWSA range from 0.0135 to 6.1 mg/kg. Concentrations tend to be highest nearer the shore.

Carbazole was also analyzed for in GWSA tissue samples. It was analyzed for in two of the four crayfish tissue samples (Table 2-5), and was not detected in either sample. Although it was not detected, concentrations used in the risk evaluations described in this Supplement were set to the method detection limit which ranged from 0.011 to 0.027 mg/kg ww. Carbazole was analyzed for in 3 of the 6 finfish tissue samples (Table 2-6), and was not detected in any sample. Although it was not detected, concentrations used in the risk evaluations described in this Supplement were set to the method detection limit which ranged from 0.007 to 0.027 mg/kg ww.

F.2.5 Summary

Carbazole was not retained as a COPC based on the following lines of evidence: no human health risk threshold exceedances; tends to adsorb to sediments; and limited detection at low concentrations in GWSA-vicinity tissue samples.

F.3 Ethylbenzene

F.3.1 Physical

Ethylbenzene is an aromatic hydrocarbon that is an isomer of xylene. As suggested by its K_{oc} of 520, ethylbenzene may adsorb to organic solids and aquatic sediments (HSDB 2010).

F.3.2 Fate

In sediment, the major ethylbenzene degradation process is aerobic transformation. Ethylbenzene is susceptible to microbial degradation by a variety of microbial species (Van der Linden and Thijsse 1965; Ehrhardt and Petrick 1984; Burback and Perry 1993). Ethylbenzene is rapidly degraded under aerobic conditions, especially with adapted microflora. Anaerobic degradation is via nitrogen reduction processes similar to that observed for benzene (Hutchins et al. 1991; HSDB 2010).

Little information on food residues in commercially important fish and shellfish species is currently available (ATSDR 2007a). Limited data are available on the uptake of ethylbenzene by aquatic organisms (ATSDR 2007a). The available data indicate that ethylbenzene does not bioconcentrate (Ogata et al. 1984), and thus is not likely to bioaccumulate in aquatic (or terrestrial) food chains. A

BCF of 15 reported by Park and Lee (1993) further suggests bioconcentration in aquatic organisms is low.

F.3.3 Toxicity

Benzene is more toxic than ethylbenzene, and benzene concentrations in the GWSA resulted in levels of risk that were orders of magnitude below acceptable risk thresholds for all human health or ecological risk pathways evaluated. For the two human health risk pathways for which ethylbenzene was evaluated, no risk threshold exceedances occurred. In the few samples in the nearshore areas used for beach play/wading exposure evaluation, the maximum surface sediment ethylbenzene concentration (0.002 mg/kg) was similar to the maximum surface sediment concentration for benzene (0.003 mg/kg). Throughout the GWSA, the maximum ethylbenzene surface sediment concentration was 5.8 mg/kg (less than one-sixth the maximum detected benzene concentration). For the beach play/wading and netfishing exposure scenarios, ethylbenzene risk estimates were one to two orders of magnitude less than those estimated for benzene.

Ethylbenzene has low acute and chronic toxicity for both animals and humans where ethylbenzene is extensively metabolized to a number of oxidation products and subsequently excreted. Ethylbenzene is an inducer of liver microsomal enzymes. It is not mutagenic or teratogenic. No information is available on reproductive toxicity or carcinogenicity of ethylbenzene (HSDB 2010).

The acute toxicity of ethylbenzene to algae, aquatic invertebrates, and fish is moderate. Data for ethylbenzene toxicity to fish obtained from EPA's EcoTox Database (EPA 2009) are limited to two studies. An estimate of relative toxicity can be based on a 10th percentile LC50 value of 6,160 µg/L. However, ethylbenzene was not evaluated for ecological risk due to the lack of TRV data. The related VOC, benzene, had estimated risk for two ecological receptors that were two orders of magnitude below risk threshold exceedances for salmon and over four orders of magnitude below risk threshold exceedances for otter.

F.3.4 Distribution

Ethylbenzene, like benzene, was detected less than 20 percent of the time, and with the exception of three samples, was detected only in samples collected as part of the EPA 1995 study. The maximum detected ethylbenzene surface sediment concentration of 5.8 mg/kg was co-located with the maximum detected benzene concentration of 34 mg/kg. Eighty-one percent of the ethylbenzene surface sediment sample results in the GWSA had non-detectable concentrations; there were only 14 detected concentrations throughout the GWSA. Only one of the detected surface sediment ethylbenzene concentrations exceeded screening criteria (provided in Section 3).

F.3.5 Summary

Ethylbenzene is not retained as a COPC based on the following lines of evidence: no human health risk threshold exceedances; evidence suggesting no ecological risk (i.e., the related volatile organic compound [VOC], benzene, resulted in no ecological risk threshold exceedances); limited detects within the GWSA; and fate and transport characteristics that indicate limited persistence (including rapid dispersion and biodegradation) and low bioconcentration potential.

F.4 Toluene

F.4.1 Physical

Toluene is a mono-substituted benzene derivative (i.e., one hydrogen atom from the benzene molecule has been replaced by a methyl group or CH_3). As suggested by its K_{oc}, which ranges from 37–178 (Howard 1990, as cited in HSDB 2010), toluene is expected to have high to moderate mobility and is not expected to adsorb to suspended organic solids in the water column and sediments.

F.4.2 Fate

Toluene is susceptible to biodegradation by a variety of microbial species, which is the primary degradation pathway in sediment. Complete degradation of toluene in aerobic soil and sediment microcosms has been observed with lifetimes ranging from 1 hour to 4 days; however, biodegradation of toluene may proceed more slowly under anaerobic conditions (HSDB 2010).

Due to its susceptibility to biodegradation and relatively high water solubility (535 mg/L), toluene is not expected to persist in sediment or surface water (in the absence of a continuous source). Toluene is expected to have a low tendency to bioconcentrate in the fatty tissues of aquatic organisms (Franke et al. 1994). A BCF ranging from 13 and 90 in fish suggests bioconcentration in aquatic organisms is low to moderate (HSDB 2010). As part of the development of ambient water quality criteria for toluene (EPA 1980), the BCF was estimated to be about 10.7 for fish and about 4.2 for mussels. Efficient metabolism of toluene by aquatic organisms also limits its tendency to biomagnify in the food chain (ATSDR 2000).

F.4.3 Toxicity

Benzene is more toxic than toluene, and benzene concentrations in the GWSA resulted in levels of risk that were orders of magnitude below acceptable risk thresholds for all human health or ecological risk pathways evaluated. No risk threshold exceedances occurred for the two human health risk pathways for which toluene was assessed. In the nearshore areas used for beach play/wading exposure evaluation, the maximum surface sediment toluene concentration (0.016 mg/kg) was higher than the maximum surface sediment concentration for benzene (0.003 mg/kg). Throughout the GWSA, the maximum toluene surface sediment concentration was 0.02 mg/kg (significantly lower than maximum detected surface sediment benzene concentration). For the beach play/wading and netfishing exposure scenarios, toluene risk estimates were an order of magnitude to nearly four orders of magnitude less than those estimated for benzene.

In humans and mammals, toluene is extensively metabolized via oxidation and then the major metabolite is excreted in the urine (HSDB 2010). Data for toluene toxicity to fish obtained from EPA's EcoTox Database (EPA 2009) are limited to several studies. An estimate of relative toxicity can be based on a 10th percentile LC50 value of 5,800 µg/L. However, toluene was not evaluated for ecological risk due to the lack of TRV data. For the related VOC, benzene, estimated risk for two ecological receptors were two orders of magnitude below risk threshold exceedances for salmon and over four orders of magnitude below risk threshold exceedances for otter.

F.4.4 Distribution

Toluene, like benzene, was detected less than 20 percent of the time in the GWSA, and was detected predominantly in samples collected as part of the EPA 1995 study. The maximum detected toluene surface sediment concentration was three orders of magnitude lower than the maximum detected benzene concentration. Eighty-four percent of the toluene surface sediment sample results in the GWSA had non-detectable concentrations; there were only 12 detected concentrations throughout the GWSA. None of the detected surface sediment toluene concentrations exceeded screening criteria (provided in Section 3).

F.4.5 Summary

Toluene is not retained as a COPC based on the following lines of evidence: no human health risk threshold exceedances; the related VOC, benzene, resulted in no ecological risk threshold exceedances; limited detects within the GWSA; and fate and transport characteristics that indicate limited persistence (including rapid dispersion and biodegradation) and low bioconcentration potential.

F.5 Xylene

F.5.1 Physical

Xylene is a mixture of three aromatic hydrocarbon isomers closely related to benzene. As suggested by its K_{oc}, which ranges from 39–365 (Seip et al. 1986; Pavlostathis and Mathavan 1992), xylene is expected to have high to moderate mobility and is not expected to adsorb to organic solids and aquatic sediments.

F.5.2 Fate

Biodegradation is the primary xylene degradation pathway in sediment (ATSDR 2007b). Complete degradation of xylene in aerobic soil and sediment microcosms has been observed with lifetimes ranging from 5–115 days for the individual isomers (HSDB 2010).

Xylene is bioconcentrated in aquatic organisms to a limited extent (HSDB 2010), with BCFs ranging from 6 in clams (Nunes and Benville 1979) to 23 in eels (Ogata and Miyake 1978) considering all xylene isomers. BCFs for other organisms have been estimated in the range of 45 to 105 considering all xylene isomers and these values form the basis of water quality criteria (EPA 1985). Bioconcentration is constrained by rapid metabolism by aquatic organisms and, thus, bioconcentration and biomagnification in the food chain is not expected to be significant (ATSDR 2007b).

F.5.3 Toxicity

Benzene is considerably more toxic than xylene, and benzene concentrations in the GWSA resulted in levels of risk that were orders of magnitude below acceptable risk thresholds for all human health or ecological risk pathways evaluated. For the two human health risk pathways for which xylene was evaluated, no risk threshold exceedances occurred. In the nearshore areas used for beach play/wading exposure evaluation, benzene and xylene were detected at the same maximum surface sediment concentration of 0.003 mg/kg. Throughout the GWSA, the maximum surface sediment xylene concentration was 2.3 mg/kg (15-fold lower than maximum detected surface sediment benzene concentration). For the beach play/wading and netfishing exposure scenarios, xylene risk estimates were two to three orders of magnitude less than those estimated for benzene.

Xylene does not accumulate significantly in the human body where it is efficiently metabolized by microsomal enzyme oxidation in the liver and the metabolic byproducts are then excreted in urine. This metabolic pathway accounts for almost the entire absorbed dose of xylene, regardless of the isomer, route of administration, administered dose, or duration of exposure.

The xylene isomers are of moderate to low toxicity for aquatic organisms. Data for xylene toxicity to fish obtained from EPA's EcoTox Database (EPA 2009) contain multiple studies. An estimate of relative toxicity can be based on a 10th percentile LC50 value of 3,300 µg/L. However, xylene was not evaluated for ecological risk due to the lack of TRV data. For the related VOC, benzene, estimated risk for two ecological receptors were two orders of magnitude below risk threshold exceedances for salmon and over four orders of magnitude below risk threshold exceedances for otter.

F.5.4 Distribution

Xylene was detected slightly more frequently than benzene. Like benzene, xylene was detected predominantly in samples collected as part of the EPA 1995 study. The maximum detected surface sediment xylene concentration was co-located with the maximum detected surface sediment benzene concentration, with the xylene concentration being one order of magnitude lower than the benzene concentration. Seventy-one percent of the xylene surface sediment sample results in the GWSA had non-detectable concentrations; there were only 18 detected concentrations throughout the GWSA.

None of the detected surface sediment xylene concentrations exceeded screening criteria (provided in Section 3).

F.5.5 Summary

Xylene is not retained as a COPC based on the following lines of evidence: no human health risk threshold exceedances; the related VOC, benzene, resulted in no ecological risk threshold exceedances; limited detects within the GWSA; and fate and transport characteristics that indicate limited persistence (including rapid dispersion and biodegradation) and low bioconcentration potential.

F.6 1,2,4-Trimethylbenzene

F.6.1 Physical

1,2,4-Trimethylbenzene (1,2,4-TMB) is an alkylated benzene. Trimethylbenzenes are like xylenes where the methyl groups can be positioned in different ways resulting in three isomers whose proportion varies depending on the mixture (1,2,4-TMB; 1,3,5-TMB; and 1,2,3-TMB). When released to aquatic systems, 1,2,4-TMB may adsorb to suspended organic particles and sediment based on its K_{oc} of 537 (SRC as cited in HSDB 2010).

F.6.2 Fate

1,2,4-TMB is actively biodegraded under aerobic conditions. As reported in HSDB (2010), Acton and Barker (1992) demonstrated biodegradation of aqueous 1,2,4-TMB within 7 days where impacted water percolated through an unsaturated soil column. Microcosms incubated with uncontaminated substrate material under anaerobic conditions indicate complete biodegradation after 45 to 50 days (Hutchins et al. 1991).

The range of BCF values determined for 1,2,4-TMB (31 to 275) is encompassed by 1,3,5-TMB BCF values, which range from 23 to 342 (both sets of values measured in carp) and are irrespective of in vivo metabolism (SRC as cited in HSDB 2010). These values thus suggest low to moderate accumulation in fish tissue in the absence of metabolism (HSDB 2010); the BCF would be expected to be lower when accounting for depuration by organisms.

F.6.3 Toxicity

For the two human health risk pathways for which 1,2,4-TMB was evaluated, no risk threshold exceedances occurred. The estimated risk from 1,2,4-TMB was orders of magnitude below the acceptable risk thresholds in all cases. The input concentration for the risk calculations was one-half the detection limit as there were no detected concentrations within the GWSA. However, the reported detection limit was likely significantly elevated due to interference from other elevated COPCs in the sample.

Metabolism of 1,2,4-TMB in humans and animals occurs by side-chain oxidation to form byproducts which are then excreted in urine. The elimination of TMBs was moderate compared to other aromatic solvents. Tissue levels declined rapidly within 24 hours of intake (HSDB 2010).

A very limited toxicity data set is available for 1,2,4-TMB. Reliable toxicity data are limited to a few species. Aquatic invertebrates appear marginally more sensitive to trimethylbenzenes than fish based on the available data. The relative toxicity of 1,2,4-TMB may be estimated by the conservatively calculated 10th percentile LC50 value of 7,720 µg/L. 1,2,4-TMB was not evaluated for ecological risk due to the lack of TRV data. However, for the more toxic related VOC, benzene, estimated risk for two ecological receptors were two orders of magnitude below risk threshold exceedances for salmon and over four orders of magnitude below risk threshold exceedances for otter.

F.6.4 Distribution

There is only one 1,2,4-TMB sample in the GWSA surface sediment data set (collected offshore southwest of the park, just east of Harbor Patrol) and none in the ALU data set. The result was non-detected, but the detection limit exceeded screening criteria (provided in Section 3).

F.6.5 Summary

1,2,4-TMB is not retained as a COPC on the basis of the following lines of evidence: no human health risk threshold exceedances; the related VOC, benzene, resulted in no ecological risk threshold exceedances; and no detects within the GWSA.

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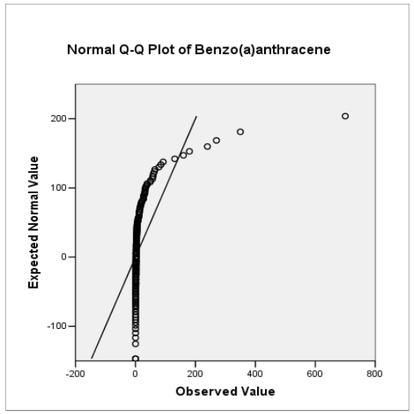
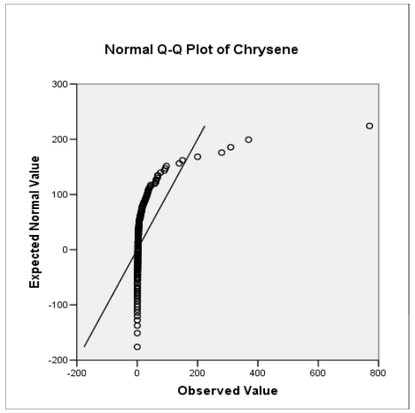
Appendix G

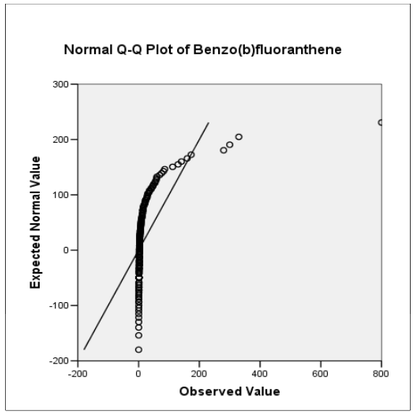
Statistical Comparison of GWSA and ALU Data

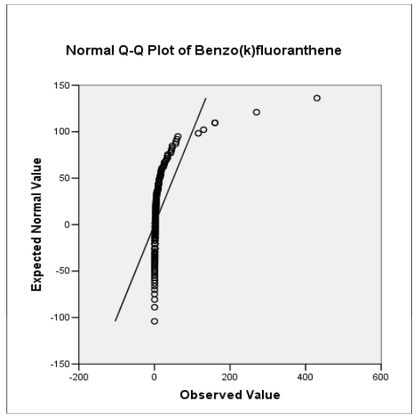
Appendix G Figure G-1. Q-Q Plots of COPCs Retained for Ambient Assessment

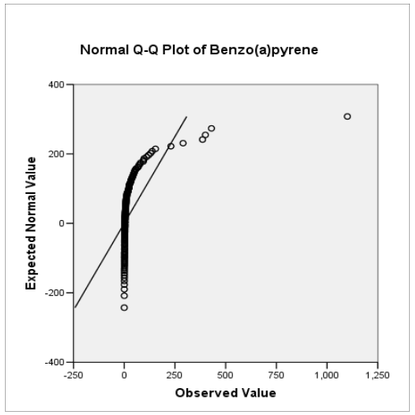
GWSA COPCs

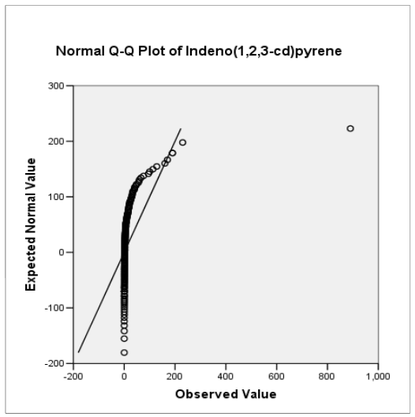


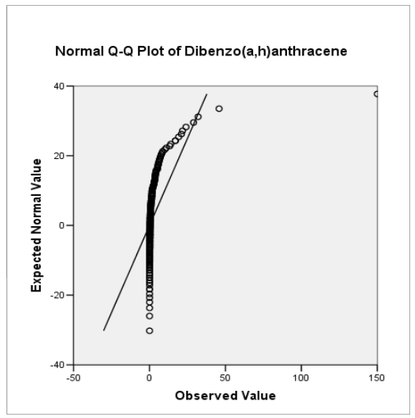


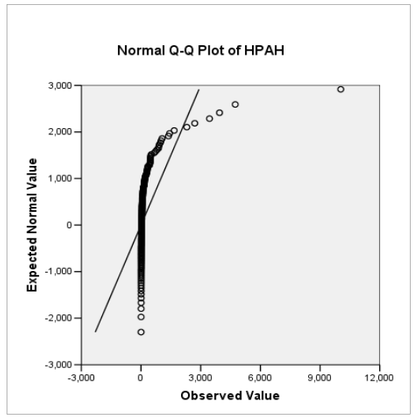


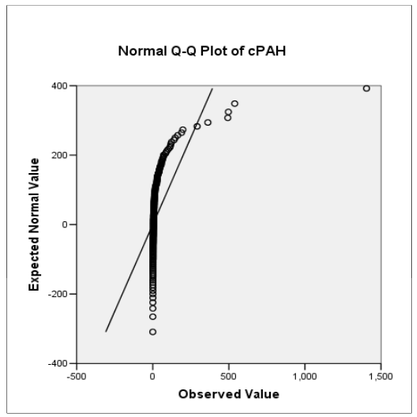


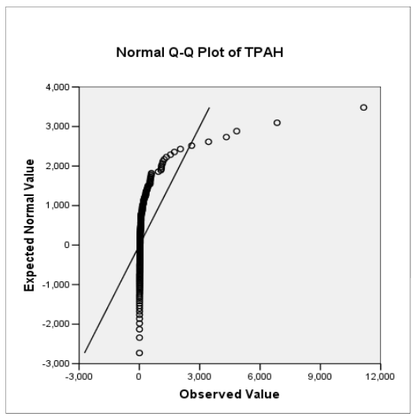


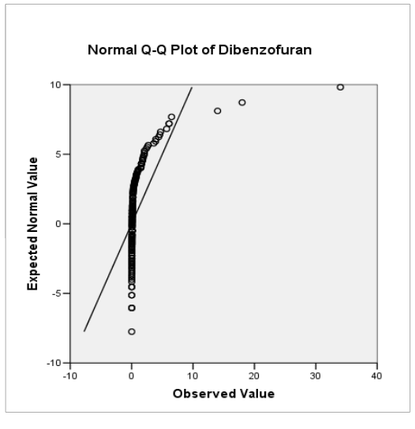






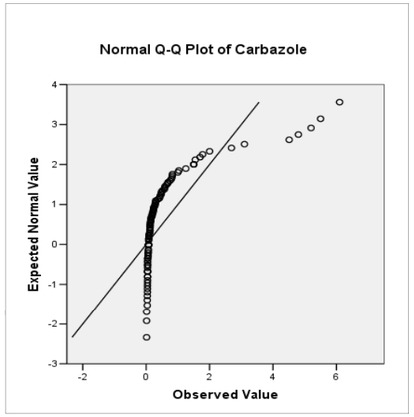


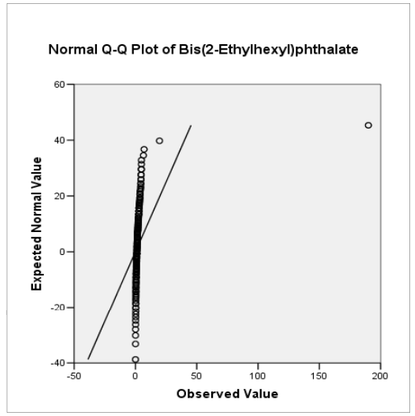


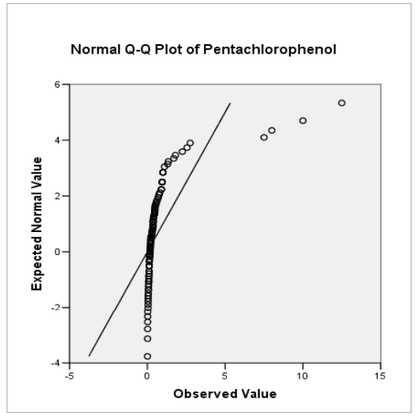


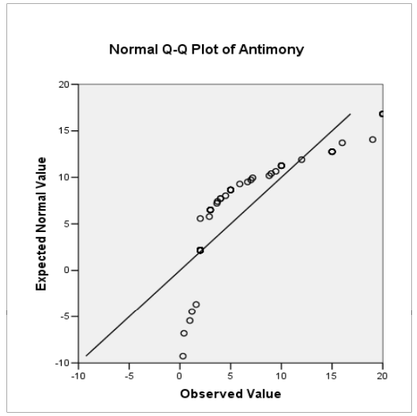
Appendix G Figure G-1. Q-Q Plots of COPCs Retained for Ambient Assessment

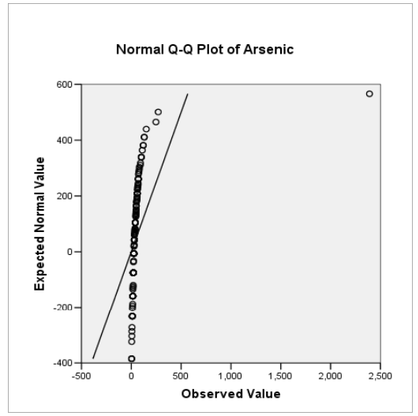
Non-GWSA COPCs

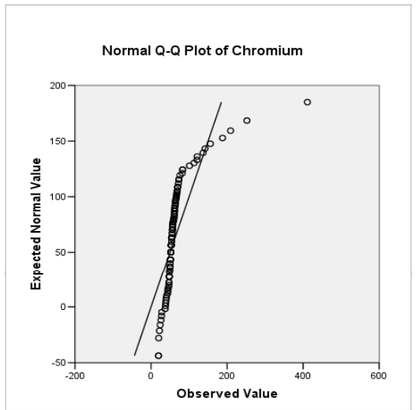


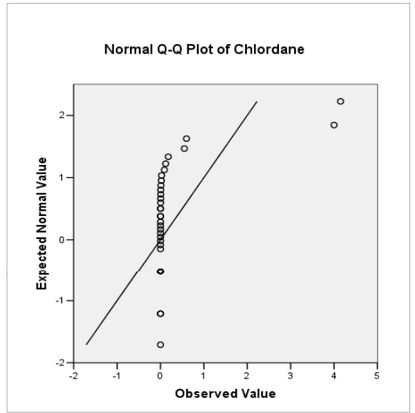


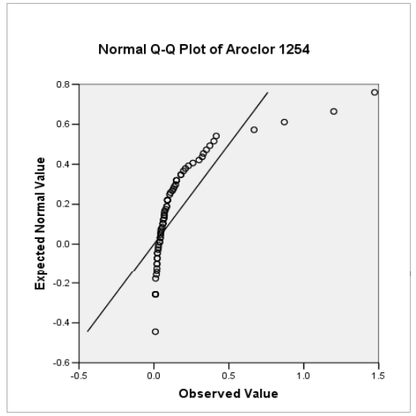


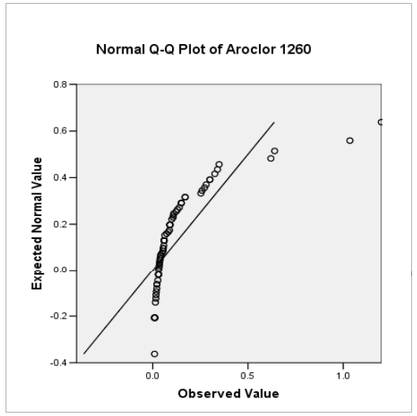


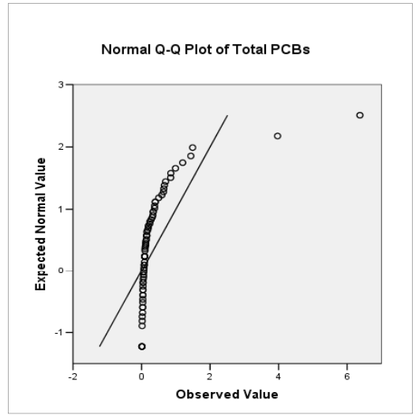


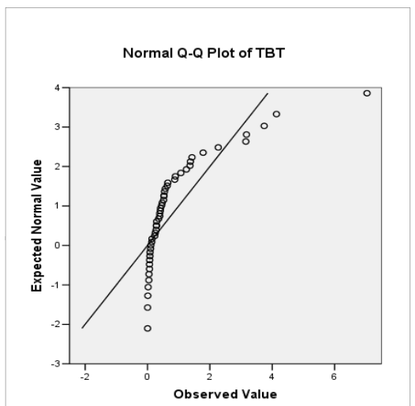


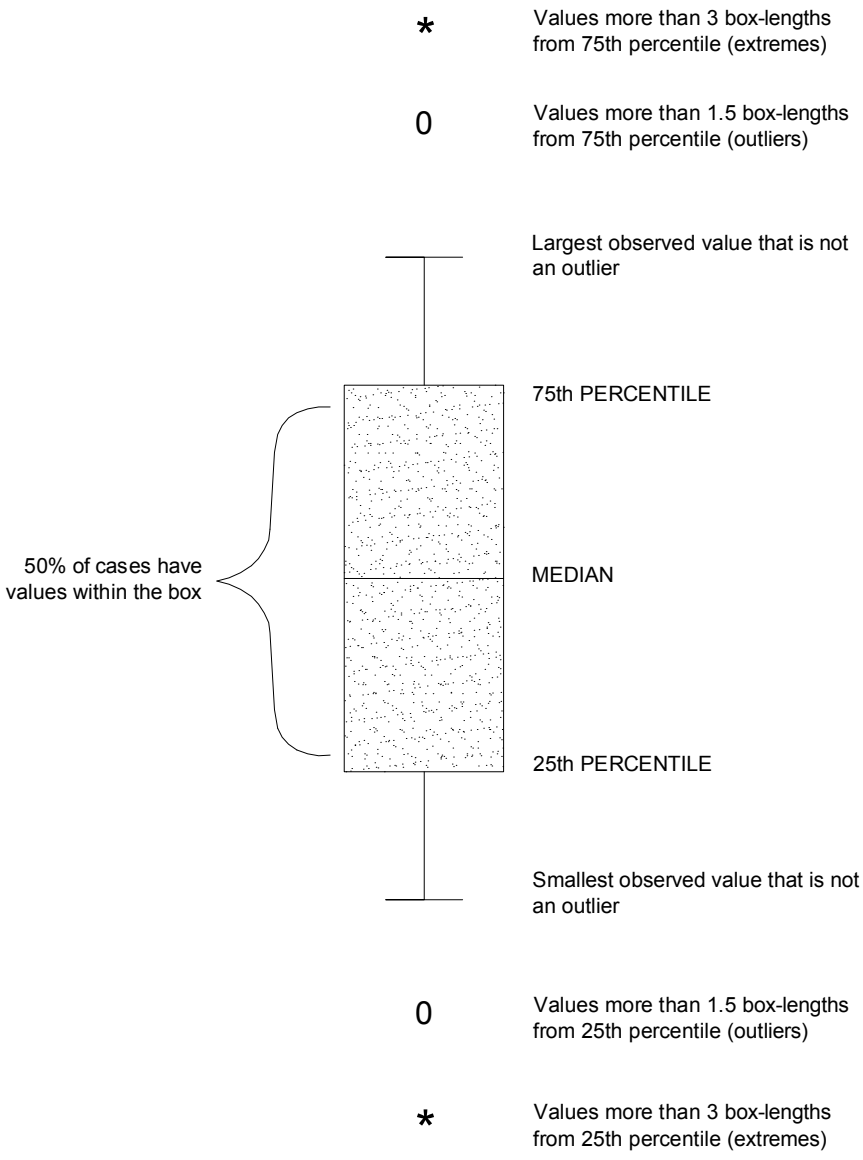












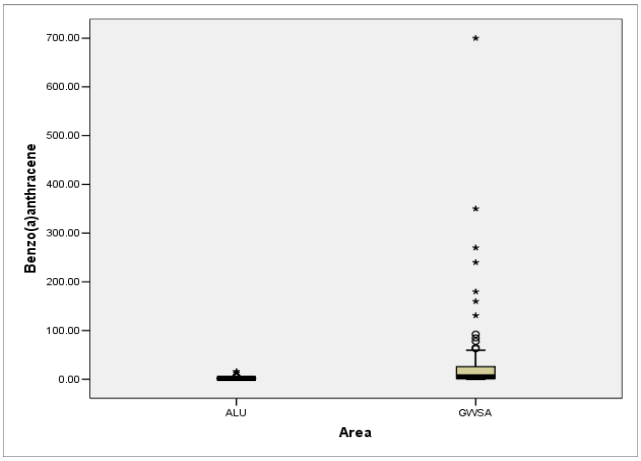
AECOM

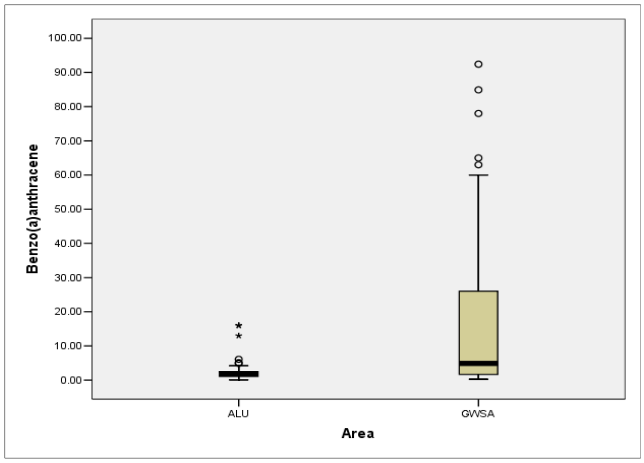
SUPPLEMENT TO THE CLEANUP STANDARDS DOCUMENT GAS WORKS SEDIMENT AREA	**ANNOTATED SKETCH OF A BOXPLOT**
	FIGURE G-2

Appendix G Figure G-3. Box Plots of COPCs Retained for Ambient Assessment

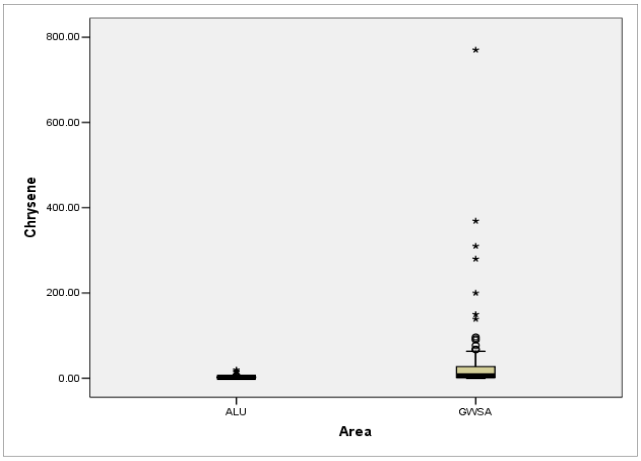
GWSA COPCs

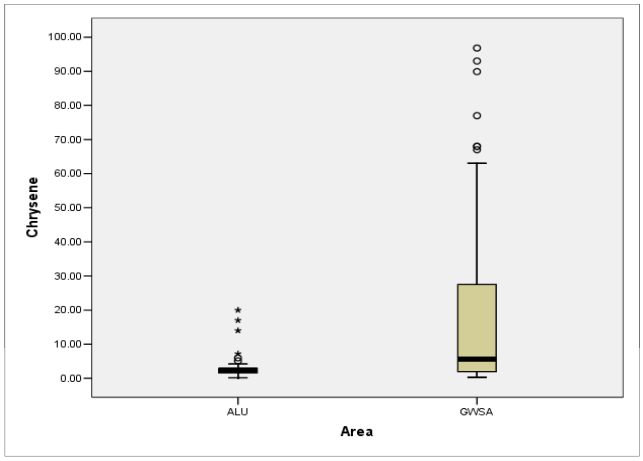
Benzo(a)anthracene





Chrysene





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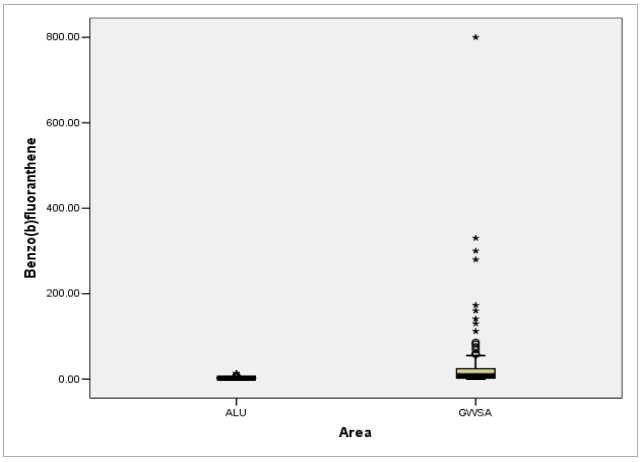
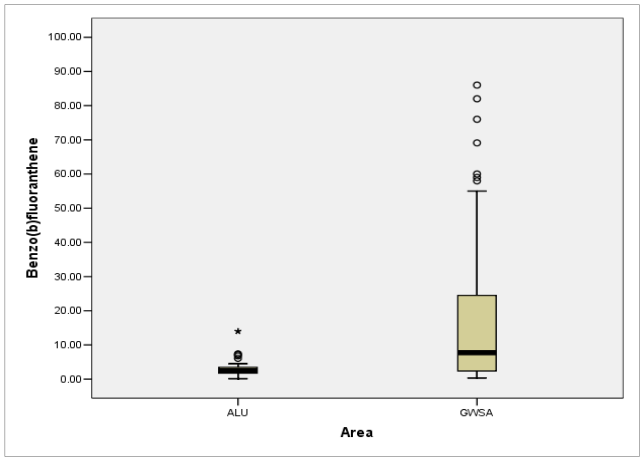
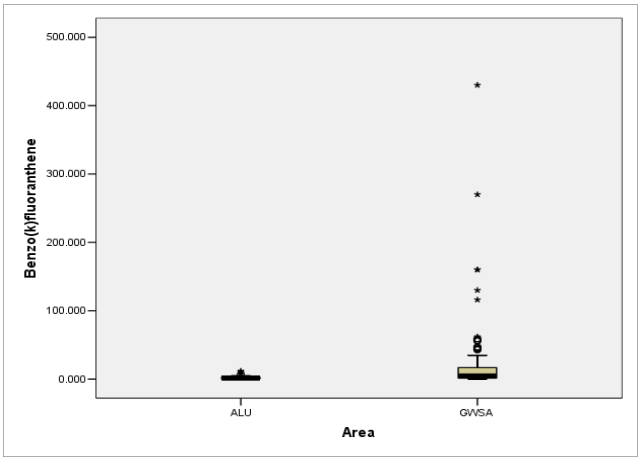
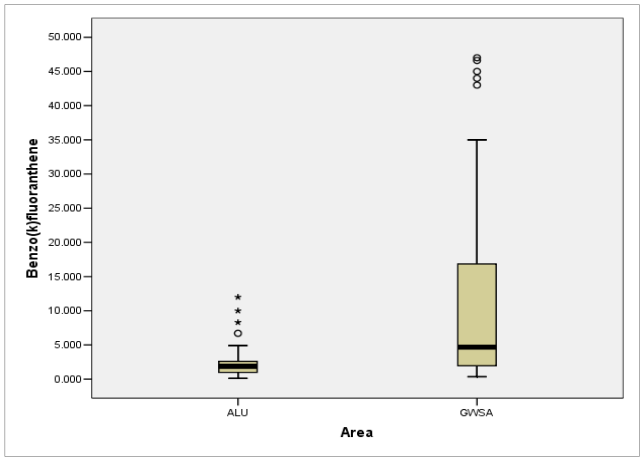




Appendix G Figure G-3. Box Plots of COPCs Retained for Ambient Assessment

Benzo(k)fluoranthene





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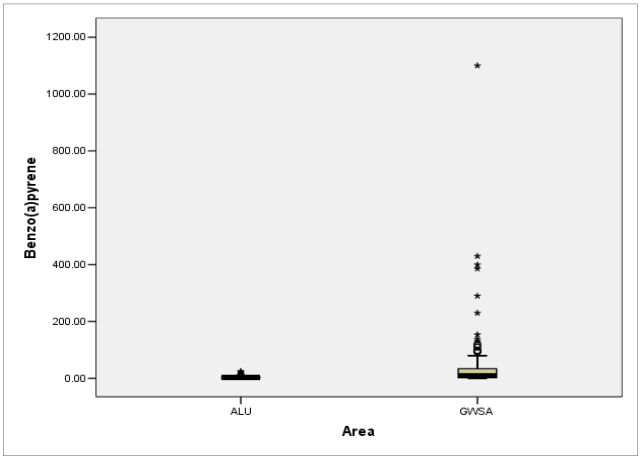

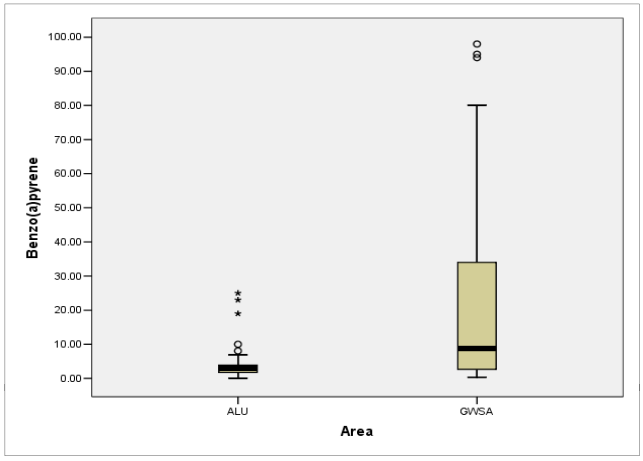

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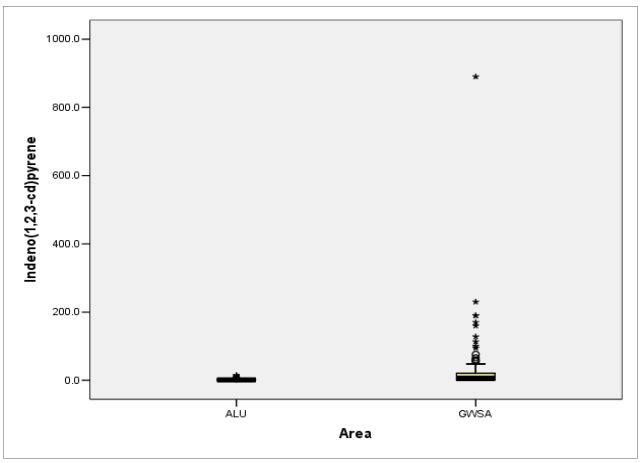
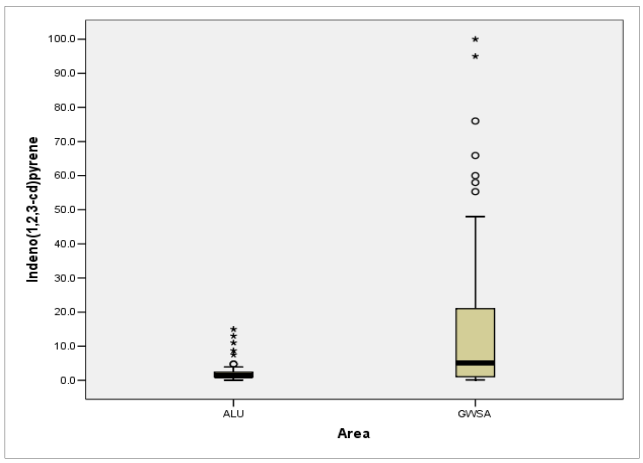
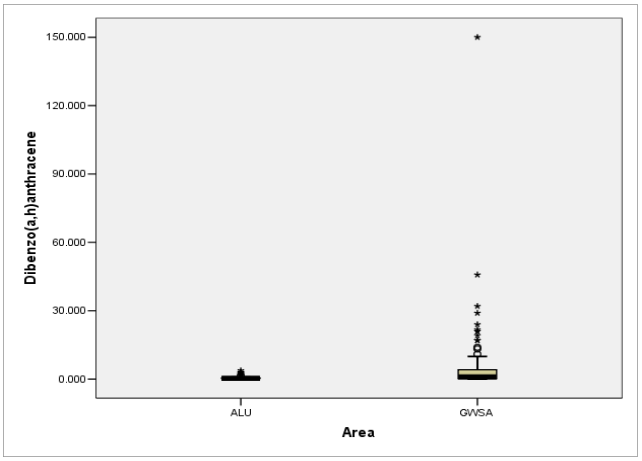
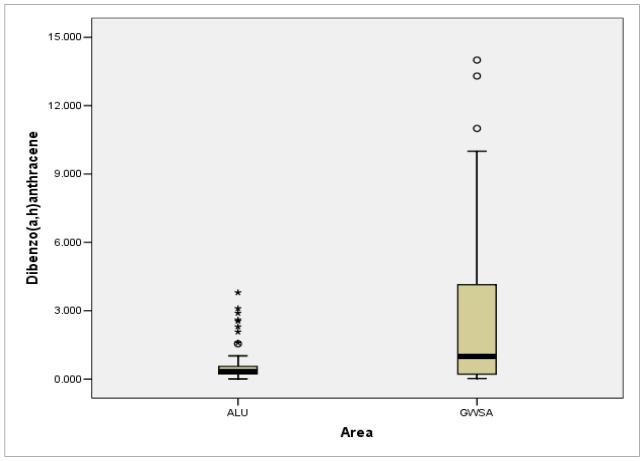




Appendix G Figure G-3. Box Plots of COPCs Retained for Ambient Assessment

Dibenzo(a,h)anthracene





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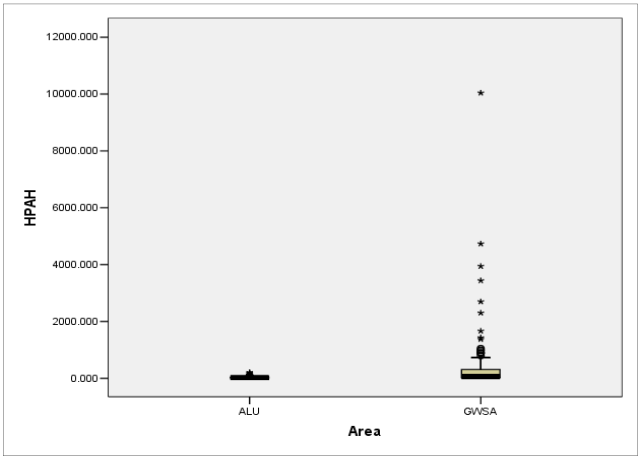

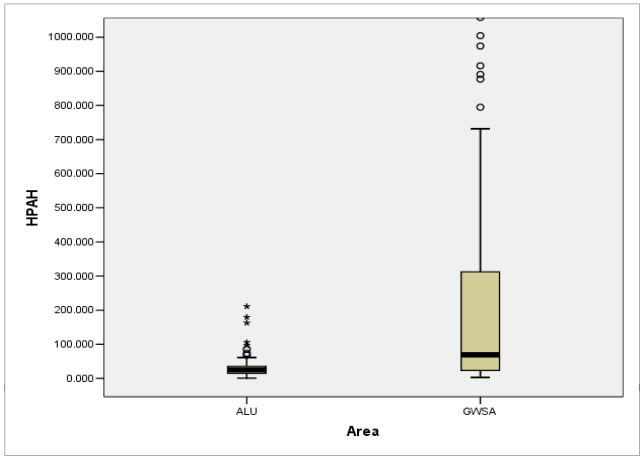

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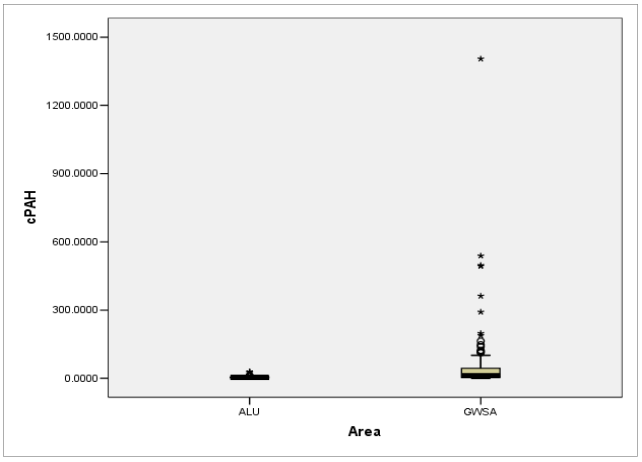
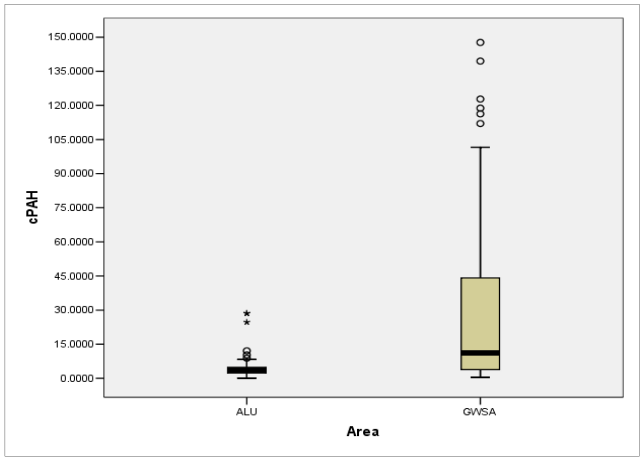
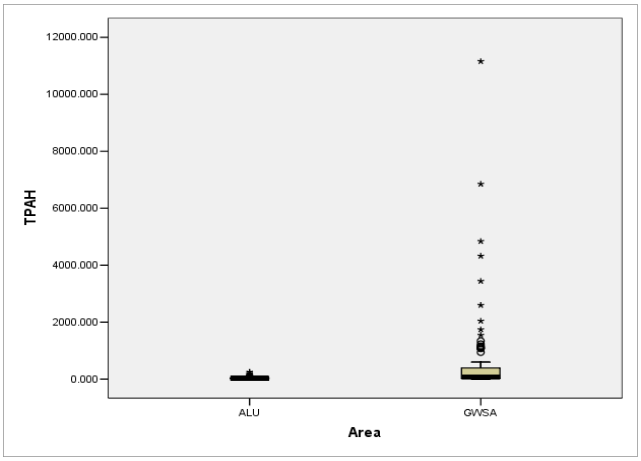
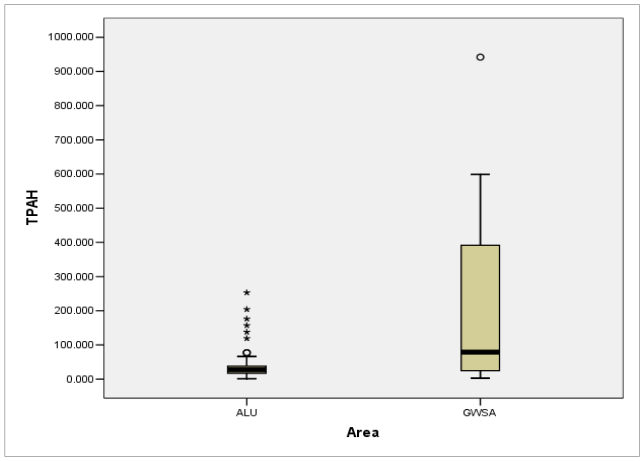




Appendix G Figure G-3. Box Plots of COPCs Retained for Ambient Assessment

TPAH





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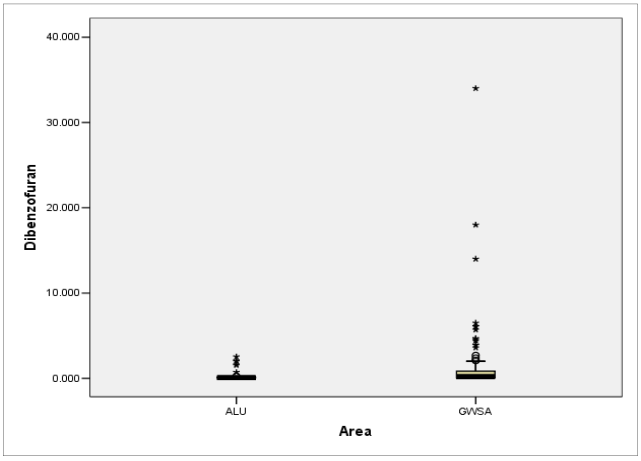

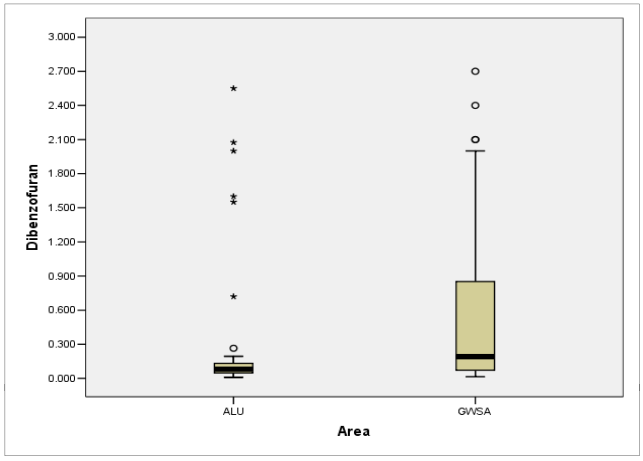

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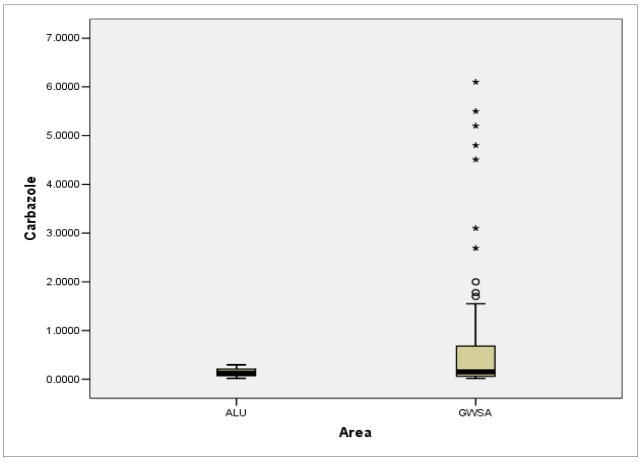

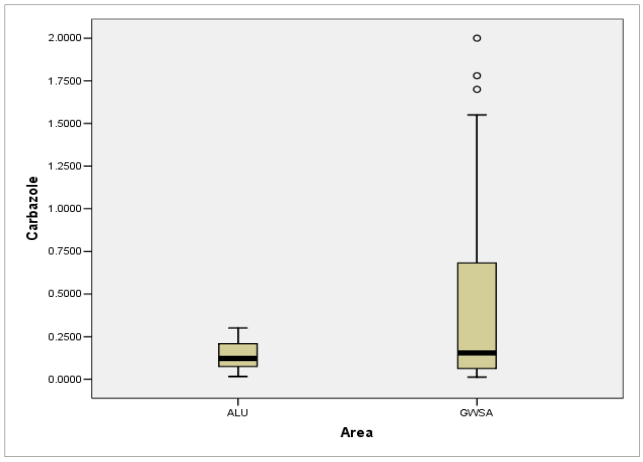

Appendix G Figure G-3. Box Plots of COPCs Retained for Ambient Assessment

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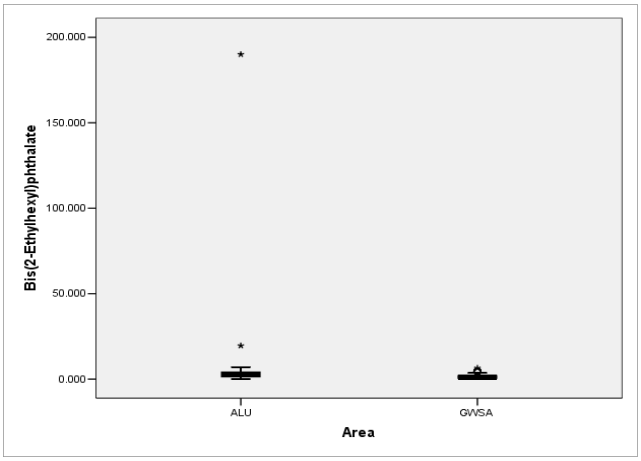
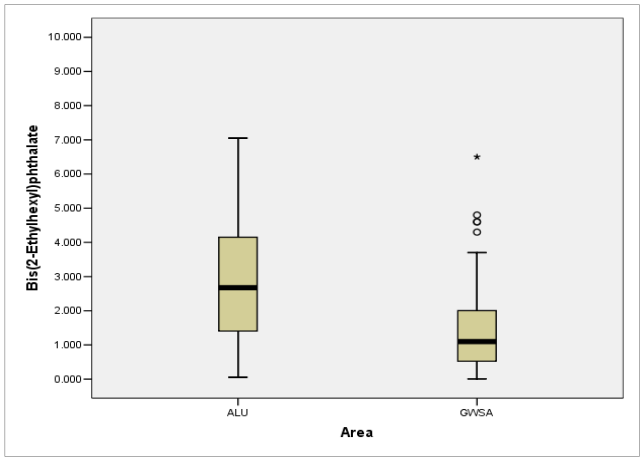
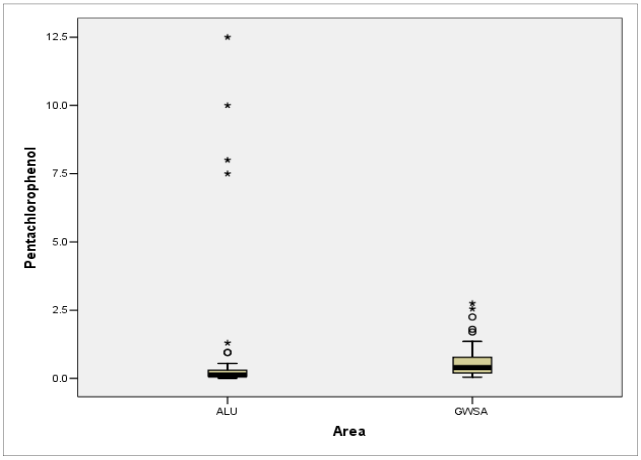
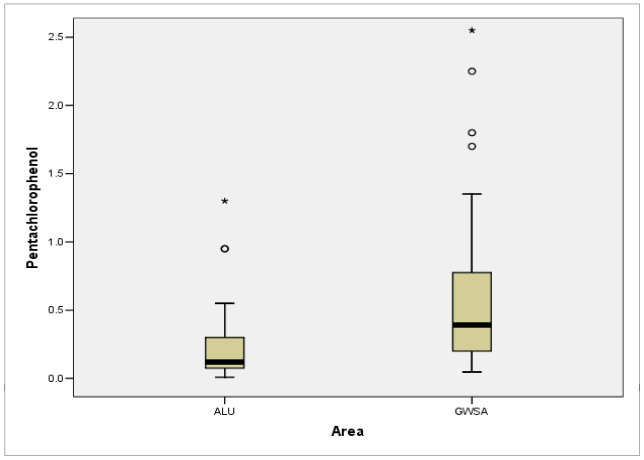


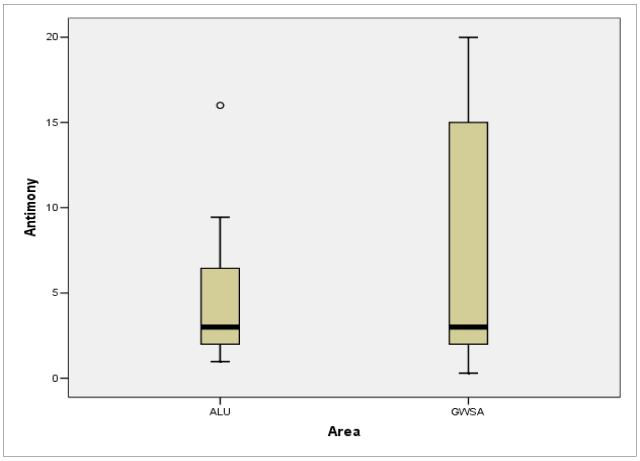


Pentachlorophenol





Antimony



Appendix G Figure G-3. Box Plots of COPCs Retained for Ambient Assessment

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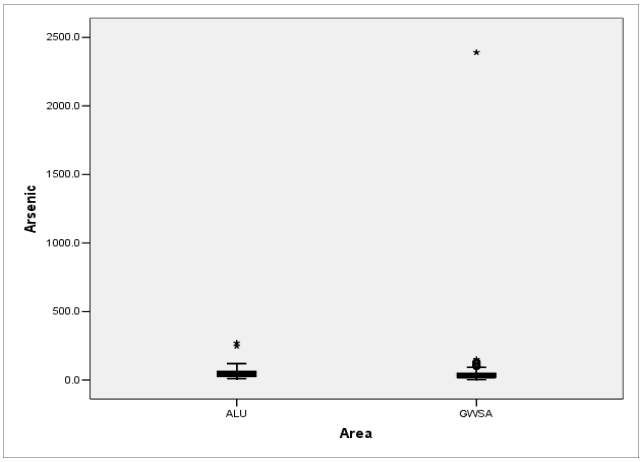

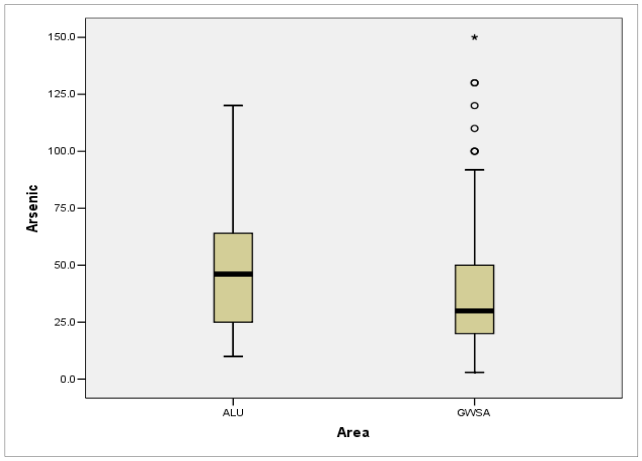

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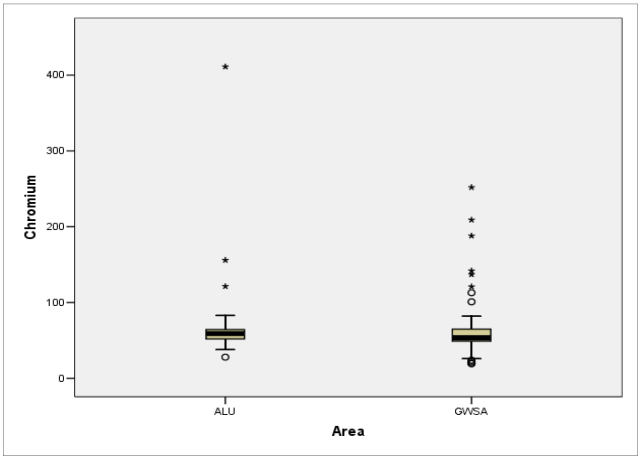

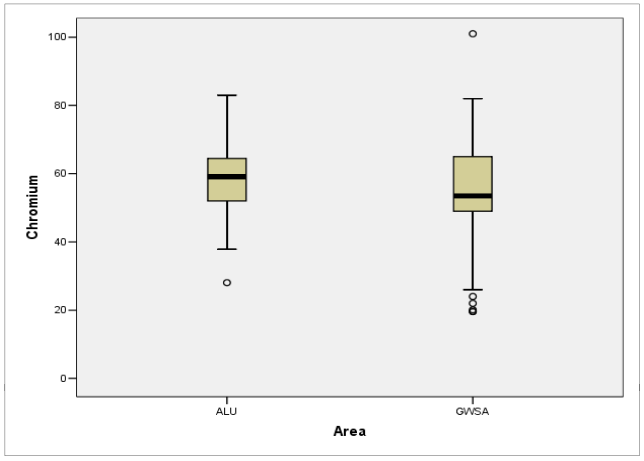

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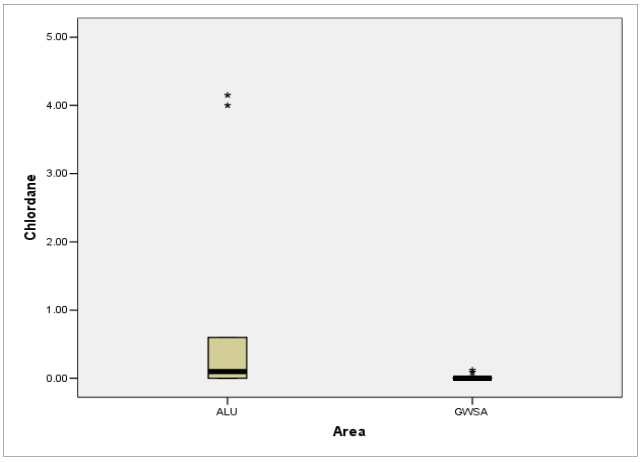

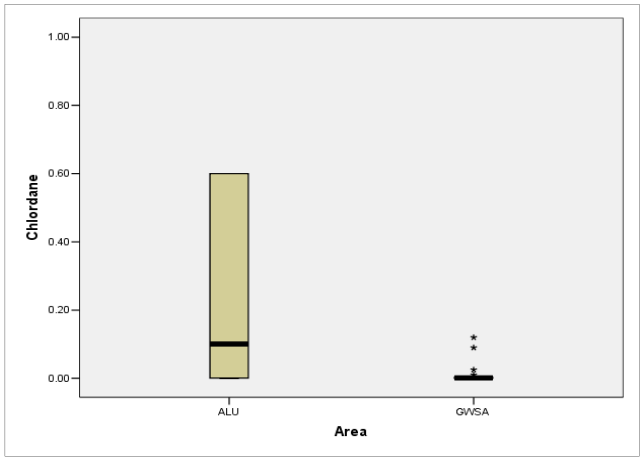

Appendix G Figure G-3. Box Plots of COPCs Retained for Ambient Assessment

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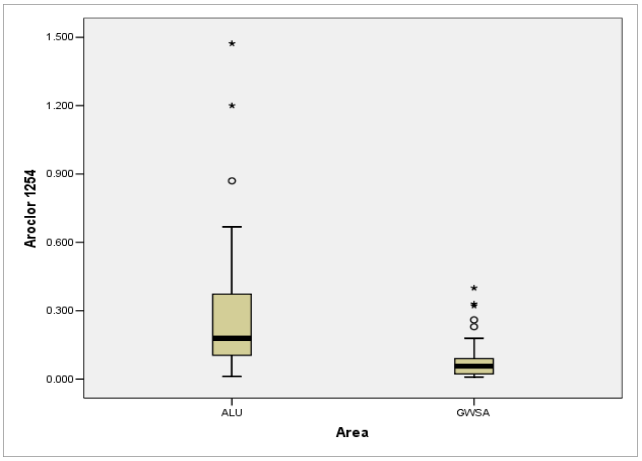

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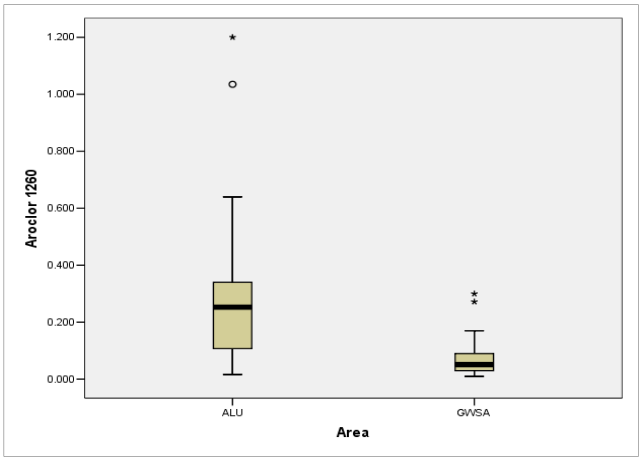

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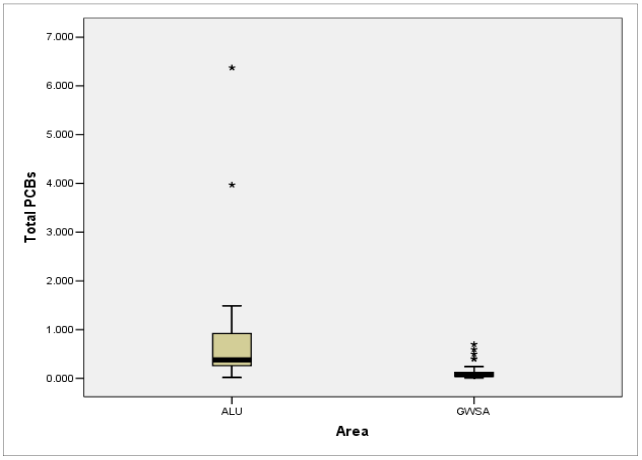

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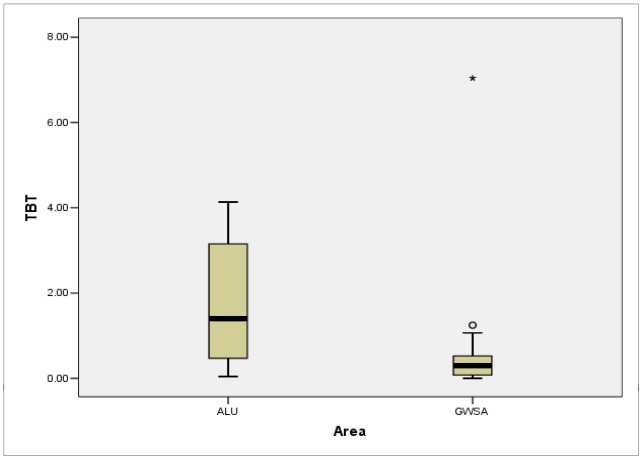

APPENDIX 4D
Upland Risk Evaluation

Table of Contents

ATTACHMENTS

1.0 INTRODUCTION

This appendix summarizes and updates previously performed human health and ecological risk evaluations for the upland portion of the Gas Works Park Site Area of Investigation (AOI). The purpose of these risk evaluations is to determine if contaminants in the AOI upland pose an unacceptable risk to people or ecological receptors under current conditions and, if so, to identify contaminants of concern (COCs) and exposure pathways representing the risk. Locations posing an unacceptable risk under current conditions will be remediated.

Actions that have been completed that inform current conditions are discussed in Section 2 and this appendix and include the following:

- A significant portion of the upland has been capped under the 1999 Consent Decree and subsequent maintenance activities, which prevents exposure to contaminated soil in these areas (see remedial investigation [RI] Sections 2.2.3 and 2.2.4).
- Restrictive covenants were recorded to prohibit cap disturbance, groundwater withdrawal, and any action that could cause a new release of contamination or expose people or environmental receptors to contamination, without prior written approval from Washington State Department of Ecology (Ecology) (see Appendix 2E).
- Human health and ecological risk evaluations have been performed in the upland portion of the AOI. These evaluations include:
    - Human health risk evaluations of soil contaminated by polycyclic aromatic hydrocarbons (PAHs) in the northeast corner (Attachment 4D-1A) and Kite Hill (Attachment 4D-1B) areas.
    - The inhalation pathway evaluation at select indoor or confined spaces (Attachment 4D-2).
    - A terrestrial ecological evaluation (TEE) (Attachment 4D-3).

Risk evaluations are updated in this appendix because of changes in upland conditions (e.g., additional capping) and guidance (e.g., changes to toxicity factors), since these evaluations were performed.

Section 2 presents the upland conceptual site exposure model (CSEM) that explains how exposure can currently occur. Section 3 evaluates human health risks, and Section 4 evaluates terrestrial ecological health risks. References cited are listed in Section 5.

Human health and ecological risks pertaining to contaminated sediment are addressed in Appendix 4C.

2.0 CONCEPTUAL SITE EXPOSURE MODEL

The evaluations described here are based on a human health and ecological CSEM, shown in Figure 4D-1. CSEMs provide a framework for risk evaluation by identifying potential exposure pathways through which organisms or people can contact contaminants and represent a series of assumptions that guide the subsequent risk evaluations. Pathways are described as complete (or potentially complete), incomplete or minor, or not applicable. The upland portions of the CSEM are discussed in this appendix; the sediment portions of the CSEM are discussed in Appendix 4C. For the risk assessments described in this appendix, it was assumed that land use in the upland portion of the AOI in the foreseeable future will remain the same as it is today.

To be considered complete, an exposure pathway must include four elements:

- An identified source of contaminants
- A mechanism of release and transport from the source
- At least one exposure medium
- An exposure route or mechanism where a receptor can contact contaminated media

Section 6 of the main RI report includes a more detailed discussion of sources, pathways, and transport mechanisms, including those relevant to human health and ecological exposure.

2.1. Human Health Conceptual Exposure Model

This section describes the upland human health exposure component of the CSEM developed for the AOI (Figure 4D-1).

2.1.1. Exposure Areas

To characterize potential exposures to soil contamination in uncapped areas under current conditions, four exposure areas were identified (see Figure 4D-2). The areas with uncapped soil are as follows:

- Northeast Corner refers to the uncapped soil surrounding the vegetated soil cap completed north of the Play Barn in 2012 and soil along the shoreline bank east and northeast of the Play Barn. As shown in Figure 4D-2, the Northeast Corner is split into two areas, the Meadow and the Bank, to facilitate postconstruction risk characterization.
- Limited Use Areas refer to the uncapped soil in the parking area, nearby berms, and two small areas near Harbor Patrol. People typically pass through rather than spend time in the limited use areas.
- Cracking Tower Area refers to the uncapped soil inside the security fence surrounding the Cracking Towers.
- Exposed Eroding Bank Areas refer to slivers of uncapped soil east and west of the Prow that are between the vegetated soil caps and the ordinary high-water mark.

Exposures were also evaluated under post-cleanup conditions. That is, after uncapped shoreline bank soils have been addressed as part of the sediment remedy (as anticipated by the 1999 Consent Decree). As shown in Figure 4D-3, areas with uncapped soil evaluated under post-cleanup conditions include the Northeast Corner – Meadow, the Limited Use Areas, and the Cracking Tower Area. The sediment remedy will address the Northeast Corner – Banks and the Exposed Eroding Bank Areas.

The human health risk evaluation focused on soil samples obtained in uncapped areas from the depth interval of 0 to 1 foot below ground surface (bgs), a depth below which park users and park maintenance workers are not expected to contact soil. The soil caps, which are typically 1 foot thick, but range from 6 inches to 4 feet thick, and geotextile barriers beneath the caps prevent exposure to contaminated soil in capped areas. As noted in Section 1.0, a restrictive covenant is in place that prohibits cap disturbance or any action that may result in the release or exposure to the environment of contamination that remains on the property without prior written approval by Ecology. Following Ecology approval, construction workers could contact soil below the protective caps; however, any work deeper than 1 foot bgs would be performed

by Hazardous Waste Operations and Emergency Response (HAZWOPER)-trained workers with appropriate engineering controls and personal protections.

2.1.2. Potential Receptors

People who may be exposed to contaminants in the upland portion of the AOI fall into one of three groups, as described below:

- Park users (adults and children)
- Park maintenance workers
- Construction workers

Park users are the same as recreational users described in previous Gas Work Park risk assessments. Reasonable maximum exposure (RME) or upper-bound exposure for park users was based on an assumed visitation frequency of 1 to 3 days per week. Exposure to contaminants is expected to be lower for this group than is assumed under a residential exposure scenario (the default exposure scenario under Model Toxics Control Act [MTCA]), which assumes an exposure frequency of 365 days per year.

Park maintenance workers and construction workers have been identified as potential receptor groups; however, potential risks for these workers were not calculated because the park-user scenario is protective of these other potential receptors. Park users are assumed to have more exposure[1] to contamination than these other receptor groups.

2.1.3. Potential Exposure Pathways

Incidental ingestion of and dermal (skin) contact with soil, and inhalation of indoor and outdoor air are the only complete or potentially complete exposure pathways for people (Figure 4D-1). Exposure for complete pathways could occur in the few accessible areas shown in Figure 4D-2 that are not covered with a soil cap, buildings, pavement, or other material that would otherwise prevent exposure to contaminated soil. Human health exposure pathways in areas that are capped or covered with gravel, pavement, or buildings are considered incomplete. Ingestion of and dermal (skin) contact with upland groundwater are also considered incomplete exposure pathways because groundwater is not used for drinking or irrigation[2].

Inhalation of outdoor air is considered a potentially complete exposure pathway. However, the potential exposures for this pathway are minimal relative to the incidental ingestion and dermal contact pathways that are evaluated in this RI. For example, the potential risks associated with soil ingestion are more than 1,000 times higher than those associated with inhalation for carcinogenic polycyclic aromatic hydrocarbons (cPAHs) and arsenic[3].

Complete or potentially complete exposure pathways in the upland area are evaluated in Section 3.

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[1] Exposure is driven by a combination of exposure frequency (days per year of exposure) and exposure duration (years of exposure). Park users are assumed to be at the AOI upland more days per year and for more years than park maintenance and construction workers.

[2] An environmental covenant prohibits withdrawal of groundwater for any use other than remediation.

[3] See ingestion and inhalation carcinogenic screening levels for benzo(a)pyrene and arsenic in U.S. Environmental Protection Agency's (EPA's) Regional Screening Levels (RSL) Resident Soil Table, April 2019 (EPA 2019b).

2.2. Ecological Conceptual Site Exposure Model

This section describes the upland ecological receptors and exposure component of the CSEM developed for the AOI upland. As shown in Figure 4D-1, the following terrestrial ecological exposure pathways were identified as incomplete or minor:

- Plants – contact with groundwater.
- Soil biota – ingestion of and dermal contact with soil and contact with groundwater.
- Wildlife – incidental ingestion of and dermal contact with soil and consumption of plants and soil biota.

An upland TEE was conducted in 2012 as part of an upland remedial investigation for Ecology (Attachment 4D-3). The 2012 upland TEE divided the AOI upland into eight upland areas (A through H; see Figure 4D-4), which are also evaluated in the updated TEE.

Upland terrestrial ecological receptors, exposure pathways, and exposure areas are evaluated in the updated upland TEE in Section 4.

3.0 UPLAND HUMAN HEALTH RISK EVALUATION

This section summarizes the most recent evaluations conducted for the upland portion of the AOI. Risk calculations previously performed have been updated to more closely reflect current conditions in the upland and to incorporate current toxicity data and MTCA exposure assumptions.

- In 2010, ENVIRON conducted two human health risk evaluations focusing on cPAHs for Seattle Parks and Recreation (Attachments 4D-1A and 4D-1B). The ENVIRON risk evaluations have been updated to incorporate new data, new toxicity criteria, and to account for additional capping.
- Floyd|Snider conducted indoor and outdoor air sampling in 2007 and 2008 to evaluate the inhalation pathway at several upland areas. The summary risk evaluation document is included as Attachment 4D-2.

3.1. Soil Ingestion and Dermal Contact

Updates to the ENVIRON risk evaluations (Attachments 4D-1A and 4D-1B) were needed because since this work was completed additional capping occurred in 2012 and 2014, additional surface soil samples were obtained in 2010, 2011, and 2013, and U.S. Environmental Protection Agency (EPA) updated the toxicity criteria for benzo(a)pyrene in 2017 (EPA 2019a). The updated risk evaluation focuses on portions of the upland that remain uncapped or are not covered by gravel, pavement, or buildings and includes the following areas shown on Figure 4D-2.

- Northeast Corner: adjust ENVIRON risk evaluations to account for additional capping that occurred in 2012 as part of maintenance activities.
- Cracking Tower Area: because most of the area, formerly referred to as the “southwest corner” in the ENVIRON risk evaluations, is now under a clean soil cap that was placed as part of maintenance activities in 2014. This area is referred to as the “Cracking Tower” area in the updated risk evaluation.
- Limited Use Areas: uncapped areas in the north-central and western portions of the upland, including the parking lot, nearby treed areas south of the walking path, and two small areas near Harbor Patrol.
- Exposed Eroding Bank Areas: uncapped shoreline bank soil.

3.1.1. Data Set

The updated human health risk evaluation focused on soil samples from the depth interval of 0 to 1 foot bgs, a depth below which park users and park workers are typically not expected to contact soil. A potentially conservative bias was introduced into the data set by including samples whose top depth ranged between 0 and 1 foot bgs (and up to 5 feet in the exposure eroding bank area) and whose bottom depth was slightly deeper than 1 foot bgs. Separate data sets were identified for each of the four areas studied (northeast corner, Cracking Tower area, limited use areas, and exposed eroding bank areas).

The data set used to evaluate the exposed eroding bank areas included soil samples collected from adjacent capped areas prior to capping, since only two soil samples were collected from the eroding bank areas. To calculate surface soil concentrations to use in the risk characterization, soil samples (collected before capping) within 100 feet of the shoreline were used. These soil samples, which were collected from the top 5 feet and represent the fill horizon, are shown on Figure 4D-2.

Replicate samples obtained at several locations were averaged to avoid spatial bias in these areas[4].

Potential risks from exposure to soil contaminated with cPAHs were evaluated by using cPAH toxicity equivalent (TEQ) concentrations[5]. However, three surface soil samples included in the data set (one in the northeast corner and two in the limited use areas), which had been obtained by the University of Washington in 1984, had been analyzed for benzo(a)pyrene only and not the remaining six individual cPAH constituents used to calculate cPAH TEQ. For these three samples, the cPAH TEQ concentration was estimated from the ratio of cPAH TEQ to benzo(a)pyrene in other surface soil samples with both benzo(a)pyrene and cPAH TEQ data. The minimum, maximum, and average ratios are 1.20, 1.51, and 1.34, respectively. The average cPAH TEQ-to-benzo(a)pyrene ratio was used to estimate cPAH TEQ concentrations for the three samples noted above.

3.1.2. Chemicals Evaluated

The ENVIRON risk evaluations (Attachments 4D-1A and 4D-1B) were limited to potential risks associated with both benzo(a)pyrene and cPAH TEQ (which also includes benzo(a)pyrene) in soil. For a more comprehensive review of potential risk, the updated risk evaluation also considers other COCs included in the 1999 upland cleanup action plan (CAP) (Parametrix 1999) for soil and groundwater. Naphthalene; pyrene; fluoranthene; benzene, toluene, ethylbenzene, and xylenes (BTEX); and arsenic were evaluated in addition to cPAHs in soil. COCs that were included in the risk evaluation were identified by comparing the maximum detected surface soil concentrations from the northeast corner, Cracking Tower area, and the limited use areas[6] against the soil screening levels identified in Section 4 of the RI report, if available, or MTCA Method B soil cleanup levels for direct contact (see Table 4D-1 for results of the screening). Compounds whose concentrations were greater than screening levels were retained for further evaluation in the updated risk evaluation and were: cPAHs and arsenic. BTEX, fluoranthene, naphthalene, and pyrene in soil were not retained for further risk evaluation because they did not exceed screening levels.

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[4] This approach affected the following sample locations, with all soil samples having been collected from a depth of 0 to 2 inches bgs: C27 (northeast corner, five samples) and WW19-03 and WW19-04 (northeast corner; two samples at each location).

[5] TEQ for cPAH is calculated as the sum of the concentrations of individual cPAHs normalized to their toxicity relative to that of benzo(a)pyrene.

[6] The exposed eroding bank areas were not used to screen upland COCs since few, if any, soil samples were collected in these areas.

3.1.3. Input Parameters and Assumptions

The exposure parameter values used to evaluate risks to park users have been updated from those used in the ENVIRON (Attachments 4D-1A and 4D-1B) risk evaluations to be consistent with current Ecology guidance.

ENVIRON included an exposure parameter "Fraction of Time Spent" to reflect the amount of time park users would spend at each area as a fraction of the time they would spend at the entire park. These fractions were calculated as the spatial extent of uncapped soil within each exposure area divided by the entire area of the upland portion of the AOI. This parameter assumed that a user visits all areas of the park and that the amount of time spent in each area is proportional to size of each area.

In 2010, ENVIRON estimated that the northeast and southwest corners of the upland portion of the AOI represented 13 percent and 30 percent, respectively, of the AOI upland. Since then, placement of soil caps in the northeast and southwest corners has reduced the areas associated with the direct-contact pathway. Accordingly, the fraction-of-time-spent values for the remaining northeast corner (meadow and bank) and the Cracking Tower area, which is the only part of the former southwest corner that has not been capped, were modified to 5.3 percent and 4.8 percent, respectively. The Cracking Tower area is fenced with "No Trespassing" signs posted indicating that access to the area is not permitted.

The fraction of time spent value for the limited use areas was reduced by 75 percent from 7.4 percent to 1.8 percent because people will typically be passing through rather than spending time in the limited use areas. Likewise, the original fraction-of-time-spent value for the exposed eroding bank areas of 0.7 percent was reduced by 90 percent to 0.07 percent because access is very limited due to the presence of blackberries (people can only be exposed to surface soil on small paths through these areas)[7].

The northeast corner (meadow and bank), Cracking Tower area, limited use areas, exposed eroding bank areas, and the upland portion of the AOI are shown in Figure 4D-2, which shows exposure areas under current conditions.

Figure 4D-3 shows exposure areas after uncapped shoreline bank soils have been addressed as part of the sediment remedy (that is, under post cleanup conditions). As shown in Figure 4D-3, exposure areas under post cleanup conditions include the northeast corner (meadow), the limited use areas, and the Cracking Tower area.

Exposure parameters and values used in the upland risk evaluation are included in Tables 4D-2 and 4D-3. Table 4D-3 includes values and parameters applicable to most COCs. The values and parameters in Table 4D-3 are used to evaluate the potential carcinogenic effects associated with cPAHs, which includes age-dependent adjustment factors (ADAFs) to account for the potential of an increased susceptibility to cancer from early-life exposure to cPAHs, relative to exposure as an adult (EPA 2005a).

Chemical-specific values, including toxicity values and absorption values, are included in Table 4D-4.

[7] The reductions in the fraction of time spent in the limited use and exposed eroding bank areas results in an increase of the fraction of time spent at the rest of the upland portion of the AOI, most of which is capped with soil or covered with impervious surfaces or gravel. Increases in the fraction of time spent in the uncapped and uncovered portions of the northeast corner are insignificant.

3.1.4. Risk Characterization

The estimated carcinogenic risk and non-carcinogenic hazard for park user exposure to surface soil under current and post-cleanup conditions at the AOI are included in Table 4D-5 and Table 4D-6, respectively. The carcinogenic risk estimates are also summarized by exposure area (see the in-text table at end of this subsection). The estimates were calculated for individual areas and then totaled to account for individuals exposed in all three areas.

RME soil concentrations were calculated using EPA's ProUCL 5.0 software (ProUCL output files are included in Attachment 4D-4). RME soil concentrations are the lesser of either the ProUCL-recommended 95 percent upper confidence limit (UCL) on the arithmetic mean or the maximum detected concentrations.

As shown in Table 4D-5, the non-carcinogenic hazard indices for the park user under current and post-cleanup conditions are 0.02 and 0.01, respectively. These values are well below the Ecology acceptable hazard index of 1.0. These results indicate that the COCs in surface soil are unlikely to pose an unacceptable non-carcinogenic hazard to people in the AOI upland. The cancer risks under current and post-cleanup conditions are summarized in the table below.

CURRENT CONDITIONS – RME PARK USER CARCINOGENIC RISK ESTIMATES

Risk Evaluation	Risk Evaluation – RME Park User Carcinogenic Risk Estimates				
	Northeast Corner (Meadow & Bank)	Cracking Tower	Limited Use Areas	Exposed Eroding Bank Areas	AOI Upland
Arsenic	3×10^{-7}	--	--	6×10^{-9}	3×10^{-7}
cPAH TEQ	2×10^{-6}	5×10^{-9}	1×10^{-7}	1×10^{-7}	2×10^{-6}

Note:
Risk results may appear to sum incorrectly because of rounding to one significant digit.

POST-CLEANUP CONDITIONS – RME PARK USER CARCINOGENIC RISK ESTIMATES

Risk Evaluation	Risk Evaluation – RME Park User Carcinogenic Risk Estimates			
	Northeast Corner (Meadow Only)	Cracking Tower	Limited Use Areas	AOI Upland
Arsenic	2×10^{-7}	--	--	2×10^{-7}
cPAH TEQ	1×10^{-6}	5×10^{-9}	1×10^{-7}	1×10^{-6}

Note:
Risk results may appear to sum incorrectly because of rounding to one significant digit.

3.1.5. Conclusion

The human health risk evaluation was conducted for areas of the upland that remain uncapped using exposure parameter values consistent with MTCA. The total cancer risk for exposures to arsenic and cPAHs in the four uncapped areas under current conditions is 2×10^{-6}, primarily due to cPAHs in the northeast corner. However, addressing uncapped shoreline bank soil as part of the sediment remedy (as anticipated by the 1999 Consent Decree) will reduce the human health risk under post-cleanup conditions to acceptable levels (1×10^{-6}).

3.2. Inhalation of Indoor and Outdoor Air

Contaminants can be transported in outdoor air as dust via wind erosion and dispersion, and as vapors via volatilization from soil and groundwater. Contaminants can be transported to indoor air via vapor intrusion from soil and groundwater. Potential exposure to contaminants via dust is expected to be minimal. Approximately 80 percent of the AOI upland has been capped or is otherwise covered with buildings, asphalt, concrete, or other impermeable surfaces (see Figure 4D-2), and the City of Seattle (City) regularly waters the remaining portion of the upland (also, see fugitive dust discussion in Section 2.1.2). The pathways involving exposure via volatilization to outdoor air and vapor intrusion to indoor air are considered minor exposure pathways (Attachment 4D-2). However, the inhalation pathway was reevaluated in this RI to confirm its prior classification as incomplete or minor.

Floyd|Snider initiated outdoor and indoor air sampling for the City to evaluate mothball-like odors near the Play Barn, the old manufactured gas plant structures, and the eastern shoreline (see air sample locations on Figure 4D-2). Air samples were obtained during three rounds in 2007 and 2008 to characterize air quality at several locations and during several seasons. Most of the air samples were obtained using thermal desorption tubes and analyzed by high-sensitivity mass spectrometry. In addition, an aromatic-specific laser ionization detector was used to conduct continuous air monitoring during the second round of sampling (August 2007).

Outdoor air samples were obtained at the Cracking Tower, the eastern shoreline, and upwind at the Prow (prevailing winds are from the southwest). Indoor air samples were obtained in the Play Barn basement (belowground confined space not accessible to the public) and the Harbor Patrol building. The air samples obtained in the Play Barn basement represent worst-case results for the park based on its location relative to subsurface contaminant and because it is a partially belowground space.

3.2.1. Results

Outdoor and indoor air results are summarized in Table 4D-7; applicable air cleanup levels (CULs) and background air concentrations are included. Four air CULs are presented in Table 4D-7: standard MTCA Method B (for unrestricted land use), park user, Harbor Patrol worker, and Play Barn basement – limited worker access.

- Standard MTCA Method B Air CUL – The MTCA Method B air CUL is included to show air concentrations protective of people exposed to outdoor or indoor air 24 hours per day, 365 days per year over either 6 years (for non-carcinogens) or 30 years (for carcinogens). These standard MTCA Method B exposure assumptions significantly overestimate exposure for the receptors considered in this evaluation.
- Park User Air CUL – The air CUL for regular park users (outdoor air) was calculated using the standard MTCA Method B equations (750-1 and 750-2), with modifications for exposure. The standard MTCA Method B air CUL is calculated using an exposure frequency value of 1, which corresponds to exposure 24 hours per day, 365 days per year (8,760 hours per year or 168 hours per week). The park user air CUL (Attachment 4D-2) reflects an assumed exposure of 4 hours per week, which results in an adjusted exposure frequency of 0.024 (4 hours per week divided by 168 hours per week). The Floyd|Snider park user exposure frequency of 4 hours per week is equivalent to an exposure frequency of 4 hours per day during 52 days per year or 2 hours per day during 104 days per year. These values bracket the

ENVIRON upper-bound user exposure frequency assumption of 78 days per year and are consistent with the park user exposure frequency of 104 days per year used in upland soil ingestion and dermal contact risk evaluation. The park user air CUL values are protective of park maintenance and construction workers because park users are assumed to have more exposure to contamination than the workers.

- Harbor Patrol Worker Air CUL – An updated exposure scenario was developed for this RI to evaluate potential risk to workers in the Harbor Patrol building. The Harbor Patrol air CUL reflects an assumed exposure of 9 hours per day, 5 days per week, 50 weeks per year (2,250 hours per year). The adjusted exposure frequency value for the Harbor Patrol worker is 0.26 (2,250 hours per year divided by 8,760 hours per year).
- Play Barn Basement – Limited Worker Access Air CUL – An updated exposure scenario was developed for this RI to evaluate potential risk to workers that enter the locked Play Barn basement; the basement is inaccessible to park users. The Play Barn Basement air CUL reflects an assumed exposure of 2 hours per day, 1 day per week, 50 weeks per year (100 hours per year). The adjusted exposure frequency value for the Play Barn basement limited access worker is 0.011 (100 hours per year divided by 8,760 hours per year).

Outdoor air background values shown in Table 4D-7, obtained from *Tacoma and Seattle Area Air Toxics Evaluation* (PSCAA and UW 2010), are 95th percentile values for the Duwamish and Beacon Hill air monitoring stations (90th percentile values were not reported). Local upwind outdoor air concentrations are represented by data from the Prow sample locations. Indoor air background values were obtained from EPA (EPA 2011a).

As shown in Table 4D-7, the outdoor air, Harbor Patrol building indoor air, and Play Barn basement air concentrations are less than applicable air CULs or background air levels.

3.2.2. Conclusion

Based on the discussion above and the information presented in Table 4D-7, the outdoor air and indoor air concentrations detected at the AOI upland are unlikely to pose an unacceptable risk to park users, Harbor Patrol workers, and park workers that access the Play Barn basement.

4.0 TERRESTRIAL ECOLOGICAL EVALUATION

The upland TEE conducted in 2012 as part of an upland remedial investigation (Attachment 4D-3) for Ecology focused on arsenic and benzo(a)pyrene, the primary soil COCs identified in the 1999 CAP. For the present comprehensive RI, risks were re-evaluated for ecological receptors due to a change in exposure areas following additional capping. The 2012 upland TEE is included in Attachment 4D-3; the updated evaluation is summarized in this section.

The AOI does not qualify for exclusion from the TEE analysis due to the quantity of undeveloped land and the spatial area and depth of contaminated soil. A site-specific TEE is not required because the park is not managed to maintain native or semi-native vegetation and is not inhabited by endangered or threatened animals or plants or State species of concern (Attachment 4D-3). Thus, a simplified TEE was conducted.

4.1. Simplified TEE

The MTCA simplified TEE approach includes three components. The exposure analysis considers the areal extent of contaminated soil and the likelihood of substantial wildlife exposure according to a scoring system in MTCA Table 749-1. The pathways analysis considers whether potential exposure pathways to soil biota, plants, or wildlife are complete. The contaminants analysis considers the concentrations of hazardous substances. If the evaluation criteria of any one of the three components of the simplified TEE are fulfilled, the TEE is ended, and it is concluded that ecological exposures in the upland portion of the AOI are not of concern. No cleanup levels are required for the TEE and no additional ecological analysis is needed. If none of the criteria are fulfilled, the TEE is not ended. In this case, the screening levels in MTCA Table 749-2 may be used as cleanup levels or a site-specific TEE may be conducted.

The scoring analysis in MTCA Table 749-1 (see Attachment 4D-5) was used to evaluate the likelihood of substantial wildlife exposure. An initial acreage score is assigned based on the amount of contiguous undeveloped land within 500 feet of contaminated soil. Four characteristics of the upland portion of the AOI are scored to evaluate the quality of the habitat and the nature of the chemicals present. If the sum of the characteristic scores exceeds the initial acreage score, the TEE is ended.

The 2012 upland TEE divided the AOI upland into eight upland areas (A through H; see Figure 4D-4) that are evaluated to develop the initial acreage score. Soils capped under the 1999 Cleanup Action Plan and Consent Decree are not considered undeveloped land. Capped areas, which include Areas A, D, E, G and part of C, typically include a foot or more of topsoil underlain by an impermeable low-density liner, geotextile, and/or a compacted gravel layer (soil caps are shown in Figure 2-7). In addition, Area B is largely paved or covered with constructed landscape berms that include a layer of organic duff. Area H is paved or covered with a building. For the purposes of the TEE, these areas are considered developed land that is not subject to evaluation. Remaining contiguous undeveloped land includes two areas totaling 1.5 acres: Area C (1.0 acres) and Area F (0.52 acres) (Figure 4D-3). The initial acreage score is 7 points.

The property is zoned for industrial/commercial use, but the current use as a park is not consistent with industrial/commercial use, so the score for land use is 1 point. The ground cover of the park is primarily mown grass and invasive Himalayan blackberries, both with low habitat value, so the score for habitat quality is 3 points. The park is likely to attract wildlife, so the score for wildlife is 1 point. No chemicals of special ecological concern (a specific list including pesticides and polychlorinated biphenyls (PCBs) is provided in MTCA Table 749-1) are present in the uplands, so the score for chemicals is 4 points. The total characteristics score site characteristics is 9 points.

The total characteristics score of 9 exceeds the acreage score of 7, so the simplified TEE is ended.

4.2. Conclusion

The simplified TEE is ended because substantial wildlife exposure is unlikely according to the scoring analysis in MTCA Table 749-1. Ecological exposures at the upland portion of the AOI are not of concern and no cleanup levels are needed to protect ecological receptors.

5.0 REFERENCES

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Table 4D-1

Upland Risk Evaluation: Screening of Upland COCs for Risk Evaluation

Gas Works Park Site

Seattle, Washington

COCs	Screening Level[a] (mg/kg)	All Three Areas		Northeast Corner		Cracking Tower Area		Limited Use Areas	
		Maximum Concentration Detected (mg/kg)	Retained for Risk Evaluation?	Maximum Concentration Detected (mg/kg)	Retained for Risk Evaluation?	Maximum Concentration Detected (mg/kg)	Retained for Risk Evaluation?	Maximum Concentration Detected (mg/kg)	Retained for Risk Evaluation?
BTEX									
Benzene	18	0.0046	No	0.0046	No	nd	No	n/a	No
Toluene	6,400	0.0064	No	0.0064	No	nd	No	n/a	No
Ethylbenzene	8,000	0.0064	No	0.0064	No	nd	No	n/a	No
Xylenes	16,000	0.0011	No	0.0011	No	nd	No	n/a	No
PAHs									
Fluoranthene	3,200	91	No	35	No	91	No	4.7	No
Naphthalene[b]	3,200	59	No	59	No	5.9	No	1	No
Pyrene	2,400	130	No	56	No	130	No	7.8	No
Benzo(a)anthracene[b]	0.137	32	Yes	18	Yes	32	Yes	2	Yes
Benzo(a)pyrene[b]	0.137	46	Yes	46	Yes	36	Yes	2.9	Yes
Benzo(b)fluoranthene[b]	0.137	35	Yes	15	Yes	35	Yes	2.3	Yes
Benzo(k)fluoranthene[b]	0.137	39	Yes	15	Yes	39	Yes	1	Yes
Chrysene[b]	0.137	35	Yes	31	Yes	35	Yes	2.6	Yes
Indeno(1,2,3-cd)pyrene[b]	0.137	47	Yes	47	Yes	44	Yes	2.6	Yes
Dibenz(a,h)anthracene[b]	0.137	19	Yes	19	Yes	5.6	Yes	0.48	Yes
cPAH TEQ[b]	0.137	56	Yes	56	Yes	48	Yes	3.8	Yes
Metals									
Arsenic	20	27	Yes	27	Yes	6.1	No	n/a	No

Notes:

[a] Values for PAHs and arsenic are 1999 Consent Decree soil clenaup levels. Values for BETX are MTCA Method B soil cleanup levels for direct contact (WAC 173-340-740; Master CLARC Spreadsheet, May 2019).

[b] The current MTCA Method B soil cleanup levels for naphthalene and carcinogenic PAHs (benzo[a]anthracene through cPAH TEQ) are 1,600 mg/kg and 0.19 mg/kg, respectively. The use of 1999 Consent Decree soil cleanup levels or current MTCA Method B soil cleanup levels for these COCs has no effect on COCs retained for the risk evaluation.

COCs = chemical of concern

mg/kg = milligram per kilogram

n/a = not applicable

nd = not detected

Shading indicates analyte is retained as a COC for the risk evaluation because the maximum detected soil concentration is greater than the applicable screening level.

See RI text for full acronym list.

Table 4D-2

Upland Risk Evaluation: Exposure Factors for Arsenic and cPAHs (Noncarcinogenic Evaluation)

Gas Works Park Site

Seattle, Washington

Factors[a]	Unit	Park User - Child		Park User - Adult	
		Cancer	Noncancer	Cancer	Noncancer
Cancer risk/hazard quotient	unitless	1E-06	1	1E-06	1
Body weight[b]	kg	14.8	14.8	77	77
Averaging time	days	27,375	2,190	27,375	8,760
Exposure frequency (NE corner, limited use areas, and exposed unstable bank areas)	days/year	104	104	104	104
Exposure frequency (cracking tower area)[c]	days/year	0	0	2	2
Exposure duration	years	6	6	24	24
Soil Ingestion Rate[d,e]	mg/day	87	87	50	50
Gastrointestinal absorption fraction (MTCA default)	unitless	1	1	1	1
Dermal surface area[b]	cm^2	2,904	2,904	6,925	6,925
Soil to skin adherence factor	mg/cm^2-day	0.2	0.2	0.07	0.07
Relative bioavailability adjustment (cPAHs only)	unitless	1	1	1	1
Fraction of time spent in NE corner (meadow and bank)[f]	unitless	0.050	0.050	0.050	0.050
Fraction of time spent in NE corner post cleanup action (bank)[f]	unitless	0.033	0.033	0.033	0.033
Fraction of time spent in Cracking Tower area[f]	unitless	0.026	0.026	0.026	0.026
Fraction of time spent in limited use area[f]	unitless	0.018	0.018	0.018	0.018
Fraction of time spent in exposed eroding bank area[f]	unitless	0.0012	0.0012	0.0012	0.0012

Notes:

Exposure factor values used to evaluate the potentical carcinogenic effects associated with carcinogenic polycyclic aromatic hydrocarbons (cPAHs), which incorporate age-dependent adjustment factors, are included in Table 4D-3.

[a] Exposure factor values are from ENVIRON (Attachment 4D-1), except where noted.

[b] Exposure factor values from EPA (2011a).

[c] The Cracking Tower area is fenced with signs indicating that access to the area is not allowed. The exposure frequency for this area assumes that children in the 6 to 16 age range will trespass in the Cracking Tower area two (2) times a year.

[d] Exposure factor values from EPA (2017).

[e] The soil ingestion rates for park users assume that people do not track substantial amounts of soil back to their homes. This is a reasonable assumption since most of the surface soil at the site is covered with grass, which will significantly limit the amount of soil that could be tracked to people's homes.

[f] Fraction of time values are based on Figure 4D-2. See text for details.

cm^2 = square centimeters

mg = milligrams

kg = kilograms

See RI text for full acronym list.

Table 4D-3

Upland Risk Evaluation: Exposure Factors for cPAHs (Carcinogenic Evaluation)

Gas Works Park Site

Seattle, Washington

Factors[a]	Unit	Park User			
		0-2 years old	2-6 years old	6-16 years old	16-30 years old
		Cancer	Cancer	Cancer	Cancer
Cancer risk/hazard quotient	unitless	1E-06	1E-06	1E-06	1E-06
Age-dependent adjustment factors[b]	unitless	10	3	3	1
Body weight[c]	kg	9.6	17.4	44.3	77
Averaging time	days	27,375	27,375	27,375	27,375
Exposure frequency (NE corner, limited use areas, and exposed unstable bank areas)	days/year	104	104	104	104
Exposure frequency (Cracking Tower area)[d]	days/year	0	0	2	0
Exposure duration	years	2	4	10	14
Soil Ingestion Rate [e,f]	mg/day	80	90	74	50
Gastrointestinal absorption fraction (MTCA default)	unitless	1	1	1	1
Dermal surface area[c]	cm^2	2,344	3,184	4,974	6,925
Soil to skin adherence factor	mg/cm^2-day	0.2	0.2	0.07	0.07
Relative bioavailability adjustment (cPAHs only)	unitless	1	1	1	1
Fraction of time spent in NE corner (meadow and bank)[g]	unitless	0.050	0.050	0.050	0.050
Fraction of time spent in NE corner post cleanup action (bank)[g]	unitless	0.033	0.033	0.033	0.033
Fraction of time in Cracking Tower area[g]	unitless	0	0	0.026	0
Fraction of time in limited use area[g]	unitless	0.018	0.018	0.018	0.018
Fraction of time in exposed unstable bank area[g]	unitless	0.0012	0.0012	0.0012	0.0012

Notes:

[a] Exposure factor values are from ENVIRON (Attachment 4D-1), except where noted.

[b] Age-dependant adjustment factors from EPA's "Supplemental Guidance for Assessing Susceptibility from Early-Exposures to Carcinogens" (EPA 2005a).

[c] Exposure factor values from EPA (2011a).

[d] The Cracking Tower area is fenced with signs indicating that access to the area is not allowed. The exposure frequency for this area assumes that children in the 6 to 16 age range will trespass in the Cracking Tower area two (2) times a year.

[e] Exposure factor values from EPA (2017).

[f] The soil ingestion rates for park users assume that people do not track substantial amounts of soil back to their homes. This is a reasonable assumption since most of the surface soil at the site is covered with grass, which will significantly limit the amount of soil that could be tracked to people's homes.

[g] Fraction of time values are based on Figure 4D-2. See text for details.

cPAHs = carcinogenic polycyclic aromatic hydrocarbons

cm^2 = square centimeters

mg = milligrams

kg = kilograms

See RI text for full acronym list.

Table 4D-4

Upland Risk Evaluation: Chemical-Specific Parameters

Gas Works Park Site

Seattle, Washington

COCs	Oral Slope Factor[a]	Oral Reference Dose[a]	Dermal Absorption Fraction[b]	Gastrointestinal Absorption Conversion Factor[c]	Dermal Slope Factor[d]	Dermal Reference Dose[e]
	kg-day/mg	mg/kg-day	unitless	unitless	kg-day/mg	mg/kg-day
Arsenic	1.5E+00	3.0E-04	0.03	1	1.5E+00	3.0E-04
Benzo(a)pyrene	1.0E+00	3.0E-04	0.13	1	1.0E+00	3.0E-04

Notes:

[a] EPA's Integrated Risk Information System online database (accessed October 2019) (EPA 2019a)

[b] Exhibit 3-4 (EPA 2004)

[c] Exhibit 4-1 (EPA 2004) and EPA Regional Screening Levels (May 2019; EPA 2019b)

[d] Dermal slope factor = oral slope factor/gastrointestinal absorption conversion factor

[e] Dermal reference dose = oral reference dose x gastrointestinal absorption conversion factor

COCs = chemicals of concern

mg = milligrams

kg = kilograms

See RI text for full acronym list.

Table 4D-5

Upland Risk Evaluation: Risk Characterization for Park Users (Current Conditions)

Gas Works Park Site

Seattle, Washington

COCs	Soil Exposure Point Concentration (mg/kg) RME	Non-Carcinogenic Risk (Park User - Child) Hazard Intake (mg/kg-day) RME	Oral RfD (mg/kg-day)	Hazard Quotient RME	Carcinogenic Risk (Park User - Adult and Child) Cancer Intake (mg/kg-day) RME	Oral CSF (mg/kg-day)	Cancer Risk RME
Northeast Corner (meadow and bank portions)							
Arsenic	15	1.5E-06	3.0E-04	0.005	1.8E-07	1.5E+00	3.E-07
cPAH TEQ	19	3.0E-06	3.0E-04	0.010	1.9E-06	1.0E+00	2.E-06
			Total Hazard Index	**0.01**		**Total Cancer Risk**	**2.E-06**
Cracking Tower Area							
Arsenic	--	--	--	--	--	--	--
cPAH TEQ	30	3.3E-07	3.0E-04	0.001	4.6E-09	1.0E+00	5.E-09
			Total Hazard Index	**0.001**		**Total Cancer Risk**	**5.E-09**
Limited Use Areas							
Arsenic	--	--	--	--	--	--	--
cPAH TEQ	3.8	2.1E-07	3.0E-04	0.0007	1.3E-07	1.0E+00	1.E-07
			Total Hazard Index	**0.0007**		**Total Cancer Risk**	**1.E-07**
Exposed Eroding Bank Areas							
Arsenic	13	3.1E-08	3.0E-04	0.00010	3.7E-09	1.5E+00	6.E-09
cPAH TEQ	50	1.9E-07	3.0E-04	0.0006	1.2E-07	1.0E+00	1.E-07
			Total Hazard Index	**0.0007**			**1.E-07**
Total Non-Capped or Covered (asphalt, concrete, buildings) Areas							
Arsenic	--	--	--	0.005	--	--	3.E-07
cPAH TEQ	--	--	--	0.01	--	--	2.E-06
			Total Hazard Index	**0.02**		**Total Cancer Risk**	**2.E-06**

Notes:

-- = Not applicable

COCs = chemicals of concern

CSF = cancer slope factor

CTE = central tendency exposure (typical park user)

mg = milligrams

kg = kilograms

RfD = reference dose

RME = reasonable maximum exposure (upper bound park user)

See RI text for full acronym list.

Table 4D-6

Upland Risk Evaluation: Risk Characterization for Park Users (Post-Cleanup Conditions)

Gas Works Park Site

Seattle, Washington

COPC	Soil Exposure Point Concentration (mg/kg)	Non-Carcinogenic Risk (Park User - Child)			Carcinogenic Risk (Park User - Adult and Child)		
		Hazard Intake (mg/kg-day)	Oral RfD (mg/kg-day)	Hazard Quotient	Cancer Intake (mg/kg-day)	Oral CSF (mg/kg-day)	Cancer Risk
	RME	RME		RME	RME		RME
Northeast Corner (meadow portion only; bank portion will be addressed as part of sediment remedy)							
Arsenic	15	1.0E-06	3.0E-04	0.003	1.2E-07	1.5E+00	2.E-07
cPAH TEQ	15	1.5E-06	3.0E-04	0.005	9.7E-07	1.0E+00	1.E-06
			Total Hazard Index	**0.01**		**Total Cancer Risk**	**1.E-06**
Cracking Tower Area							
Arsenic	--	--	--	--	--	--	--
cPAH TEQ	30	3.3E-07	3.0E-04	0.001	4.6E-09	1.0E+00	5.E-09
			Total Hazard Index	**0.001**		**Total Cancer Risk**	**5.E-09**
Limited Use Areas							
Arsenic	--	--	--	--	--	--	--
cPAH TEQ	3.8	2.1E-07	3.0E-04	0.0007	1.3E-07	1.0E+00	1.E-07
			Total Hazard Index	**0.0007**		**Total Cancer Risk**	**1.E-07**
Total Non-Capped or Covered (asphalt, concrete, buildings) Areas							
Arsenic	--	--	--	0.003	--	--	2.E-07
cPAH TEQ	--	--	--	0.01	--	--	1.E-06
			Total Hazard Index	**0.01**		**Total Cancer Risk**	**1.E-06**

Notes:

-- = Not applicable
CSF = cancer slope factor
CTE = central tendency exposure (typical park user)
mg = milligrams
kg = kilograms
RfD = reference dose
RME = reasonable maximum exposure (upper bound park user)
See RI text for full acronym list.

Table 4D-7

Upland Risk Evaluation: Outdoor and Indoor Air Evaluation

Gas Works Park Site

Seattle, Washington

Chemicals	MTCA Method B Air CUL (µg/m^3)	Outdoor Air (µg/m^3)[a]				Occupied Space Indoor Air (µg/m^3)[b]			Limited Access Indoor Air (µg/m^3)[c]	
		Site-Specific Park User Air CUL[d]	95th Percentile Background[e]	Prow - GWPS Upwind	Cracking Tower and East Shoreline	Harbor Patrol Air CUL[f]	90th Percentile Background[g]	Harbor Patrol Building	Play Barn Basement Air CUL[g,h]	Play Barn Basement
Chlorinated VOCs										
Chloroform	0.11	4.5	0.17 - 0.25	nd	nd	0.63	nd - 6.2	nd - 0.9	14	nd
Tetrachloroethene	9.6	400	0.34 - 0.58	nd - 1	nd - 1.6	56	nd - 7	0.4 - 1.3	1,300	nd - 0.5
Carbon tetrachloride	0.42	17	1	nd	nd - 0.3	2.4	nd - 0.94	nd	55	nd
1,4-Dichlorobenzene	0.23	9.5	--	nd	nd - 0.4	1.3	1.5 - 28	nd	30	nd
Methylene chloride	250	10,000	--	nd - 1.8	nd - 1.3	1,500	2.0 - 510	nd - 1	33,000	nd - 0.5
Aromatic VOCs										
Benzene	0.32	13	1.5 - 2.6	0.8 - 2.1	0.9 - 2.9*	1.9	5.2 - 15	1.4 - 3.3	42	1.3 - 2.1
Toluene	2,300	95,000	--	3.3 - 7.9	3.9 - 15*	19,000	25 - 77	7.7 - 12	440,000	3.5 - 8
Ethylbenzene	460	19,000	--	0.6 - 1.7	0.6 - 2.8*	3,900	4.8 - 13	1.2 - 3.5	88,000	0.5 - 0.6
m,p-Xylene	46	1,900	--	1.8 - 5.2	2 - 8.1	390	12 - 56	4.1 - 11	8,800	1.9 - 2.2
o-Xylene	46	1,900	--	0.6 - 2.1	0.7 - 3.2	390	5.5 - 16	1.4 - 3.4	8,800	0.7 - 0.8
n-Propylbenzene	460	19,000	--	nd - 0.8	nd - 1.1	3,900	--	0.3 - 1.2	88,000	nd
1,3,5-Trimethylbenzene	27	1,100	--	nd - 1.2	nd - 1.5	230	2.5 - 4.2	0.4 - 1.8	5,200	nd - 0.4
1,2,4-Trimethylbenzene	27	1,100	--	0.9 - 4.2	0.8 - 5.3	230	6.7 - 13	1.8 - 7.8	5,200	nd - 1.4
p-Isopropyltoluene	--	--	--	nd	nd - 0.4	--	--	nd - 0.4	--	nd
Naphthalene	0.074	3.1	--	nd	nd - 2.5	0.43	2.2 - 4.8	0.4 - 1	9.7	1.6 - 6.8
2-Methylnaphthalene	--	--	--	nd	nd - 0.4	--	--	nd - 0.5	--	nd - 1.6
Styrene	460	19,000	--	nd	nd	3,900	1.3 - 3.8	nd	88,000	nd - 0.4

Notes:

[a] Outdoor air locations include the upwind Prow location, Cracking Tower and east shoreline locations.

[b] Occupied space, indoor air includes the Harbor Patrol building.

[c] Limited access indoor air locations includes the Play Barn basement.

[d] Site-Specific Park User Air CULs were calculated using MTCA Method B Air CUL Equations 750-1 and 750-2 and by modifying the residental exposure frequency (EF) value from 1.0 (24 hours per day exposure, 365 days per year) to 0.024 (0.57 hours per day exposure, 365 days per year). EF of 1.0 assumes 168 hours per week; EF of 0.024 assumes 4 hours per week.

[e] 95th percentile background ambient air values from *Tacoma and Seattle Area Air Toxics Evaluation* (PSCAA/UW 2010). Range of values represents data obtained at Seattle Duwamish and Seattle Beacon Hill monitoring stations.

[f] Harbor Patrol Air CULs were calculated using MTCA Method B Air CUL equations 750-1 and 750-2 and modifying the breathing rate and body weight assumptions from child to adult values for non-carcinogens and modifying the EF value from 1.0 (24 hours per day exposure, 365 days per year) to 0.26 (9 hours per day exposure, 250 days per year). EF of 0.26 assumes 2,250 hours per year whereas an EF of 1 assumes 8,760 hours per year.

[g] Range of 90th percentile background indoor air concentrations from EPA's *Background Indoor Air Concentrations of Volatile Organic Compounds in North American Residences (1990-2005): A Compilation of Statistics for Assessing Vapor Intrusion* (EPA 2011).

[h] The Play Barn basement is locked and inaccessible to park users and seldom accessed by park workers. Play Barn Basement Air CULs were calculated using MTCA Method B Air CUL equations 750-1 and 750-2 and modifying the breathing rate and body weight assumptions from child to adult values for non-carcinogens and modifying the EF value from 1.0 (24 hours per day exposure, 365 days per year) to 0.011 (2 hours per day exposure, 50 days per year [1 day per week]). EF of 0.011 assumes 100 hours per year whereas an EF of 1 assumes 8,760 hours per year.

CUL = cleanup level

MTCA = Model Toxics Control Act

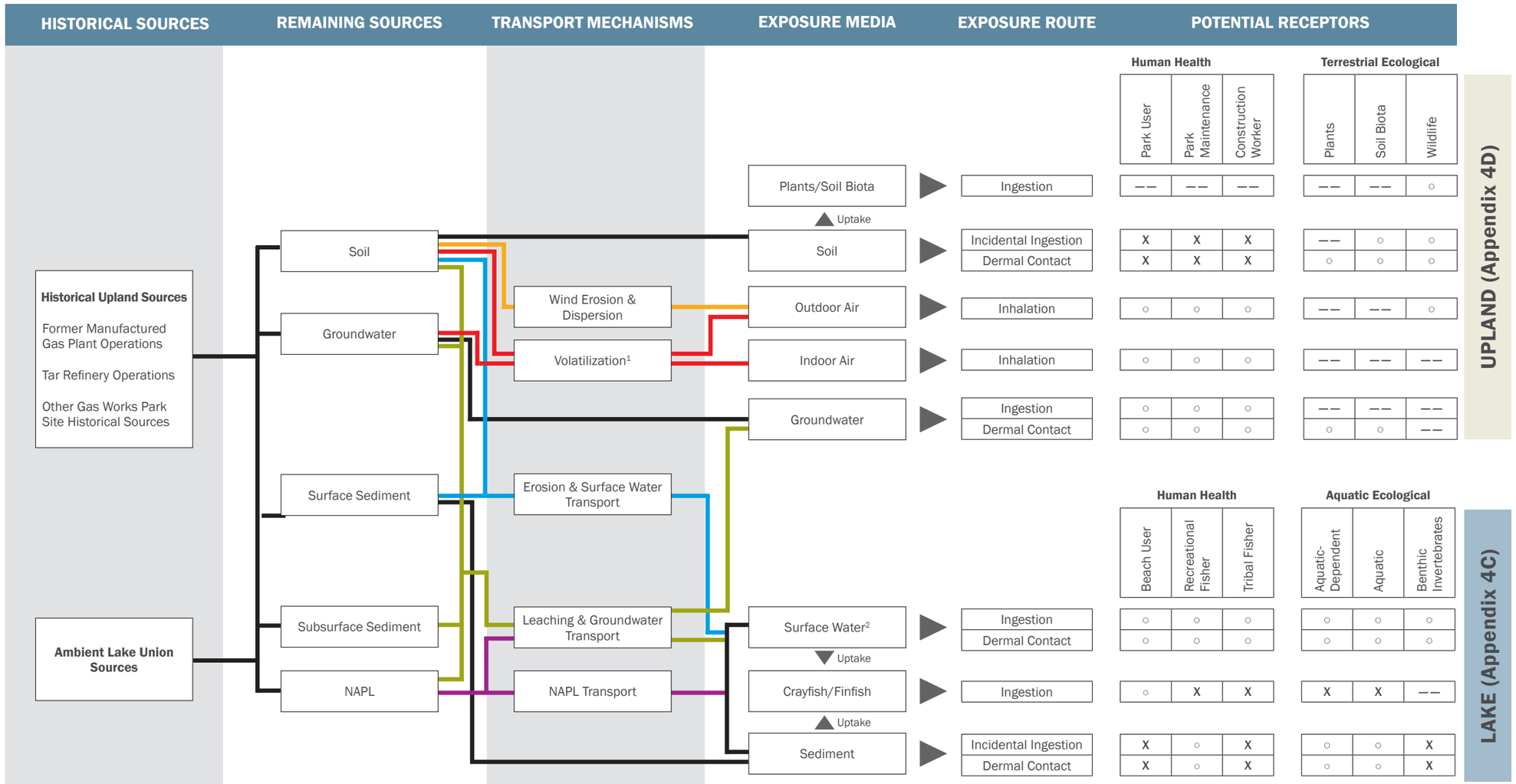
µg/m^3 = microgram per cubic meter

VOC = volatile organic compound

-- = Not applicable

* Does not include erroneous reading at Cracking Tower during the first quarter of monitoring (see text for discussion).

nd = not detected



Legend

- Volatilization
- Wind Erosion & Dispersion
- Leaching & Groundwater Transport
- Mobile Non-Aqueous Phase Liquid (NAPL) Transport
- Erosion & Surface Water Transport
- X — Complete Pathway
- ○ — Incomplete or Minor Pathway
- –– — Not Applicable

Notes

1. Upland NAPL is a potential source to soil and groundwater; associated contaminants can volatilize to air.
2. The protection of surface water is addressed by the use of surface water screening levels in the evaluation of offshore groundwater.

Conceptual Site Exposure Model

Gas Works Park Site
Seattle, Washington

GeoEngineers | Figure 4D-1

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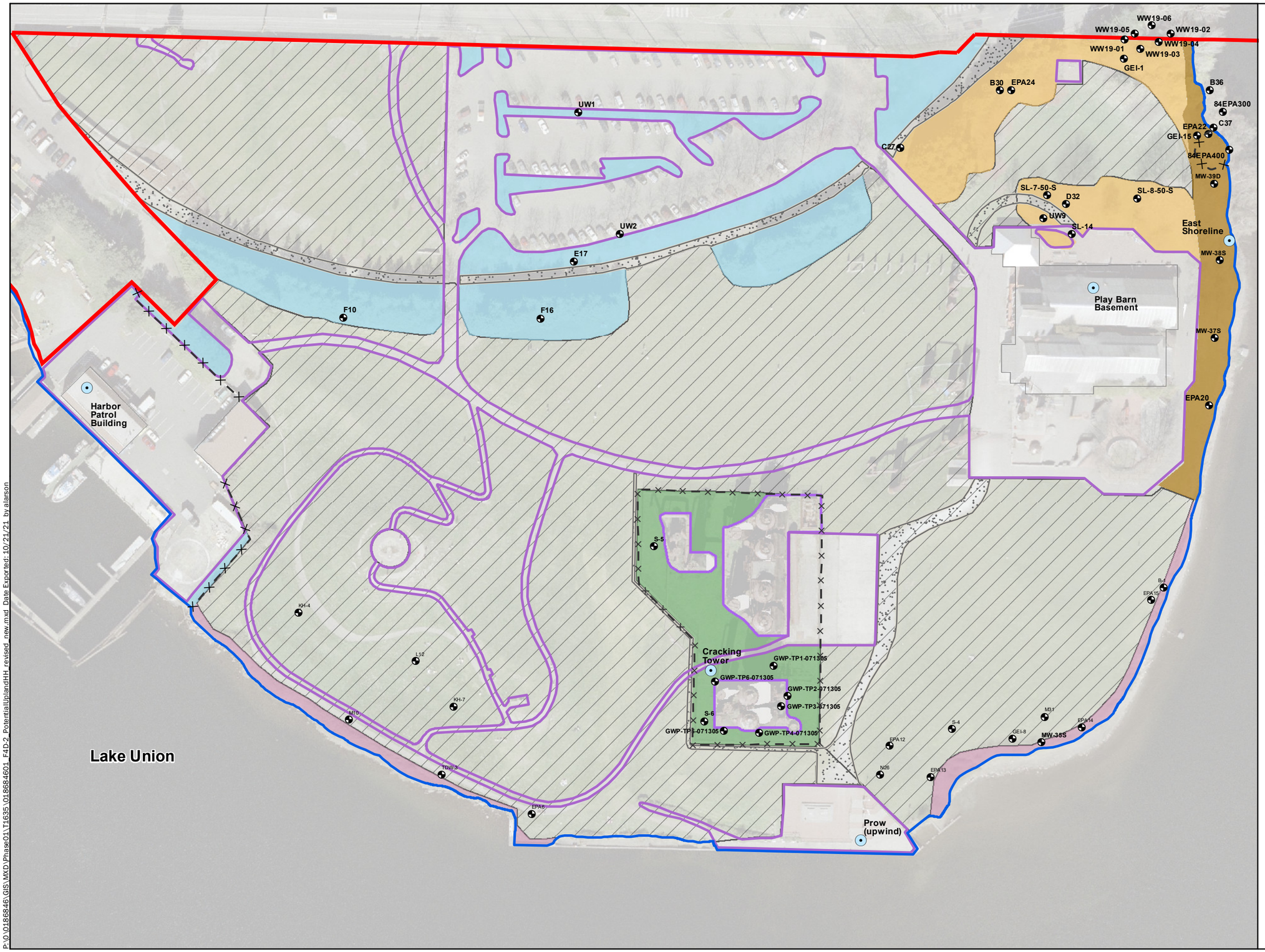

Legend

- Area of Investigation
- Shoreline (OHWM)
- Security Fence
- Soil Sample Location for Human Health Risk Evaluation
- Approximate Air Sample Location

Surface Cover Preventing Exposure

- Vegetated Soil Cap
- Impervious (Paved or Structures)
- Gravel

Exposure Areas (Uncapped)

- Northeast Corner - Meadow (0.67 acres or 3.3% of upland)
- Northeast Corner - Bank (0.35 acres or 1.7% of upland)
- Limited Use Areas (1.5 acres or 7.2% of upland)
- Cracking Tower Area (0.52 acre or 2.6% of upland)
- Exposed Eroding Bank Areas (0.24 acre or 1.2% of upland)

Notes:

1. References: Construction Completion Report by RETEC 2001. As-Built Set of Drawings by Seattle Parks and Recreation 2005. NE Corner Capping Project by Hart Crowser 2012, adjusted for existing structures. Kite Hill Construction Completion Report by GeoEngineers 2015 .
2. Basemap - 2005 USGS aerial photograph. Does not show current conditions.
3. Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

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Potential Upland Human Health Exposure Areas and Sample Locations (Current Conditions)

Gas Works Park Site
Seattle, Washington

GeoEngineers

Figure 4D-2

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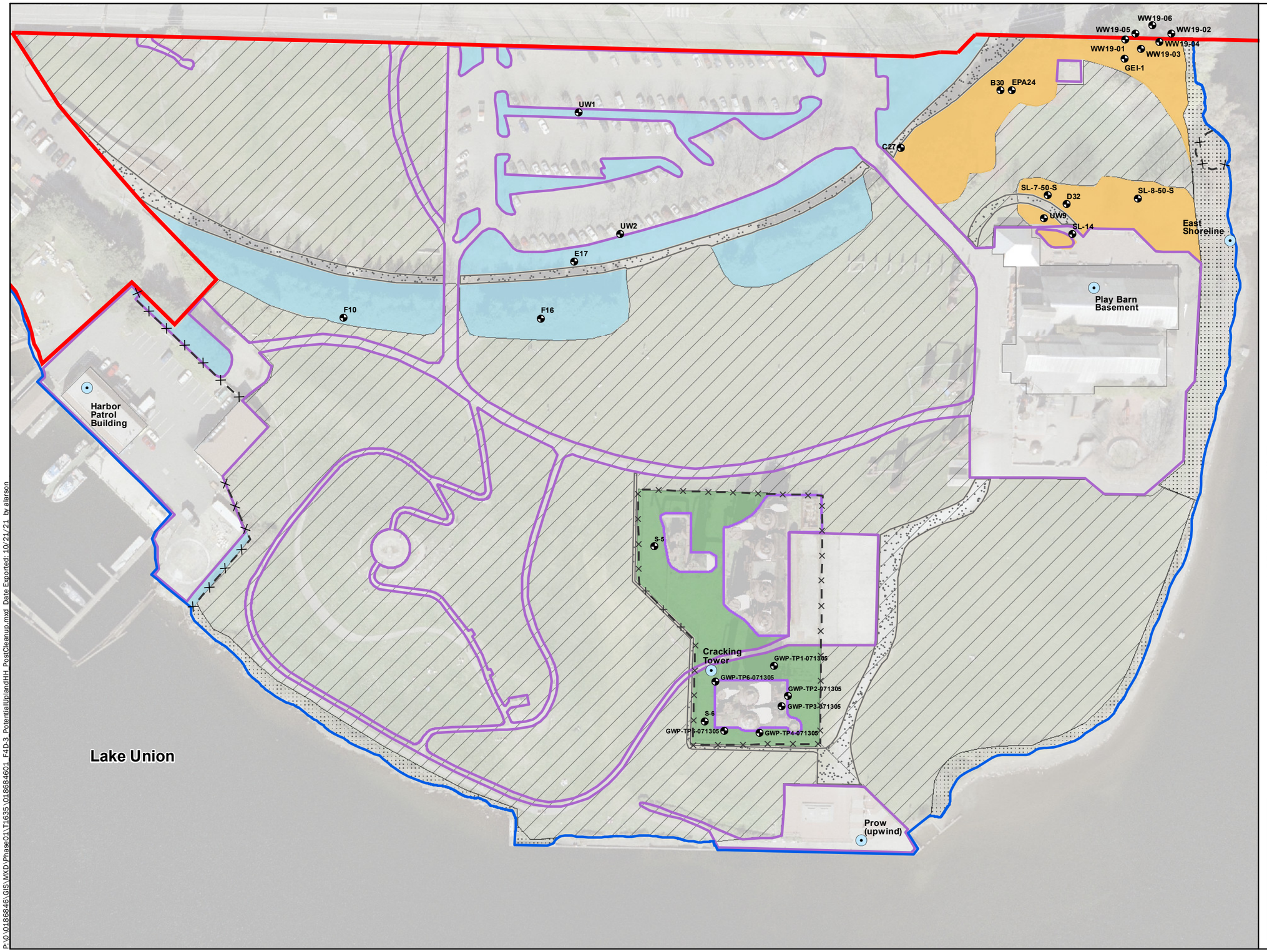

Legend

- Area of Investigation
- Shoreline (OHWM)
- Security Fence
- Soil Sample Location for Human Health Risk Evaluation
- Approximate Air Sample Location

Surface Cover Preventing Exposure

- Vegetated Soil Cap
- Impervious (Paved or Structures)
- Gravel
- Bank Capping/Stabilization as Part of Sediment Cleanup

Exposure Areas (Uncapped)

- Northeast Corner - Meadow (0.67 acres or 3.3% of upland)
- Limited Use Areas (1.5 acres or 7.2% of upland)
- Cracking Tower Area (0.52 acre or 2.6% of upland)

Notes:

1. References: Construction Completion Report by RETEC 2001. As-Built Set of Drawings by Seattle Parks and Recreation 2005. NE Corner Capping Project by Hart Crowser 2012, adjusted for existing structures. Kite Hill Construction Completion Report by GeoEngineers 2015 .
2. Basemap - 2005 USGS aerial photograph. Does not show current conditions.
3. Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

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Potential Upland Human Health Exposure Areas and Sample Locations (Post Cleanup)

Gas Works Park Site
Seattle, Washington

GeoEngineers

Figure 4D-3

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AREA A
Northwest
Corner

AREA B
Parking Lot
and Berms

AREA C
Northeast Corner
and Play Barn

AREA E
Central and
Southeast Area

AREA H
Harbor
Patrol

AREA D
Groundwater
Treatment Area

AREA F
Cracking
Towers

AREA G
Kite Hill

Lake Union

Legend

- Area of Investigation
- Ecological Exposure Areas

Contiguous Undeveloped Land

- Revised Area C (1.0 acres)
- Revised Area F (0.52 acres)

Notes:

1. Ecological Exposure Areas adapted from Attachment 4D-3, Figure D-3. Area C and Area F revised to be consistent with Figure 4D-2.
2. Basemap - USGS 2005 aerial photograph. Does not show current conditions.

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Potential Terrestrial Ecological Exposure Areas

Gas Works Park Site
Seattle, Washington

GeoEngineers | **Figure 4D-4**

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ATTACHMENT 4D-1
ENVIRON Human Health Risk Assessments (2010)

May 5, 2010

David Graves
Seattle Department of Parks and Recreation
800 Maynard Avenue South, 3rd Floor
Seattle, WA 98134

Re: Evaluation of 2009 and Older Data for Polycyclic Aromatic Hydrocarbons in Soil Samples from the Northeast Corner of Gas Works Park

Dear Mr. Graves:

Analytical data for surface soil samples collected last year from the northeast (NE) corner of Gas Works Park (GWP) were reviewed and compared with data from samples collected during the 1980s and 1990s. Our review focused on concentrations of seven polycyclic aromatic hydrocarbons (PAHs) considered by the United States Environmental Protection Agency (EPA) to be potential carcinogens (referred to as cPAH). We also evaluated potential exposures and health risks for park users who might come into contact with soil in the NE corner of GWP. cPAH are typically evaluated by measuring benzo(a)pyrene (BaP) and benzo(a)pyrene equivalent (BaPE) concentrations. BaPE concentrations include concentrations of BaP and concentrations of six additional cPAH (benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, and chrysene) adjusted to reflect their potency relative to BaP.

Sources of PAH data for soil samples collected in the NE corner of GWP that were reviewed include:

- Ecology and Environment Inc. 1984. Gasworks Park, Summary of Results. Submitted to U.S. Environmental Protection Agency, Region X, Seattle, WA.
- EPA. 1984. EPA Gas Works Park Surface Soil Grab Samples.
- Kalman, D. 1984. Gas Works Park surface soils contamination survey. Prepared for City of Seattle Office of Intergovernmental Relations. School of Public Health and Community Medicine, Department of Environmental Health, University of Washington. (Appendix 7a to Ongerth, J. 1985 Draft Evaluation of Health Risk For Public Use of Gas Works Park)
- Tetra Tech. 1985. Gas Works Park Supplemental Soils Testing, Phase I Surface Soils Analysis. Prepared for Seattle Parks Department. Tetra Tech, Inc., Bellevue, Washington.
- Parametrix and KEY Environmental, 1998. Draft – Gas Works Park Environmental Cleanup, Focused Feasibility Study Report.
- Floyd Snider. 2010. Gas Works Park Northeast Corner Source Control Data Report. Prepared for City of Seattle, Seattle Public Utilities.

In addition, we reviewed a health risk evaluation for GWP completed in 1985 *(Evaluation of Health Risk for Public Use of Gas Works Park)* by the Gas Works Park Health Risk Evaluation Panel (the risk panel) led by Dr. Jerry Ongerth of the University of Washington. This report

included an evaluation of data collected from the NE corner. At that time, EPA had not yet developed standard methods for human health risk assessment. Instead, the risk panel devised methods to estimate intake of PAHs via incidental ingestion of soil, inhalation, and dermal contact. They then compared the intake estimates with known intake levels from other sources, including cigarette smoke, urban air (Seattle and Detroit), diet, and occupational sources. One of the recommendations of the risk panel was to cover areas with BaP soil concentrations higher than 100 mg/kg. This recommendation was subsequently carried out by the City, and we have modified our data summaries to remove data for those samples.

At the request of the City, available data for the NE corner of GWP were evaluated to answer the following questions:

1. Are recent analytical results for BaP and BaPE (collected in 2009) similar to or different than prior analytical results (collected in 1984, 1985, 1997) from the perspective of potential contact by park users?
2. Do results for recent and older samples represent BaP and BaPE concentrations that could pose an unacceptable risk to the public?

cPAH data from 29 soil samples collected during 2009 and 21 older samples were evaluated for use in estimating exposure point concentrations for park users. The following data treatment rules were applied:

1. For the older dataset, one sample with a BaP concentration greater than 100 mg/kg in the NE corner was excluded from the prior dataset because, as recommended by the risk panel, this location was covered.
2. For the recent data, oversampling directly around the storm drains (SL7, SL8, SL14) results in a spatial sampling bias relative to the rest of the NE corner of the park. To account for this bias, the results for the four samples collected in the immediate vicinity of each storm drain were composited, or averaged. The mean composited concentration for each of the three storm drains then was used in the data evaluation.
3. Samples from prior studies were collected from two depths at locations EPA 23 and EPA 24 (0-3 inches bgs and 3-6 inches bgs). To avoid bias resulting from oversampling at these two locations, results from both depths were not used. PAH concentrations tend to be greater at the more shallow depth and visitors to the park are more likely to contact soil found at the shallow depth. To obtain the dataset most representative and protective of exposures to surface soil, only the results from 0-3 inches bgs were evaluated for locations EPA 23 and EPA 24.
4. Similarly, two sample depths were collected at EPA 22. However, BaP was not analyzed in the sample collected from 0-3 inches bgs but was analyzed in the sample collected from 0-6 inches bgs. In this case, the results for the sample from 0-6 inches was retained to maximize usable data for this evaluation.
5. One duplicate sample appears to have been collected at UW 9 during a prior study but only BaP was analyzed in one of the samples and a subset of the carcinogenic PAHs were analyzed in the second sample. To maximize the usable data for this evaluation, the sample for which the greater number of results was available was retained. The other sample for which only a BaP result was available was discarded.
6. One duplicate sample was collected in the vicinity of SL8 in the recent 2009 soil study. The average of the results for the duplicate sample (SL8-2-N-101309) and investigative sample (SL8-2-N-101309D) were used to represent this location.

Also, it should be noted that analytical results were not available for each of the seven carcinogenic PAHs for each sample within the older dataset. In some cases, only BaP results

are available and in other cases, only a subset of the seven carcinogenic PAH results are available. To account for these differences, it is useful to evaluate BaP (alone) as well as BaPE when sufficient data are available.

Following data treatment, a total of 20 soil samples collected in 2009 and 16 soil samples collected in 1984, 1985, and 1997 were used in the evaluation. Data summaries are provided in Table 1. Sample locations are shown in Figure 1. Exposure point concentrations (as the upper confidence limit on the mean or UCLM) were calculated using EPA's ProUCL software (Version 4.00).

Summary statistics and the 95th percentile upper confidence limit of the mean (UCLM) recommended by EPA's ProUCL software are provided for each dataset in Table 1. As noted in the table, the older and recent mean and UCLM concentrations are similar. The similarities in these datasets were confirmed using the Wilcoxon-Mann-Whitney test for two populations provided in ProUCL. There is no statistically significant difference between the data collected in the 1980's and 1990s, and the data collected in 2009 (where H_o: mean/median of historic data = current data and p >0.4; do not reject null hypothesis.)

In response to question 1, above, the recent results yield mean concentrations that are not statistically different than those from the 1980's and 1990s. The analytical results for samples collected in 2009 also yield essentially identical exposure point concentrations as calculated for the older data.

ENVIRON performed a screening-level assessment to evaluate whether current levels of PAHs in surface soil present an unacceptable risk to recreational users at the park. Two hypothetical recreational user scenarios were developed, a "typical" user and an "upper bound" user scenario. The typical scenario is based on a combined child/adult who frequents the park 1 day per week for 3 months of the year and 1 day every 2 weeks for the remaining 9 months of the year for 9 years. The upper bound user is assumed to frequent the park 3 days per week for 3 months of the year and 1 day per week for the remaining 9 months of the year for 30 years. It is not realistic to assume that each recreational user spends 100 percent of their time in the NE corner of the park; however, information is not available regarding how much time is spent within different areas of the park. In the absence of park-specific usage information, the area of the NE corner relative to the total park area was calculated and this ratio (0.13 or 13 percent) was used to represent the fraction of total soil contacted at the park that is within the NE corner. In reality, it is likely that a much lower fraction of soil in the NE corner is contacted relative to the entire park area because the NE corner does not contain popular park features such as play structures, Kite Hill, the Prow, or the play barn. Additional exposure factors are provided in Table 2.

Cancer risks were calculated using the 2009 and older data sets for the typical and upper bound child/adult recreational user of the NE corner of the park, as shown in Table 3. Excess lifetime cancer risks ranged from 2×10^{-7} to 3×10^{-7} for the typical user contacting older or recent levels of BaP or BaPE in surface soil. Excess lifetime cancer risks ranged from 8×10^{-6} to 1×10^{-5} for the reasonable upper bound user contacting older or recent levels of BaP or BaPE in surface soil. As expected, there is essentially no difference in calculated risks whether evaluating older or recent data and the estimated cancer risks are not of concern. EPA's National Oil and Hazardous Substances Pollution Contingency Plan guidance (March 8,1990; 40 CFR 300) identifies estimated cancer risks falling between 1×10^{-6} and 1×10^{-4} (or, one additional cancer case per million people and one additional cancer case per ten-thousand people) as within an acceptable risk management range.

There are a number of uncertainties associated with these risk estimates. Although some chemical mixtures (e.g., tobacco smoke, chimney soot, others) that include PAHs have been shown to be carcinogenic by inhalation or dermal contact in humans, the relative potency of the individual PAH compounds has not been established in humans. The EPA toxicity assessment for BaP and the other cPAHs has been based on the results of studies in rodents; however, these chemicals have only been shown to be rodent carcinogens at portal of entry sites such as the skin or lung. Carcinogenic potency of each cPAH was estimated relative to BaP based primarily on comparison of mouse skin tumor data. While skin tumor data from mice for multiple PAHs may allow a comparison across PAHs, the relevance and predictiveness of this test system for oral cancer risk in humans is questionable. Consequently, cancer risk estimates for the cPAHs could be overestimated.

On the other hand, USEPA is beginning to modify cancer risk estimates to reflect increased cancer risks associated with exposures that occur during early life stages. Such adjustments could increase the cancer risk estimates. There are also uncertainties associated with the exposure estimates. In particular, assuming that a high end park user might ingest 50 to 100 mg of park soil per day for 78 days per year for 30 years is extremely conservative. Finally, in assessing the potential significance of the estimated cPAH intakes, we considered normal dietary intakes and concluded that potential park-related exposures are within the range of intakes that might be consumed in typical diets.

In response to question 2, above, the concentrations of PAHs in samples collected in 2009 are not likely to present an unacceptable risk to the public.

Sincerely,

Rosalind A. Schoof

Rosalind A. Schoof, PhD, DABT
Principal

605 First Avenue, Suite 300, Seattle, WA 98104
Tel: +1 206.336.1650 Fax: +1 206.336.1651

www.environcorp.com

Table 1. Prior and Current BaP and BaPE datasets, summary statistics, and UCLM values.

	Prior Data		Current Data	
	BaP	BaPE	BaP	BaPE
	3.2	3.2	1.8	2.3
	5.5	5.5	107	138
	24	28	22	28
	46	56	74	98
	61	68	4.1	5.4
	17	18	22	28
	44	60	33	41
	63	91	4.7	6.2
	19	24	7.5	10
	6.9	10	16	22
	2.0	2.9	4.5	5.9
	16	20	3.3	4.2
	0.7	0.9	5.1	6.6
	3.8	5.0	6.0	7.9
	14	19	2.1	2.6
	11	15	6.2	7.9
			2.3	2.8
			16	21
			8.5	11
			6.7	8.5
number of samples (n)	16	16	20	20
minimum	0.7	0.9	1.8	2.3
median	15	18	6.5	8.2
average	21	27	18	23
maximum	63	91	107	138
standard deviation	21	27	27	35
range	62	90	106	135
ProUCL recommended distribution	Gamma	Gamma	Lognormal	Lognormal
ProUCL recommended UCLM	36	45	36	46
UCLM method	95% Approximate Gamma	95% Approximate Gamma	95% Chebychev (MVUE)	95% Chebychev (MVUE)

Note: Data presented in this table represent post-treatment dataset (see page 2) that were used in the evaluation.

BaP = benzo(a)pyrene

BaPE = benzo(a)pyrene equivalents

MVUE = minimum variance unbiased estimate

UCLM = upper confidence limit of the mean

Table 2. Exposure assumptions for child and adult recreational users.

Adult Exposure Assumptions					
Parameter	**Abbrev**	**Typical**	**Upper Bound**	**Units**	**Source**
Soil ingestion rate	IR	22	50	mg/day	Prof. judgement[b]
Relative bioavailability adjustment	RBA	0.6	0.6	--	Literature review
Adherence factor	AF	0.01	0.07	mg/cm^2-event	Typ: Prof. judgement[b], Upper: Std. Default[c]
Surface Area	SA	5,700	5,700	cm^2	Std. Default[c]
Event frequency	EV	1	1	event/day	EPA 2004
Exposure frequency	EF	32.5	78	day/yr	Prof. judgement[c]
Exposure duration	ED	6	24	yr	Typ: EPA Region 10, Upper: Std. Default[d]
Fraction of time spent in NE corner	FI	0.13	0.13	--	Prof. judgement[e]
Averaging time cancer	ATc	25,550	25,550	day	Std. Default[d]
Body weight	BW	70	70	kg	Std. Default[d]
Unit conversion factor	CF	1.00E+06	1.00E+06	mg/kg	N/A
LADD intake factor	LADDif	2.40E-09	5.23E-08	1/day	N/A

Child Exposure Assumptions					
Parameter	**Abbrev**	**Typical**	**Upper Bound**	**Units**	**Source**
Soil ingestion rate	IR	45	100	mg/day	Prof. judgement[b]
Relative bioavailability adjustment	RBA	0.6	0.6	--	Literature review
Adherence factor	AF	0.04	0.2	mg/cm^2-event	Typ: Prof. judgement[b], Upper: Std. Default[c]
Surface Area	SA	2,800	2,800	cm^2	Std. Default[c]
Event frequency	EV	1	1	event/day	EPA 2004
Exposure frequency	EF	32.5	78	day/yr	Prof. judgement[c]
Exposure duration	ED	3	6	yr	Typ: EPA Region 10, Upper: Std. Default[d]
Fraction of time spent in NE corner	FI	0.13	0.13	--	Prof. judgement[e]
Averaging time cancer	ATc	25,550	25,550	day	Std. Default[d]
Body weight	BW	15	15	kg	Std. Default[d]
Unit conversion factor	CF	1.00E+06	1.00E+06	mg/kg	N/A
LADD intake factor	LADDif	1.14E-08	1.22E-07	1/day	N/A

[a]Fractional intakes shown assume time spent in various locations within the park is distributed equally by area.

[b]Based on a review of available literature.

[c]Standard default factors per Exhibit 4-1 of EPA Region 9's PRGs table User's Guide, http://www.epa.gov/region09/superfund/prg/index.html.

[d]Exposure frequency assumptions:

Typical: 1 day/week for 3 months and 1 day/2 weeks for 9 months.

Upper bound: 3 days/week for 3 months and 1 day/week for 9 months.

[e]Based on total area (13%) of NE corner relative to entire park.

LADD = lifetime average daily dose

LADDif = IR x EF x ED / (ATc x BW x CF)

LADD = Csoil x FI x RBA x LADDif

Total LADD = LADDchild + LADDadult

CR = Total LADD x SF

Table 3. Cancer risks associated with recreational exposures to surface soils.

Chemical	Exposure Point Concentration		Cancer Risk	
	Average (mg/kg)	UCLM (mg/kg)	Typical[a] (unitless)	Reasonable Upper Bound[b] (unitless)
Prior BaP	22	34	3.E-07	8.E-06
Prior BaPE	24	46	3.E-07	1.E-05
Recent BaP	18	36	2.E-07	8.E-06
Recent BaPE	23	46	3.E-07	1.E-05

Note: Risks include incidental ingestion of and dermal contact with soils.

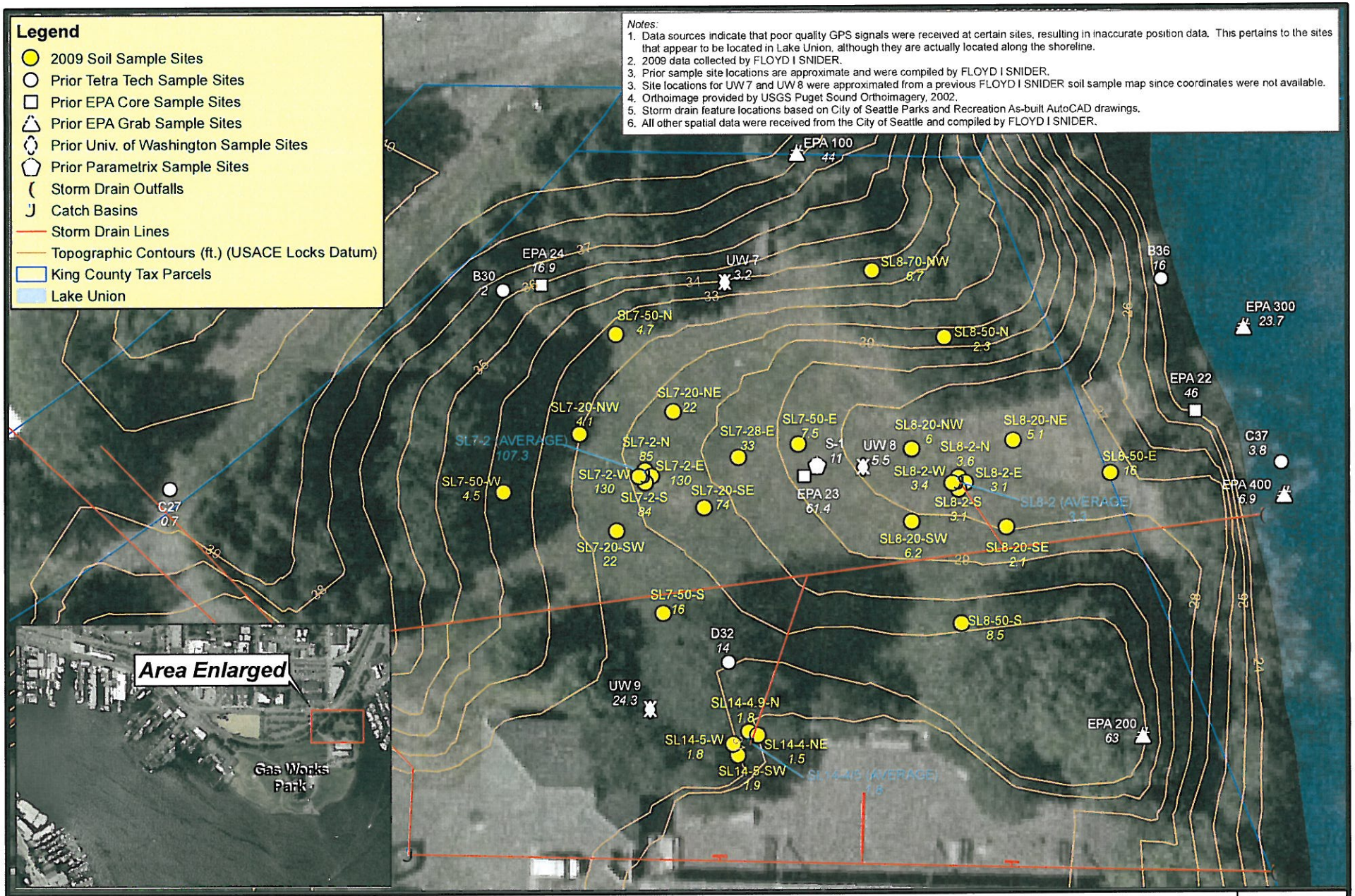
[a]Exposure frequency assumes 1 day/week for 3 months and 1 day/2 weeks for 9 months.

[b]Exposure frequency assumes 3 days/week for 3 months and 1 day/week for 9 months.

BaP = benzo(a)pyrene

BaPE = benzo(a)pyrene equivalents

UCLM = upper confidence limit of the mean



ENVIRON

605 First Avenue, Suite 300
Seattle, WA 98104

Recent and Prior Concentrations of Benzo(a)Pyrene (mg/kg) in Soil Samples at Gas Works Park, Seattle, WA.

Labels show sample site name followed by benzo(a)pyrene concentrations (mg/kg) in italics.

0 12.5 25 50 75 100 Feet

Figure 1

Prepared by: AF/AC Date: 5/4/2010 Project Number: 3025123A Approved: Revised:

November 18, 2010

David Graves
Seattle Department of Parks and Recreation
800 Maynard Avenue South, 3rd Floor
Seattle, WA 98134

Re: Evaluation of Polycyclic Aromatic Hydrocarbons in Soil Samples from the Southwest Corner of Gas Works Park

Dear Mr. Graves:

As requested, we have evaluated potential exposures and health risks for park users who might come into contact with polycyclic aromatic hydrocarbons (PAHs) in soil in the southwest (SW) corner of Gas Works Park (GWP). This evaluation mirrors the evaluation reported in our May 5, 2010 letter providing an evaluation of PAH data from the northeast corner of GWP. As with our May 5th evaluation, our review focused on concentrations of seven PAHs considered by the U.S. Environmental Protection Agency (EPA) to be potential carcinogens (referred to as cPAH). cPAH are typically evaluated by measuring benzo(a)pyrene (BaP) and benzo(a)pyrene equivalent (BaPE) concentrations. BaPE concentrations include concentrations of BaP and concentrations of six additional cPAH (benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, and chrysene) adjusted to reflect their potency relative to BaP.

Analytical data for surface soil samples collected during the 1980s and 1990s were reviewed and evaluated. As indicated by the findings of our May 5th comparison of data collected in the northeast corner (NE) during 2009 with data collected in the 1980s and 1990s, these older data are likely to still be representative of current conditions in the park. Sources of data reviewed include:

- Ecology and Environment Inc. 1984. Gasworks Park, Summary of Results. Submitted to U.S. Environmental Protection Agency, Region X, Seattle, WA.
- EPA. 1984. EPA Gas Works Park Surface Soil Grab Samples.
- Kalman, D. 1984. Gas Works Park surface soils contamination survey. Prepared for City of Seattle Office of Intergovernmental Relations. School of Public Health and Community Medicine, Department of Environmental Health, University of Washington. (Appendix 7a to Ongerth, J. 1985 Draft Evaluation of Health Risk For Public Use of Gas Works Park)
- Tetra Tech. 1985. Gas Works Park Supplemental Soils Testing, Phase I Surface Soils Analysis. Prepared for Seattle Parks Department. Tetra Tech, Inc., Bellevue, Washington.
- Parametrix and KEY Environmental, 1998. Draft – Gas Works Park Environmental Cleanup, Focused Feasibility Study Report.

In addition, we reviewed a health risk evaluation for GWP completed in 1985 *(Evaluation of Health Risk for Public Use of Gas Works Park)* by the Gas Works Park Health Risk Evaluation Panel (the risk panel) led by Dr. Jerry Ongerth of the University of Washington. This report included an evaluation of data collected from the SW corner. At that time, EPA had not yet developed standard methods for human health risk assessment. Instead, the risk panel devised methods to estimate intake of PAHs via

incidental ingestion of soil, inhalation, and dermal contact. They then compared the intake estimates with known intake levels from other sources, including cigarette smoke, urban air (Seattle and Detroit), diet, and occupational sources. One of the recommendations of the risk panel was to cover areas with BaP soil concentrations higher than 100 mg/kg. This recommendation was subsequently carried out by the City, and we have modified our data summaries to remove data for those samples.

The following data treatment rules were applied to data collected from the SW area of GWP:

1. Three samples with BaP concentrations greater than 100 mg/kg (EPA4, EPA7, and EPA700) were excluded from evaluation because, as recommended by the risk panel, these locations were covered.
2. Several replicate samples were collected at location J14. Only the original sample, J14-00, was retained for evaluation. The remaining five replicates were not included in the data evaluation.
3. Samples from prior studies were collected from two depths at locations EPA5 and EPA6 (0-3 inches bgs and 3-6 inches bgs). To avoid bias resulting from oversampling at these two locations, results from both depths were not used. PAH concentrations tend to be greater at the more shallow depth and visitors to the park are more likely to contact soil found at the shallow depth. To obtain the dataset most representative and protective of exposures to surface soil, only the results from 0-3 inches bgs were evaluated for locations EPA5 and EPA6.
4. One duplicate sample appears to have been collected at UW21 during a prior study but only BaP was analyzed in one of the samples and a subset of the carcinogenic PAHs were analyzed in the second sample. To maximize the usable data for this evaluation, the sample for which the greater number of results was available was retained. The other sample for which only a BaP result was available was discarded.

Also, it should be noted that analytical results were not available for each of the seven carcinogenic PAHs for each sample within the dataset. In some cases, only BaP results are available and in other cases, only a subset of the seven carcinogenic PAH results are available. To account for these differences, it is useful to evaluate BaP (alone) as well as BaPE when sufficient data are available.

Following data treatment, a total of 28 soil samples collected in 1984, 1985, and 1997 were used in the evaluation. This resulted in 28 BaPE and 26 BaP results. Data summaries are provided in Table 1. Sample locations are shown in Figure 1. Exposure point concentrations (as the upper confidence limit on the mean or UCLM) were calculated using EPA's ProUCL software (Version 4.00.05).

Summary statistics and the 95th percentile upper confidence limit of the mean (UCLM) recommended by EPA's ProUCL software are provided for each dataset in Table 1.

ENVIRON performed a screening-level assessment to evaluate whether current levels of PAHs in surface soil present an unacceptable risk to recreational users at the park. Two hypothetical recreational user scenarios were developed, a "typical" user and an "upper bound" user scenario. The typical scenario is based on a combined child/adult who frequents the park 1 day per week for 3 months of the year and 1 day every 2 weeks for the remaining 9 months of the year for 9 years. The upper bound user is assumed to frequent the park 3 days per week for 3 months of the year and 1 day per week for the remaining 9 months of the year for 30 years. It is not realistic to assume that each recreational user spends 100 percent of their time in the SW corner of the park; however, information is not available regarding how much time is spent within different areas of the park. In the absence of park-specific usage information, the area of the SW corner relative to the total park area was calculated and this ratio (0.3 or 30 percent) was used to represent the fraction of total soil contacted at the park that is within the SW corner. Additional exposure factors are provided in Table 2.

Potential cancer risks were calculated for the typical and upper-bound child/adult recreational user contacting surface soil of the SW corner of the park, as shown in Table 3. Risk estimates for a user of the NE corner as presented in our May 5th letter are also summarized in this table, as are combined risks for all affected areas of the park. Excess lifetime cancer risks for the SW corner were estimated to be 4×10^{-7} for the typical user contacting either BaP or BaPE. For the reasonable upper bound user excess lifetime cancer were estimated to be 9×10^{-6} and 1×10^{-5} for contacting BaP or BaPE, respectively. These risk estimates are very close to the estimated excess cancer risks for the NE corner. Combined risk estimates for a typical user of both areas of the park are 6×10^{-7} and 7×10^{-7} for contacting BaP or BaPE, respectively. For the reasonable upper bound user combined risk estimates were 2×10^{-5} for contacting either BaP or BaPE. These risk estimates are well within EPA's acceptable risk management range of 1×10^{-6} and 1×10^{-4}.[1]

There are a number of uncertainties associated with these risk estimates. Although some chemical mixtures (e.g., tobacco smoke, chimney soot, others) that include PAHs have been shown to be carcinogenic by inhalation or dermal contact in humans, the relative potency of the individual PAH compounds has not been established in humans. The EPA toxicity assessment for BaP and the other cPAHs has been based on the results of studies in rodents; however, these chemicals have only been shown to be rodent carcinogens at portal of entry sites such as the skin or lung. Carcinogenic potency of each cPAH was estimated relative to BaP based primarily on comparison of mouse skin tumor data. While skin tumor data from mice for multiple PAHs may allow a comparison across PAHs, the relevance and predictiveness of this test system for oral cancer risk in humans is questionable. Consequently, cancer risk estimates for the cPAHs could be overestimated.

On the other hand, USEPA is beginning to modify cancer risk estimates to reflect increased cancer risks associated with exposures that occur during early life stages. Such adjustments could increase the cancer risk estimates. There are also uncertainties associated with the exposure estimates. In particular, assuming that a high end park user might ingest 50 to 100 mg of park soil per day for 78 days per year for 30 years is extremely conservative. Finally, in assessing the potential significance of the estimated cPAH intakes, we considered normal dietary intakes and concluded that potential park-related exposures are within the range of intakes that might be consumed in typical diets.

In conclusion, the concentrations of PAHs in soil at Gas Works Park are not likely to present an unacceptable risk to the public.

Sincerely,

Rosalind A. Schoof, PhD, DABT
Principal

[1] The National Oil and Hazardous Substances Pollution Contingency Plan guidance (March 8,1990; 40 CFR 300) identifies estimated cancer risks falling between 1×10^{-6} and 1×10^{-4} (or, one additional cancer case per million people and one additional cancer case per ten-thousand people) as within an acceptable risk management range.

Table 1. BaP and BaPE datasets, summary statistics, and UCLM values

	SW Area	
	BaP	BaPE
	1.6	1.6
	2.8	2.8
	7.9	7.9
	5.7	5.7
	2.2	2.2
	22	22
	16	19
	12	12
	15	15
	36	55
	5.0	0.1
	1.3	5.7
	13	2.4
	7.1	0.004
	16	18
	2.4	9.9
	13	21
	23	3.6
	35	18
	16	31
	1.9	46
	16	22
	36	3.1
	8.7	21
	12	48
	4.1	11
		16
		5.5
number of samples (n)	26	28
minimum	1.3	0.1
median	12	11.6
average	13	15
maximum	36	55
standard deviation	11	15
ProUCL recommended distribution	Gamma	Gamma
ProUCL recommended UCLM	17	22
UCLM method	95% approximate gamma UCLM	95% approximate gamma UCLM

Note: Data presented in this table represent post-treatment dataset that were used in the evaluation.

BaP = benzo(a)pyrene

BaPE = benzo(a)pyrene equivalent

MVUE = minimum variance unbiased estimate

UCLM = upper confidence limit of the mean

Table 2. Exposure assumptions for child and adult recreational users.

Adult Exposure Assumptions					
Parameter	**Abbrev**	**Typical**	**Upper Bound**	**Units**	**Source**
Soil ingestion rate	IR	22	50	mg/day	Prof. judgement[a]
Relative bioavailability adjustment	RBA	0.6	0.6	--	Literature review
Adherence factor	AF	0.01	0.07	mg/cm^2-event	Typ: Prof. judgement[a], Upper: Std. Default[b]
Dermal absorption value	ABSd	0.13	0.13	--	EPA 2004
Surface Area	SA	5,700	5,700	cm^2	Std. Default[b]
Event frequency	EV	1	1	event/day	EPA 2004
Exposure frequency	EF	32.5	78	day/yr	Prof. judgement[c]
Exposure duration	ED	6	24	yr	Typ: EPA Region 10, Upper: Std. Default[b]
Fraction of time spent in SW area	FI	0.6	0.6	--	Prof. judgement[d]
Averaging time cancer	ATc	25,550	25,550	day	Std. Default[b]
Body weight	BW	70	70	kg	Std. Default[b]
Unit conversion factor	CF	1.00E+06	1.00E+06	mg/kg	N/A

Child Exposure Assumptions					
Parameter	**Abbrev**	**Typical**	**Upper Bound**	**Units**	**Source**
Soil ingestion rate	IR	45	100	mg/day	Prof. judgement[a]
Relative bioavailability adjustment	RBA	0.6	0.6	--	Literature review
Adherence factor	AF	0.04	0.2	mg/cm^2-event	Typ: Prof. judgement[a], Upper: Std. Default[b]
Dermal absorption value	ABSd	0.13	0.13	--	EPA 2004
Surface Area	SA	2,800	2,800	cm^2	Std. Default[b]
Event frequency	EV	1	1	event/day	EPA 2004
Exposure frequency	EF	32.5	78	day/yr	Prof. judgement[c]
Exposure duration	ED	3	6	yr	Typ: EPA Region 10, Upper: Std. Default[b]
Fraction of time spent in SW area	FI	0.6	0.6	--	Prof. judgement[d]
Averaging time cancer	ATc	25,550	25,550	day	Std. Default[b]
Body weight	BW	15	15	kg	Std. Default[b]
Unit conversion factor	CF	1.00E+06	1.00E+06	mg/kg	N/A

[a]Based on a review of available literature.

[b]Standard default factors per Exhibit 4-1 of EPA Region 9's PRGs table User's Guide, http://www.epa.gov/region09/superfund/prg/index.html.

[c]Exposure frequency assumptions:

Typical: 1 day/week for 3 months and 1 day/2 weeks for 9 months.

Upper bound: 3 days/week for 3 months and 1 day/week for 9 months.

[d]Based on total area of NE corner (13%) and SW area (60%) relative to entire park.

Table 3. Cancer risks associated with recreational exposures to surface soils.

Chemical	Exposure Point Concentration		Cancer Risk	
	Average (mg/kg)	95UCLM (mg/kg)	Typical[a] (unitless)	Reasonable Upper Bound[b] (unitless)
NE Corner BaP (recent)[c]	18	36	2.E-07	8.E-06
SW Area BaP[d]	13	17	4.E-07	9.E-06
NE Corner + SW Area BaP[e]			6.E-07	2.E-05
NE Corner BaPE (recent)[c]	23	46	3.E-07	1.E-05
SW Area BaPE[d]	15	23	4.E-07	1.E-05
NE Corner + SW Area BaPE[e]			7.E-07	2.E-05

Note: Risks include incidental ingestion of and dermal contact with soils.

[a]Exposure frequency assumes 1 day/week for 3 months and 1 day/2 weeks for 9 months.

[b]Exposure frequency assumes 3 days/week for 3 months and 1 day/week for 9 months.

[c]Time spent in the northeast area assumed to be 13 percent of the time spent in the park as a whole.

[d]Time spent in the southwest area assumed to be 30 percent of the time spent in the park as a whole.

[e]Risks calculated for the entire park assume time spent in various locations within the park is distributed equally by area.

95UCLM = Upper 95 percent confidence limit on the mean

BaP = Benzo(a)pyrene

BaPE = Benzo(a)pyrene equivalent

Equations for calculating intake via incidental ingestion:

LADDif = IR x EF x ED / (ATc x BW x CF); where LADDif is the lifetime average daily dose intake factor

LADD = Csoil x FI x RBA x LADDif; where Csoil is the concentration of BaP or BAPE in soil

Total LADD = LADDchild + LADDadult

Equations for calculating dermal dose:

DAevent = Csoil x FI x CF x AF x ABSd; where DAevent is the dermal absorbed dose per soil contact event

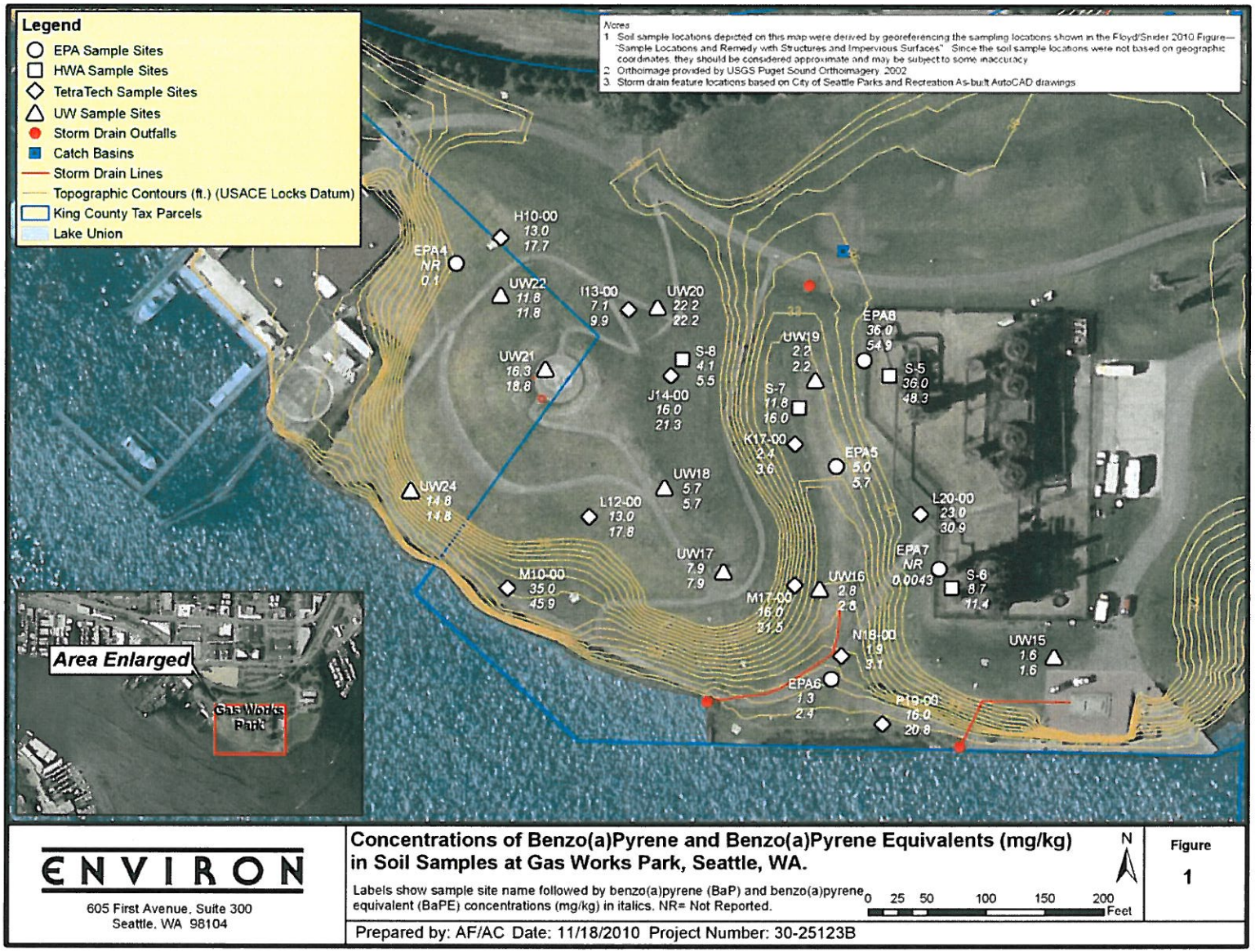
LDADif = EF x ED x EV x SA / (ATc x BW); where LDADif is the lifetime daily absorbed dose intake factor

LDAD = DAevent x LDADif

Total LDAD = LDADchild + LDADadult

Equation for calculating cancer risk:

CR = (Total LADD x SF) + (Total LDAD x SF); where SF is the cancer slope factor of 7.3 kg-day/mg


Legend
EPA Sample Sites
HWA Sample Sites
TetraTech Sample Sites
UW Sample Sites
Storm Drain Outfalls
Catch Basins
Storm Drain Lines
Topographic Contours (ft.) (USACE Locks Datum)
King County Tax Parcels
Lake Union
Notes
1 Soil sample locations depicted on this map were derived by georeferencing the sampling locations shown in the Floyd/Snider 2010 Figure— "Sample Locations and Remedy with Structures and Impervious Surfaces" Since the soil sample locations were not based on geographic coordinates, they should be considered approximate and may be subject to some inaccuracy
2 Orthoimage provided by USGS Puget Sound Orthoimagery 2002
3 Storm drain feature locations based on City of Seattle Parks and Recreation As-built AutoCAD drawings
H10-00 13.0 17.7
EPA4 NR 0.1
UW22 11.8 11.8
I13-00 7.1 9.9
UW20 22.2 22.2
UW21 16.3 18.8
S-8 4.1 5.5
J14-00 16.0 21.3
UW19 2.2 2.2
EPA8 36.0 54.9
S-5 36.0 48.3
S-7 11.8 16.0
K17-00 2.4 3.6
EPA5 5.0 5.7
UW24 14.8 14.8
UW18 5.7 5.7
L12-00 13.0 17.8
L20-00 23.0 30.9
UW17 7.9 7.9
EPA7 NR 0.0043
S-6 8.7 11.4
M10-00 35.0 45.9
M17-00 16.0 21.5
UW16 2.8 2.8
N18-00 1.9 3.1
UW15 1.6 1.6
EPA6 1.3 2.4
P19-00 16.0 20.8
Area Enlarged
Gas Works Park
ENVIRON
605 First Avenue, Suite 300
Seattle, WA 98104
Concentrations of Benzo(a)Pyrene and Benzo(a)Pyrene Equivalents (mg/kg) in Soil Samples at Gas Works Park, Seattle, WA.
Labels show sample site name followed by benzo(a)pyrene (BaP) and benzo(a)pyrene equivalent (BaPE) concentrations (mg/kg) in italics. NR= Not Reported.
N
0 25 50 100 150 200 Feet
Figure 1
Prepared by: AF/AC Date: 11/18/2010 Project Number: 30-25123B

ATTACHMENT 4D-2
Floyd|Snider Air Evaluation Summary Memo (2008)

FLOYD | SNIDER
strategy • science • engineering
Two Union Square • 601 Union Street • Suite 600
Seattle, Washington 98101 • tel: 206.292.2078 • fax: 206.682.7867

Memorandum

To: David Graves, Seattle Parks and Recreation Department

Copies: Marrel Livesay, Seattle Parks and Recreation Department ; Kathy Gerla, Law Department, and Teri Floyd

From: Jessi Massingale

Date: June 13, 2008

Project No: COS-GWP-UP

Re: Summary of Air Quality Evaluation

This memorandum presents a summary of the results of an air quality evaluation at Gas Works Park (Site) and the Seattle Police Department (SPD) Harbor Patrol Facility conducted by The Floyd|Snider Team on behalf of the City of Seattle.

INTRODUCTION

During late summer and early fall of 2006, numerous studies were taking place at the Gas Works Park Site to support the selection of sediment remedies. At this time, it was noticed that several uplands sections of the park had the distinct odor of mothballs, especially around the play barn, the old Manufactured Gas Plant (MGP) structures, and along the eastern shoreline where there were visible tar seeps. The City elected to conduct a year long air quality monitoring program to better understand the nature and significance of the odors.

The purpose of this evaluation was to measure the concentrations of key volatile organic compounds (VOCs) in ambient air during different seasons and at different locations.

The air quality evaluation consisted of three quarterly monitoring events conducted from spring 2007 to winter (January) 2008. To estimate the concentration range of VOCs quarterly[1] (seasonal) air monitoring events were conducted for a period of one year. Thermal desorption tube (TDT) sampling and high-sensitivity mass spectrometry (HS/MS) analysis was conducted during each of the three quarterly monitoring events. Additionally, continuous air monitoring for total aromatics using an aromatic-specific laser ionization detector (ARSLID) was conducted during the month of August as part of the second quarter (summer) monitoring event. The second quarter (summer) consisted of ARSLID sampling in August and TDT sampling in early

[1] The term quarterly has been used to represent the concept of seasonal measurements. Measurements taken at three times during the year: spring, summer, and winter are considered to represent the range of conditions that would be expected during a typical year-long period in Seattle.

September. These time periods were chosen to represent the warmer summer and fall months in Seattle and therefore an additional fall quarter monitoring event was not conducted. The first quarter of monitoring was conducted during spring, April 2007. The third quarter of monitoring was conducted during winter, January 2008.

Air samples were collected from five locations within the Park and Harbor Patrol facility (Figure 1). At each of the five sampling locations, one pair of replicate samples was collected on TDTs. Meteorological conditions during TDT sample collection were monitored using a Davis Vantage Pro Weather Station.

QUARTERLY SAMPLING AND ANALYSIS RESULTS

The complete quarterly air monitoring events and analytical results are presented in the Quarterly Air Sampling Data Reports (The Floyd|Snider Team 2007a, 2007b, 2008). A summary of the air quality evaluation is described below.

As shown in Table 1, five chlorinated VOCs were detected that are not chemicals of concern (COCs) at Gas Works. Their concentrations were less than 2 ng/L and were often just greater than the detection limit. In addition, they were generally around 1 percent of the total VOCs and were similar at different locations and different seasons as well as being similar to background and upwind locations. There is no indication that these compounds were released from the facility, nor does there appear to be an association with the facility.

Twelve aromatic hydrocarbons were detected in the air samples. They include benzene, alkylated benzenes such as toluene, and naphthalene (the most volatile of the polycyclic aromatic hydrocarbons [PAHs]). These VOCs are consistent with the COCs identified for the site.

In general, the highest concentrations of most analytes were detected during the summer sampling event and the lowest were detected in the winter (Table 1). There were a few exceptions to this trend within confined spaces such as under the Play Barn and in the Harbor Patrol Building, where winter concentrations for some analytes were higher than summer concentrations.

Except for a single sample collected from the Cracking Tower area, the rest of the samples had similar concentrations between quarterly events and locations. The one anomalous sample was collected from within the fenced area of the Cracking Towers (an area that is inaccessible to the public) in spring 2007. Its replicate was also analyzed. The detected concentrations of benzene in the two replicate samples were 870 ng/L and 0.9 ng/L. To better understand whether the structures (or soils) within the Cracking Tower area were contributing to the benzene, or whether the sample result might have been an anomaly, four additional TDT sampling locations—plus a screening level flux chamber air sample—were added to the second quarter (summer) monitoring event in the vicinity of the Cracking Towers. The results of the additional Cracking Tower samples collected during the second quarter (summer) monitoring event were consistent with the results of the Cracking Towers Area replicate sample, and did not significantly differ from the results of the other sampling locations. The detected benzene

concentrations during the second and third quarters suggested that the first quarter (spring) elevated benzene and VOC concentrations were an anomaly.

The Prow upwind (background) benzene concentrations detected during the three quarters were within the Seattle Beacon Hill 2000 to 2002 background concentrations (Table 2) (PSCAA 2003). Naphthalene was not detected in the Prow upwind sample during any of the quarterly monitoring events.

ASIDE ON NE CORNER RESULTS

You have recently asked about air quality in the NE Corner based on the results of the NE Corner Investigation soil gas survey. The following is provided to clarify the differences between this ambient air quality monitoring and the NE Corner soil gas survey. The soil gas survey was conducted as a screening method to identify locations where total aromatics measured in the subsurface soil may be associated with the presence of shallow subsurface tar and/or DNAPL. The soil gas survey consisted of collecting soil gas from the subsurface, approximately 18 inches below the ground surface. The sampling probe was driven approximately 18 inches into the ground and sample tubing was connected to the portable ARSLID (Aromatic-Specific Laser Ionization Detector). The ARSLID monitor includes an internal sampling pump which pulls soil gas from the subsurface soils, and does not rely on passive diffusion and does not reflect any potential gas that would be present at the ground surface, which would be lower in any potential VOC concentrations. Additionally, the ARSLID detects and reports total aromatic hydrocarbons, as the air stream is drawn into the ARSLID, it is ionized and an electrical current is generated as the ions are drawn to electrodes via a potential bias. Therefore, any and all compounds which ionize upon exposure to the laser generate an electrical response. The presence or contribution of individual compounds to the total reading cannot be determined. For these reasons, the soil gas survey can not be used to predict air concentrations above ground.

The quarterly air samples collected from the Eastern Shoreline sampling location (where previous tar seeps were located and odors observed) is located just south of the meadow and within the extent of the NE Corner Investigation. The air samples collected at the Eastern Shoreline location were collected from a height equivalent to an average breathing zone, reflecting the ambient air quality at that location.

CONCLUSIONS

The detected concentrations of VOCs in air samples collected from both the Park sampling locations and Harbor Patrol locations do not exceed any of the OSHA occupational standards (PEL) that would be applicable to Park and Harbor Patrol employees.

Although air cleanup levels were not established under the existing cleanup action plan for the site, a modified Method B value appropriate for a park user has been defined for this memo. The value was calculated using the MTCA Method B equation in WAC 173-340-150, with a modification for the frequency of exposure. In the Method B default exposure, exposure is assumed to be for 100% of the time or the equivalent of 24 hr per day for 7 days per week. In the Park User scenario, the exposure was assumed to be for 4 hours per week. All other parameters remained the same.

Excluding the anomalous[2] air sample collected from within the fenced Cracking Tower area during the spring 2007, detected concentrations of all VOCs were below the park user scenario air standards. The maximum detected naphthalene concentration (6.8 ng/L) was approximately an order of magnitude below the park user air standard (58 ng/L). Additionally, the maximum naphthalene concentration was detected from within the locked Play Barn basement that is inaccessible to park users. This location was selected because it is near known areas of subsurface concentrations, is a "confined space," and is below ground – it was expected to represent a "worst case" condition at the Park.

The average detected benzene concentration of (1.9 ng/L) and the maximum concentration (3.3 ng/L) were an order of magnitude below the park user air standard (13.3 ng/L). Additionally, the detected benzene concentrations are within the range of Seattle background benzene concentrations, ranging from 1.21 ng/L to 2.68 ng/L (Table 2).

The mothball like odor observed during the summer of 2006 was likely associated with elevated concentrations of naphthalene. During the subsequent Winter (January 2007) the Parks Department conducted tar maintenance actions, consistent with the Consent Decree, of excavating surface tar expressions along the eastern shoreline of the park (where naphthalene-like odors had been observed) and then covering the areas with gravel. Following the Parks Department maintenance actions, no odors were observed during the spring or summer of 2007. These actions resulted in a reduction of the previously observed odors and risks associated with VOC air concentrations.

Based on the results of the air quality evaluation no additional air sampling is recommended at the Gas Works Park site. The quarterly results showed that the detected concentrations of VOCs, benzene and naphthalene in particular do not exceed the park user scenario; and do not exceed OSHA occupational standards (PEL) that would be applicable to Park and Harbor Patrol employees. Since the concentrations are below both of these benchmarks, we believe that they are protective of human health.

REFERENCES

Puget Sound Clean Air Agency (PSCAA) and Washington State Department of Ecology (Ecology) 2003. Final Report: Puget Sound Air Toxics Evaluation. Seattle, Washington. October. http://www.pscleanair.org/airq/basics/psate_final.pdf

The Floyd|Snider Team. 2007a. *First Quarter (Spring) 2007 Air Sampling Data Report.* 22 June.

_____. 2007b. *Second Quarter (Summer) 2007 Air Sampling Data Report.* 11 November.

[2] Again, we believe that the spring 2007 sample with an elevated benzene concentration was an anomaly as neither the co-located replicate sample, nor subsequent air samples collected at the same location or adjacent to it showed the same level of concentrations.

_____. 2008. *Third Quarter (Winter) 2008 Air Sampling Data Report.* 8 April.

FIGURES

TABLES

Notes:

- Air sample locations are approximate.
- Air samples were collected using thermal desorption tubes (TDTs).
- Orthophoto provided by City of Seattle and dated 2005.

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TRENARY & ASSOCIATES, LLC

Summary of Air Quality Evaluation
Gas Works Park
Seattle, Washington

Figure 1
Air Sampling Locations

File: F:\projects\COS-GWP-UP\GIS\MXD\Figure 2.1 (Air Sampling Locations Summer Qtr 2007).mxd
Date: 10/9/2007

Table 1
Comparison of Quarterly Air Sampling Thermal Desorption Tube Quantitative Volatile Organic Compound Concentrations

Location	**Cracking Towers (CT)**				**East Shoreline (ES)**			**Harbor Patrol (HP)**			**Play Barn Basement (PBB)**			**Prow Upwind (PUP)**			**Samples**	
Sample Event	**Spring**		**Summer**	**Winter**	**Spring**	**Summer**	**Winter**	**Spring**	**Summer**	**Winter**	**Spring**	**Summer**	**Winter**	**Spring**	**Summer**	**Winter**	**Min**	**Max**
Sample ID	CT-042707	CT-042707-Rep	CT-091107	CT-011608	ES-042707	ES-091107	ES-011608	HP-042707	HP-091107	HP-011608	PBB-042707	PBB-091107	PBB-011608	PUP-042707	PUP-091107	PUP-011608		
Sample Date	4/27/2007		9/11/2007	1/16/2008	4/27/2007	9/11/2007	1/16/2008	4/27/2007	9/11/2007	1/16/2008	4/27/2007	9/11/2007	1/16/2008	4/27/2007	9/11/2007	1/16/2008		
Parameters (ng/L)																		
Total No. of detected VOCs	35	24	37	13	18	36	18	27	31	28	19	12	13	15	28	11		
Total VOCs	1300	390	280	110	120	250	150	230	240	380	130	180	110	120	200	100	110	1300
Chlorinated VOCs (ng/L)																		
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.9	ND	ND	ND	ND	ND	ND	0.9	0.9
Tetrachloroethene	0.4	0.7	1.6	ND	ND	1.2	0.5	0.4	1.3	0.6	ND	ND	0.5	ND	1	ND	0.4	1.6
Carbon tetrachloride	ND	ND	ND	ND	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3	0.3
1,4-Dichlorobenzene	ND	ND	0.4	ND	ND	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3	0.4
Methylene chloride	ND	ND	1.3	ND	ND	0.9	ND	ND	1	ND	ND	0.5	ND	ND	1.8	ND	0.5	1.3
Aromatic VOCs (ng/L)																		
Benzene	870	0.9	2.8	1.6	2.5	2.9	2	1.4	2.5	3.3	1.3	1.6	2.1	0.8	2.1	1.6	0.9	870
Toluene	74	15	13	4.7	3.9	9.9	7.7	7.7	12	10	3.5	5.8	8	3.3	7.9	4	3.5	74
Ethylbenzene	3.7	0.9	2.8	0.8	0.6	2	1	1.2	2.4	3.5	0.5	0.6	0.6	0.6	1.7	0.7	0.5	3.7
m,p -Xylene	6.9	2.8	8.1	2.3	2	5.8	3.1	4.1	7.8	11	2	2.2	1.9	1.8	5.2	1.9	1.9	11
o -Xylene	1.2	1	3.2	0.9	0.7	2.3	1.1	1.4	2.9	3.4	0.7	0.8	0.8	0.6	2.1	0.7	0.7	3.4
n -Propylbenzene	0.6	0.6	1	ND	ND	1.1	ND	0.3	0.9	1.2	ND	ND	ND	ND	0.8	ND	0.3	1.2
1,3,5-Trimethylbenzene	0.9	1	1.2	0.4	ND	1.5	ND	0.4	0.9	1.8	0.4	ND	ND	ND	1.2	ND	0.4	1.8
1,2,4-Trimethylbenzene	4.4	3.1	5.3	1.7	0.8	6.4	1.2	1.8	3.6	7.8	1.4	ND	0.8	0.9	4.2	1	0.8	7.8
p -Isopropytoluene	ND	ND	0.4	ND	ND	0.3	ND	ND	0.4	ND	ND	ND	ND	ND	ND	ND	0.3	0.4
Naphthalene	0.3	0.3	0.8	0.4	ND	2.5	0.4	0.4	1	0.7	1.9	6.8	1.6	ND	ND	ND	0.3	6.8
2-Methylnaphthalene	ND	ND	ND	ND	ND	0.4	ND	ND	0.5	0.3	0.5	1.6	ND	ND	ND	ND	0.3	1.6
Styrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4	ND	ND	ND	ND	0.4	0.4

Notes:

1 All samples were collected on thermal desorption tube (TDTs) over a period of approximately 3 1/2 to 4 1/2 hours. Samples were directly desorbed from the tubes with heat and analyzed by high-sensitivity mass spectrometry (HS/MS).
2 Only quantitative quarterly results are presented. Calculated semi-quantitative results are not shown.
ND Not detected.
VOC Volatile organic compound.

Table 2
Seattle Average Annual Background Volatile Organic Compound Concentrations (2000 to 2002)[1]

Site	Beacon Hill			Georgetown		
Year	2000	2001	2002	2000	2001	2002
Analyte (ng/L, µg/m^3)						
benzene	1.69	1.31	1.21	2.68	1.82	1.88
1,3-butadiene	0.18	0.11	0.09	0.24	0.13	0.22
carbon tetrachloride	0.63	0.63	0.63	0.69	0.63	0.69
chloroform	0.29	0.20	0.24	0.20	0.15	0.15
dichloromethane	5.38	1.53	NA	7.04	1.84	NA
tetrachloroethylene	0.20	0.14	0.27	0.47	0.34	0.41
trichloroethylene	0.27	0.16	0.11	0.64	0.38	0.54
acetaldehyde	1.51	1.30	1.49	1.84	1.22	1.46
formaldehyde	2.25	1.66	1.64	3.51	1.48	1.43

Notes:
1 Data obtained from Seattle Air Toxics 2000-02.xls (Ecology 2004).
NA Not available.

Table 3
Comparison of Maximum Air Monitoring Results

Parameters[1]	Maximum Result	Location and Time of Maximum	Maximum Upwind	Resident (Method B)	Park User (4 hr/wk)
Total No. of detected VOCs	37	Towers, summer	28	--	--
Total VOCs	1,300	Towers, spring	200	--	--
Chlorinated VOCs (ng/L)					
chloroform	0.9	Harbor Patrol, winter	ND	0.11	4.6
tetrachloroethene	1.6	Towers, summer	1.0	0.42	18
carbon tetrachloride	0.3	East Shore, spring	ND	0.17	7.1
1,4-Dichlorobenzene	0.4	Harbor Patrol, summer	ND	370	15,000
Methylene Chloride	1.3	Towers, summer	1.8	5.3	220
Aromatic VOCs (ng/L)					
benzene	870, 3.3[2]	Towers spring, Harbor Patrol summer	2.1	0.32	13.3
toluene	74, 15[2]	Towers, spring	7.9	2,200	92,000
ethylbenzene	3.7, 3.5[2]	Towers spring, Harbor Patrol winter	1.7	460	19,000
m,p-xylene	11	Harbor Patrol, winter	5.2	46	1,900
o-xylene	3.4	Harbor Patrol, winter	2.1	46	1,900
n-propylbenzene	1.2	Harbor Patrol, winter	0.8	NA	NA
1,3,5-trimethylbenzene	1.8	Harbor Patrol, winter	1.2	2.7	110
1,2,4-trimethylbenzene	7.8	Harbor Patrol, winter	4.2	2.7	110
p-Isopropytoluene	0.4	Harbor Patrol, summer	ND	NA	NA
naphthalene	6.8	Play Barn, summer	ND	1.4	58
2-methylnaphthalene	1.6	Play Barn, summer	ND	NA	NA
Styrene	0.4	Play Barn, summer	ND	4.4	180

Notes:

1 Complete quartelry air monitoring results are presented in Table 1.

2 As discussed in the first quarterly report, one sample from the cracking towers contained high concentrations of benzene and toluene that were not present in its replicate. This triggered additional sampling in the second quarter around the towers. The first number represents the sample with the high readings, the second number represents the maximum of all other samples.

NA Not available

ND Not detected

VOC Volatile organic compound

ATTACHMENT 4D-3
Hart Crowser Terrestrial Ecological Evaluation (2012)

APPENDIX D
SIMPLIFIED TERRESTRIAL ECOLOGICAL EVALUATION OF THE GAS WORKS PARK SITE

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APPENDIX D
SIMPLIFIED TERRESTRIAL ECOLOGICAL EVALUATION OF THE GAS WORKS PARK SITE

D1.0 INTRODUCTION

This ecological assessment evaluates potential ecological hazards associated with residual chemical concentrations present in soil at the Gas Works Park site (the Site). A simplified terrestrial ecological evaluation (TEE) was deemed the most appropriate method for this assessment and it was prepared following procedures prescribed in the Model Toxics Control Act (MTCA) (WAC 173-340-7492). The MTCA TEE methods are consistent with US Environmental Protection Agency (EPA) ecological risk assessment guidelines (EPA 1997).

This simplified TEE forms part of the remedial investigation (RI) of the Site. Some information contained in the main body of the RI report has been included in the TEE for descriptive purposes. Additional information on the industrial processes, redevelopment, and cleanup activities that occurred at the Site are provided in the main body of the RI report.

The Site is located on the north shore of Lake Union and occupies approximately 20.5 acres (Figure D-1). The Site includes Gas Works Park and the Seattle Police Department Harbor Patrol facility located to the west of the park. Gas Works Park is an urban park managed by the Seattle Parks and Recreation Department. Dominant park features include the parking lot, gravel trail, Kite Hill, Cracking Towers, Play Barn, and Prow (Figure D-1).

Gas Work Park is located on the site of a former manufactured gas plant (MGP). The plant began producing manufactured gas from coal in 1907 (Ecology 2005). In 1937, the plant was modified to use oil to produce manufactured gas. A succession of companies including The American Tar Company (ATCO) operated a tar refinery on the west side of the former MGP facility and used steam distillation to produce tar and tar products. Industrial operations ceased at the MGP in 1956. The property was purchased by the City of Seattle in 1973 and developed into a park which opened to the public in 1976. A number of development and cleanup activities have occurred at the park since 1976.

This simplified TEE is organized into the following sections:

- D2.0 Land Use, Ecological Goals, and Points of Compliance – describes the ecological goals and points of compliance for the TEE

- D3.0 Ecological Setting – describes the existing biotic and abiotic characteristics of the Site
- D4.0 Exposure Analysis – assesses the extent of ecological receptor exposure to residual chemicals
- D5.0 Pathways Analysis – identifies complete exposure pathways
- D6.0 Contaminants Analysis – identifies suitable ecological soil screening values and screens soil chemical concentrations in Site soils using those values
- D7.0 Uncertainty Analysis – describes the major sources of uncertainty associated with the TEE
- D8.0 Summary and Conclusions – integrates information from Sections 2.0 through 7.0 to formulate conclusions about ecological hazards at the Site
- D9.0 – References

D2.0 LAND USE, ECOLOGICAL GOALS, AND POINTS OF COMPLIANCE

MTCA uses land use to help determine the appropriate ecological goals for the TEE (WAC 173-340-7490(3)). For industrial or commercial properties, the ecological goal is the protection of wildlife (i.e., birds and mammals). For all other land uses, the ecological goal is protection of plants, soil biota (i.e., invertebrates), and wildlife.

The western portion of the Site including the Harbor Patrol facility is zoned industrial commercial[1]. Therefore, the goal of this simplified TEE for this area is the protection of wildlife.

Gas Works Park is zoned industrial buffer. The function of industrial buffer zones is to provide an appropriate transition between industrial areas and adjacent residential zones, or commercial zones having a residential orientation and/or pedestrian character. Given its current and future land use as a community park, the goal of this simplified TEE for Gas Works Park should be the protection of plants, soil biota, and wildlife under unrestricted land use. However, the vegetation in Gas Works Park predominantly consists of either nonnative landscape plantings or invasive nonnative plants such as Himalayan blackberry and reed canary grass. Since the intent of the TEE process is to protect native vegetation and not landscape plantings or invasive nonnative plants, the goal of this simplified TEE for the Gas Works Park area of the Site is the protection of soil biota and wildlife.

[1] Obtained From Seattle Department of Planning and Development zoning maps available on-line at http://www.seattle.gov/dpd/Research/Zoning_Maps/default.asp

The standard point of compliance for a TEE extends from the soil surface to a depth of 15 feet (WAC 173-340-7490(4)). MTCA also allows the use of a conditional point of compliance which represents the bioactive soil layer extending from 0 to 6 feet below ground surface (bgs). The conditional point of compliance represents a conservative estimate of the maximum depth of rooting and burrowing soil biota and wildlife. However, site-specific conditions may limit the bioactive soil layer to less than the default bioactive layer of 0 to 6 feet. MTCA provides for the development of site-specific points of compliance for a TEE based on analysis of the biological and physical conditions present at the Site. A detailed discussion of site-specific points of compliance is presented in Section 5.0.

D3.0 ECOLOGICAL SETTING

The Site, including Gas Works Park and the Harbor Patrol facility, occupies approximately 21 acres (Figure D-1). Gas Works Park is located on the site of a former industrial facility that was redeveloped into a park in the 1970s. Areas north of the Site are commercial and residential. Areas along the Lake Union shoreline west of the Site are commercial and industrial, and marinas are along the Lake Union shoreline east of the Site. A small (< 0.5 acres) habitat revegetation project lies adjacent to the northeast corner of the Site.

The Site terrain is relatively flat with manmade topographic features including Kite Hill, the berms paralleling the gravel trail, and the gentle rolling mounds found in the northwest area (Figure D-2). The land gently slopes down to the Lake Union shoreline. Most of these topographic features were created during redevelopment of the park in the early 1970s.

A significant portion of the Site is covered by pavement, structures, or compacted gravel paths (Figure D-2). Turfgrass covers most of the open areas. Landscape plantings of ornamental tree and shrub species are found along the Lake Union shoreline bordering the gravel trail, along medians in the parking lot, and are scattered elsewhere on the Site. Invasive and volunteer tree and shrub species have become established along much of the Site shoreline and along the boundary between Gas Works Park and the Harbor Patrol facility. The only native plants known to exist at the Site are western red cedar trees planted along the gravel trail and several species of native shrub and tree species planted in three groupings along the Lake Union shoreline. Section 5.1 contains detailed descriptions of the existing vegetation.

Habitats on the Site include developed, upland, and shoreline (Parametrix and Key Environmental 1998). Developed habitat includes the Play Barn, Cracking

Towers, Harbor Patrol, and other paved or covered areas. This habitat is typically devoid of vegetation. While developed habitats provide limited food for birds and mammals, they can provide perching sites for birds and possibly nesting sites for some bird species (e.g., barn swallows typically build their mud nests on manmade structures).

The upland habitat is dominated by open turfgrass areas. Turfgrass areas are irrigated to maintain the vegetative cover and are periodically mowed. Turfgrass areas are mowed, on average, once a week to maintain a three-inch standard height[2]. Parts of Kite Hill that are not accessible by rolling mowers and the area inside the Cracking Towers fence are maintained by hand approximately once per month. Irrigation begins in approximately April or May and continues through the beginning of October. The irrigation system is controlled to adjust watering duration based on weather and moisture, and is usually operated every other day, expect during very dry weather. Turfgrass areas are fertilized twice a year, while other plantings are fertilized as needed. Weed control is limited to periodic spraying of weeds growing in cracks around the Plat Barn foundation.

Geese are commonly seen feeding on grass shoots along Lake Union, while robins, starlings, crows, and flickers have been observed feeding on soil invertebrates (e.g., earthworms, insect larva). Barn swallows patrol turfgrass areas feeding on flying insects. Landscape tree and shrub plantings predominantly occur around the parking lot, western area, eastern area, and along the gravel trail. Invasive tree and shrub areas are found along the Lake Union shoreline and the fence separating Gas Works Park from the Harbor Patrol facility. Trees and shrubs provide roosting and possibly nesting areas for birds. However, the wildlife food value for most trees species found on the Site is low. For example, the wildlife food value for the western red cedar plantings on the south side of the gravel trail is low[3] as is the food value of American sycamore and red maple planted around the parking area[4]. One plant species that does provide an important seasonal food source for wildlife is the invasive Himalayan blackberry. In addition, two isolated plants—a single beech tree located in the northeast corner of Gas Works Park and a single plum tree located at the Prow—provide some food value to wildlife.

The transition from upland habitat to Lake Union includes a concrete seawall located in front of the Prow that extends approximately 125 yards, concrete riprap along the Gas Works Park shoreline near the Harbor Patrol facility,

[2] Personal communication with Mr. David Graves (Seattle Department of Parks and Recreation) on 11/16/2010.

[3] See USDA Natural Resources Conservation Service Plants Database at http://plants.usda.gov/index.html

[4] See University of Purdue tree descriptions at http://agriculture.purdue.edu/fnr/wildlife/PDFfiles/trees.pdf

boulder riprap west of the Prow, and a gradual sloping of upland habitat to a coarse gravel beach for most of the shoreline located east of the Prow. A narrow band of vegetation grows along the shoreline. Most shoreline vegetation consists of invasive plants, but plantings of native species (e.g., willow, red-osier dogwood, and sedge) were established in three locations east of the Prow. This shoreline vegetation provides some habitat value in the form of food, roosting, breeding, nesting, and refuge sites to certain species of birds and mammals including fruit-eating birds such as robins.

Wild bird and mammal species observed on the terrestrial portion of the Site are typical of urban environments and include several introduced species (Table D-1)[5]. Although only one mammal species was observed on the Site, other mammals such as the eastern cottontail (*Sylvilagus floridanus* – introduced), house mouse (*Mus musculus* – introduced), Norway rat (*Rattus norvegicus* – introduced), and several native rodents (family Muridae [e.g., mice and voles]) may inhabit fringe areas of the site that provide added food and cover. Signs of past use of the Site by beaver (i.e., old gnaw marks on tree stumps) were observed in the northeast corner of the Site. However, the continuous and intensive use of the park by humans and their pets, and park maintenance activities such as periodic mowing and irrigation tend to discourage use of the turfgrass areas by birds and mammals. No burrowing animals were observed on the Site during four reconnaissance visits in 2010[6].

A field survey was conducted on September 23 and 24, 2010, to assess the presence of soil macroinvertebrates at the Site (Attachment D-1). Turfgrass areas support diverse and healthy earthworm populations. Both shallow burrowing (endogenic) and deep burrowing (anecic) earthworms were present. Few other macroinvertebrate species were observed during the survey.

An ecological evaluation was conducted as part of the focused feasibility study for Gas Works Park (Parametrix and KEY Environmental 1998). As part of that evaluation, the Washington State Department of Fish and Wildlife Priority Habitats and Species Database was queried and no records of endangered or threatened animals or plants or State species of concern were returned for the Site.

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[5] These include species noted in the Ecological Evaluation of Gas Works Park (Parametrics and Key Environmental 1998), as well as species observed during four site visits in 2010 by Dr. Dana Houkal (DH Environmental Consulting).

[6] The most common burrowing mammal expected to potentially occur at the Site is the Townsend's mole (*Scapanus townsendii* – native). These moles leave conspicuous soil mounds and near-surface tunnels that indicate their presence. No mounds or tunnels were observed on the Site during four site visits in 2010.

D4.0 EXPOSURE ANALYSIS

The purpose of the exposure analysis is to determine if there is substantial exposure of wildlife to soil-borne chemicals. This simplified TEE may be ended if potential wildlife exposure is limited.

Sites with a total area of contaminated soil of 350 square feet or less may be excluded from further analysis (WAC 173-340-7492(2)(a)(i)). Since the Gas Works Park site covers approximately 20.5 acres, it does not meet this criterion.

If land use at the site and surrounding area makes substantial wildlife exposure unlikely, further analysis is not required. MTCA Table 749-1 provides the exposure analysis procedures and the result of applying these procedures to the Site is shown in Table D-2.

The Site includes paved/built areas (i.e., parking lot, Play Barn, and pathways), open turf, localized plantings of landscape shrubs and trees, and areas vegetated by invasive nonnative vegetation. The Site is surrounded by industrial, commercial, and residential areas to the west, north, and east. However, a small habitat revegetation project (Waterway 19 Habitat Demonstration Project) has been established adjacent to the northeast corner of the Site. The south side of the Site is bounded by Lake Union.

This urban setting provides limited habitat for wildlife, which justified a score of 3 for parameter 3. Although the Site provides limited wildlife habitat value, several species of urbanized avian wildlife such as geese, ducks, American robins, European starlings, and crows, have been observed foraging on vegetation and soil macroinvertebrates at the Site. Therefore, parameter 4 was given a score of 1. PCBs have been detected in soils at the Site, which resulted in a score of 1 for parameter 5.

Based upon results of the exposure analysis shown in Table D-2, it was concluded the Gas Works Park Site required further evaluation, and was carried into the pathways analysis.

D5.0 PATHWAYS ASSESSMENT

The purpose of the pathways assessment is to identify complete exposure pathways leading from chemically impacted soil to ecological receptors of concern. An exposure pathway includes five components: sources of chemicals, release/migration mechanisms, exposure media, routes of exposure, and receptors. If any of these components are missing, the exposure pathway is

incomplete. Further ecological evaluation of sites with incomplete exposure pathways is unnecessary and it can be concluded that ecological hazards are either nonexistent or below a level of concern. The pathways assessment is consistent with the development of a detailed ecological conceptual site model under EPA's Superfund process (EPA 1997).

The sources of chemicals at the Gas Works Park Site were released to the soil during MGP operations from 1906 to 1956. Residual concentrations of chemicals, primarily polycyclic aromatic hydrocarbons (PAHs), remained in the soil across much of the former MGP facility following its closure in 1956.

This simplified TEE process was developed to be protective of terrestrial ecological receptors at most qualifying sites. The default soil screening values (SSVs) used in the contaminants analysis step of this simplified TEE (MTCA Table 749-2) were derived for the protection of plants, soil biota, and wildlife. Two surrogate wildlife species, the shrew and robin, were used by Ecology (2000) to derive SSVs for this simplified TEE. These surrogate species are potentially exposed to soil-borne chemicals through the ingestion of soil and ingestion of soil biota such as earthworms or insect larvae. These two routes of exposure constitute the primary means by which wildlife are exposed to soil-borne chemicals.

The landscape plantings that cover the Site consist primarily of nonnative ornamental grasses, shrubs, and trees (see Section 5.1). Several invasive plant species including Himalayan blackberry, reed canary grass, plantain, and hawkweed have also become established on turfgrass areas, along the Lake Union shoreline, and on other areas of the Site. The only native species known to occur on the Site are the plantings of western red cedar on the berm just south of the gravel trail and approximately 55 feet of native sedges and shrubs planted along part of the Lake Union shoreline. These native species occur in landscape plantings and do not constitute native or semi-native plant communities. Since the intent of the TEE is to protect native ecological receptors, the ornamental plantings and invasive plant species that occur on the Site were not identified as receptors of concern for this simplified TEE. Furthermore, although these ornamental and invasive plants can act as part of an exposure pathway to wildlife (e.g., residual chemicals in soil accumulating in plants that are forage for birds and mammals), herbivorous birds and mammals were not selected as surrogate wildlife species for use in deriving SSVs (Ecology 2000). In order to be consistent with MTCA methods for this simplified TEE, the soil to plant to wildlife exposure pathway will not be evaluated in this TEE for the Gas Works Park site.

For purposes of this simplified TEE, the Site was divided into eight areas for characterizing potential exposure of ecological receptors to soil-borne chemicals (Figure D-3). Gas Works Park has undergone a series of redevelopment activities since it was acquired by the City of Seattle in the 1970s. These activities have resulted in differing soil characteristics in each of the eight areas that affect potential ecological exposures.

D5.1 Ecological Exposure Areas

The former MGP facility was developed into Gas Works Park in the 1970s and the park was opened to the public in 1976. Many of the MGP structures (Figure D-4) were decommissioned during redevelopment, but some structures were retained as park features (e.g., Cracking Towers, Machine Building, Prow). After decommissioning the industrial structures, the land surface was recontoured and a soil cover consisting of sawdust, dewatered sludge, and imported fill was the then placed over much of the park (ThermoRetec 2000). EPA (1995) noted that soils were amended with sawdust, bacteria, and dewatered sludge in the hope that these amendments would eventually break down the remaining pollutants and leave the soil in a neutral state able to support plant life. The depth of this soil cover was reported to range from 1 to 5 feet (RETEC 2005). Kite Hill was created by mounding over 20,000 cubic yards of gas plant waste materials and covering the mound with thousands of yards of imported fill from the Safeco Building construction site in the University District (Parametrix and Key Environmental 1998). The thickness of the fill may exceed 50 feet in some areas (RETEC 2005). Much of the park was landscaped with turfgrass and group plantings of shrubs and trees before opening in 1976. A parking lot (Area B on Figure D-3) and paved walkways were constructed at this time. Area A was not originally developed into a recreational component of Gas Works Park, and Area H was not included in the park redevelopment.

Gas Works Park was closed for several months in 1984 due to potential health concerns associated with elevated levels of chemicals in the soil (Sobal et al. 1988). Subsequently, known areas elevated levels of chemicals were covered with fill material. Sobel et al. (1988) shows twelve areas were covered with fill that ranged in size from approximately 10 to 150 square feet.

Redevelopment and cleanup activities undertaken at Gas Works Park since 1976 include but are not limited to:

- Placement of additional soil cover, planting, and installation of an irrigation system in Areas D and E in 2001
- Reseeding of turfgrass and installation of an irrigation system in Area G in 2001

- Development of Area A into a recreational area in 2005
- Development of the railroad right-of-way into part of the gravel trail in Areas A and B

The following sections describe the historical use, soil characteristics, and current condition of each of the eight ecological exposure areas shown on Figure D-3.

D5.1.1 Area A (Northwest Corner)

Area A is located in the northwest corner of Gas Works Park and covers approximately 2 acres (Figure D-3). This area was formerly the site of two large tanks used to store No. 4 and No. 5 oil, which were used to manufacture heating and cooking gas at the MGP from 1937 to 1956 (Parametrix 2004) (Figure D-4). These tanks were reportedly situated in depressions and surrounded by a concrete wall to contain spills. Following the MGP closure, the tanks were removed and the depressions were filled with MGP demolition debris and soil, followed by a soil cover. In addition, Area A was used as a staging area for wastes generated during development of the park (concrete debris mixed with wood chips, contaminated soil, and other debris), which were ultimately moved to form the base of Kite Hill (HDR 1988).

Although Area A is part of Gas Works Park, it remained unused from 1976 to 2005. The area was surrounded by a chain-link fence and a concrete wall to discourage public access (Parametrix and Key Environmental 1998; Parametrix 2004).

Geologic data from three test pits and one boring from Area A collected in the 1980s and 1990s showed that the Gas Works deposit[7] was encountered at depths of 2 to 4 feet below ground surface (Parametrix 2004). Between 1998 and 2000, between 1,500 and 2,000 cubic yards of clean fill from another City of Seattle park project was stockpiled in the central part of Gas Works Park (Parametrix 2004). Although no chemical testing of the stockpiled soil was conducted, this fill was not known or suspected to have been contaminated. The stockpiled soil was subsequently moved to and spread over Area A.

An environmental investigation was conducted on Area A in 2004 prior to redevelopment into a recreational area (Parametrix 2004). Results of soil sampling showed a relatively high concentration of PAHs in one subsurface soil sample (2.2 to 2.5 feet below ground surface) located along the eastern border

[7] The Gas Works deposit is a mixture of native soil and MGP materials including cinders, bricks, wood, concrete, lampblack, tar, and various types of oil (Parametrix 2004).

of Area A and field observations indicated this subsurface soil sample encountered the Gas Works deposit. The relatively low levels of PAHs found in the other soil samples was believed to be the result of comingling the fill with existing area soil during the original placement, and moving and regrading of Area A (Parametrix 2004). Thirteen test pits were subsequently excavated in the eastern portion of Area A along the alignment of a future footpath to assess the depth of the fill layer. The thickness of the fill layer in the eastern portion of Area A varied between 1 and 3 feet.

Area A was redeveloped into a park feature in 2005. Existing fill was graded to form an undulating topography, covered by a geogrid identifier layer, and then covered by a loamy soil layer at least 1 foot thick[8]. An irrigation system was installed and the area was landscaped with turfgrass and group plantings of shrubs and trees.

A discontinuous 3- to 7-foot-tall concrete wall currently borders most of the north, west, and east sides of Area A. An asphalt walking path runs north-south on the eastern portion of the area. Area A is planted in turfgrass with isolated groupings of ornamental shrubs and trees (red-osier dogwood, katsura, birch) (Figure D-3). Weeds have invaded the turfgrass area with dandelion, clover, plantain, hawkweed, and English daisy occurring in well-drained areas; buttercup, sedges, and bitter nightshade occur in wetter areas. Landscaped areas are irrigated and the turfgrass is regularly mowed. A parking area that formerly existed west of Area A was landscaped in 2010. This area is the site of a gravel trail which was developed on the former railroad grade. Landscaping was established on both sides of the trail consisting of an imported soil layer, an irrigation system, tree planting (e.g., birch, Japanese maple, western red cedar), and a bark mulch cover layer.

D5.1.2 Area B (Parking Lot and Berms)

Area B is located on the north side of Gas Works Park and covers approximately 3 acres (Figure D-3). It was the former site of a large gas storage holder (2 million cubic feet) and underground propane storage tanks (Figure D-4; Seattle Gas Company 1953). A railroad right-of-way crossed along the south side of Area B.

During redevelopment of the park in the 1970s, Area B was covered by an asphalt parking lot. Ornamental trees were planted along parking medians and the perimeter of the parking lot. Tree-lined berms, between 2 and 3 feet tall,

[8] Personal communication with Mr. Merrell Livesay (Seattle Department of Parks and Recreation) on September 23, 2010.

parallel both sides of the railroad right-of-way. Some waste material generated during redevelopment of the park was incorporated into the base of the berms, which were then covered with fill imported during park construction (HDR 1988).

The railroad right-of-way that bisects Gas Works Park was redeveloped into a gravel trail. Redevelopment consisted of removal of former rail lines and covering the rail bed with compacted gravel for recreational use.

Most of Area B is currently an asphalt parking lot servicing Gas Works Park (Figure D-3). The trail located along the southern border of Area B is surfaced with compacted gravel to provide a suitable surface for recreational users. Red maple and sycamore trees that were planted in the 1970s border the parking areas. The raised medians contain compacted soil with little grass cover that browns out during the summer. The berm on the north side of the gravel trail supports a row of sycamore trees and turfgrass, while the berm on the south side of the trail supports two rows of planted western red cedar trees. The ground surface beneath the cedar trees is covered by tree bark mulch and the berm sloping to the trail supports turfgrass. The turfgrass areas located on either side of the trail are irrigated and periodically mowed[9].

D5.1.3 Area C (Northeast Corner and Play Barn)

Area C is located in the northeast portion of Gas Works Park (Figure D-3) and covers approximately 3 acres. This area was the former site of a water gas house, a diesel oil storage tank, a tar storage tank, water gas circulating liquor well, water gas tar separator, two primary condensers, and three 100 KVA transformer banks (Figure D-4).

During redevelopment of Gas Works Park in the 1970s, Area C was recontoured and a soil cover consisting of sawdust, dewatered sludge, and fill was then placed over the area (ThermoRetec 2000). The depth of this soil cover was reported to range from 1 to 5 feet (RETEC 2005). The northern portion of Area C was subsequently planted with grass and landscaped with a variety of ornamental trees. An irrigation system was installed at this time. Outside of placing fill material over three locations with known elevated chemical concentrations in 1984 (Sobal et al. 1988), no other soil treatments are known to have been applied to Area C.

[9] Personal communication with Mr. David Graves (Seattle Department of Parks and Recreation) on 11/16/2010.

The topography of Area C is relatively flat, sloping down to Lake Union. The southern portion of Area C currently consists of paved areas and the Play Barn (former MGP machine building) with black locust and katsura tree plantings contained in elevated concrete planting boxes. The northern portion is a turfgrass field with a perimeter planting of ornamental sycamore, birch, red maple, European beech, black locust, and apple trees (Figure D-3). Area C is irrigated and regularly mowed. The Lake Union shoreline slopes gently from the uplands to a narrow, coarse gravel beach. The shoreline is vegetated with invasive and native volunteer grasses, shrubs, and trees, including Himalayan blackberry, butterfly bush, horsetail, thistle, bindweed, yellow flag iris, birch, and willow. A 4-foot-tall chain link fence controls human access to a small tar out-cropping located on the shoreline of the northern portion of Area C.

The Waterway 19 Habitat Demonstration Project is located immediately north of Area C between North Northlake Way and Lake Union. This small abandoned street-end area (less than 0.5 acres) was planted with butterfly bush, columbine, vine maple, willow, red-osier dogwood, salmonberry, and a variety of tree species to provide habitat for hummingbirds, songbirds, waterfowl, and other wildlife.

D5.1.4 Area D (Groundwater Treatment Area)

Area D is located along the eastern shoreline of Gas Works Park (Figure D-3) and covers less than 0.5 acres. This area was the former site of a light oil plant and distillation towers for the MGP (Figure D-4).

Following redevelopment of the park in the 1970s, Area D was recontoured and a soil cover consisting of sawdust, dewatered sludge, and fill was then placed over the area (ThermoRetec 2000). The depth of this soil cover was reported to range from 1 to 5 feet (RETEC 2005). The area was subsequently planted with turfgrass. Prior to 2001, turfgrass within Area D was not irrigated and experienced water stress during the summer months when the grass would die back and turn brown (HDR 1988). The feasibility of installing an irrigation system in Area D was investigated in 1988. Turfgrass in Areas E and G also suffered summer water stress prior to installation of irrigation systems.

An *in situ* groundwater air sparging and soil vapor extraction system was installed at Area D in 2001 to remove volatile organic chemicals from the groundwater (ThermoRetec 2001). The surface characteristics of the system consist of (from top to bottom) a grass turf layer, 12 inches of sandy loam soil, 6 inches of sand, a 30-mil linear low density polyethylene (LLDPE) liner, and 12 inches of bedding sand to protect the *in situ* system piping placed on top of the native soil (ThermoRetec 2001). The LLDPE liner is impervious to water and acts

to trap soil gas released by the sir sparging system. Prior to the installation of the air sparging system, Area D was scarified and rough graded to a depth of 4 to 6 inches below ground surface. From 1 to 2 feet of fill were added to bring Area D up to the desired grade. An irrigation system was installed in 2001 to help maintain the turfgrass layer.

Area D is relatively flat, sloping toward the Lake Union shoreline. It is currently covered by turfgrass, which is irrigated and regularly mowed (Figure D-3).

D5.1.5 Area E (Central and Southeast Area)

Area E is located in the central and eastern portions of Gas Works Park (Figure D-3) and covers approximately 6 acres. It was the site of American Tar Company, the MGP office and laboratory building, water gas house, purifier boxes, tank farms, and other MGP operations (Figure D-4).

Following redevelopment of the park in the 1970s, Area E was recontoured and a soil cover consisting of sawdust, dewatered sludge, and fill was then placed over the area (ThermoRetec 2000). The depth of this soil cover was reported to range from 1 to 5 feet (RETEC 2005). The area was subsequently planted with turfgrass. In 1984, fill material was placed on six locations with known elevated chemical concentrations (Sobal et al. 1988).

In 2001, a new vegetative soil cover was placed over unpaved open areas in Area E (ThermoRetec 2001). Prior to the installation of the new cover, Area E was scarified and rough graded to a depth of 4 to 6 inches below ground surface. The soil cover consists of (from top to bottom) a grass turf layer, 12 inches of sandy loam soil, and a geogrid identifier layer to visually demark the top of the underlying soil (ThermoRetec 2001). The polypropylene geogrid has a mesh size of 1.0 by 0.8 inches, which allows water percolation. An irrigation system was installed to help maintain the turfgrass layer. The new soil cover was planted with a blend of perennial rye grasses using drill-seeding equipment. A police path consisting of 4 inches of crushed surfacing top course over 8 inches of gravel was installed leading from the Play Barn to the Prow (Figure D-3). Three sections of shoreline (totaling approximately 55 linear feet of shoreline) were planted with native plants including Sitka willow, prick current, red-osier dogwood, shore and slough sedge, smooth Labrador tea, soft rush, and trailing blackberry.

The current topography of Area E gradually slopes to the south and east toward Lake Union. Several MGP structures left in place following redevelopment in the 1970s are located just west of the Play Barn (Figure D-3). The Prow is a concrete structure located on the Lake Union shoreline that was historically used

for unloading coal from barges for use at the MGP facility. A gravel path runs from the southwest corner of the Play Barn to The Prow. A concrete pad is located between the gravel path and Area F. Much of Area E is currently planted with turfgrass which is bisected by asphalt paths (Figure D-2). The turf area is irrigated and periodically mowed. The Lake Union shoreline begins at the concrete seawall at the Prow and becomes a shoreline of discontinuous rock riprap sloping to a coarse gravel beach to the north. The shoreline is vegetated by invasive plants (Himalayan blackberry, Scotch broom, fennel, thistle, yellow flag iris, reed canary grass) interspersed with three areas of native species plantings established in 2001.

D5.1.6 Area F (Cracking Towers)

Area F is located in the central portion of Gas Works Park (Figure D-3) and covers approximately 1 acre. It contained the oil gas generators, numerous scrubbers, oil heaters, and wash boxes from the MGP (Figure D-4). The six gas generators towers as well as several scrubbers remain on the area and all structures appear to be mounted on concrete pads (Parametrix 1998).

The soil surface in the open areas within Area F is believed to have been amended during redevelopment in the 1970s with a soil cover consisting of sawdust, dewatered sludge, and fill. Turf grasses may also have been planted following this soil treatment. No other soil treatments are known to have been applied to Area F.

Area F is currently surrounded by a 7-foot-tall cyclone fence with several locked gates. The open areas surrounding the remaining structures contain a mixture of grasses and forbs (primarily invasive hawkweed, plantain, clover, and reed canary grass). Although the open areas are periodically mowed, they do not appear to be irrigated. Invasive shrubs (mainly Himalayan blackberry) and a few trees have become established adjacent to many of the structures.

D5.1.7 Area G (Kite Hill)

Area G (Kite Hill) is located is the southwestern portion of Gas Works Park (Figure D-3) and covers approximately 4 acres. The American Tar Company facility was located on the northwest corner of Area G (Figure D-4). A water gas relief holder, a fuel storage tank, lampblack thickeners, and other MGP facilities were formerly located on the eastern portion of Area G.

Kite Hill was created during Park construction by mounding approximately 20,000 cubic yards of gas plant waste materials and covering the mound with thousands of yards of imported fill from the Safeco Building construction site in

the University District (Parametrix and Key Environmental 1998). The thickness of the fill may exceed 50 feet in some portions of Area G (RETEC 2005). The low area located between Kite Hill and the Cracking Towers was likely amended during redevelopment in the 1970s with a soil mixture consisting of sawdust, dewatered sludge, and fill. Area G was subsequently planted with turfgrass. In 1984, fill material was placed on three locations with known elevated chemical concentrations (Sobal et al. 1988). An irrigation system was installed in 2000-2001 to help maintain the turfgrass[10].

The topography of Area G slopes from the top of Kite Hill to Lake Union. It is bisected by several asphalt footpaths (Figure D-2) and planted with turfgrass, which is irrigated and regularly mowed. Invasive plants (e.g., hawkweed, dandelion, plantain, clover, and English daisy) have become established in turfgrass areas. The Lake Union shoreline begins as a concrete rubble riprap on the western side of Area G, changes to boulder riprap moving to the east, and ends as a concrete seawall extending approximately 250 feet to the Prow. The shoreline slopes steeply to the concrete and boulder riprap. Shoreline vegetation is dominated by dense stands of invasive grasses and shrubs (e.g., reed canary grass, Himalayan blackberry, and thistle) mixed with some volunteer native species (e.g., horsetail). The fence line with the Harbor Patrol facility contains dense thickets of Himalayan blackberry mixed with invasive grasses and forbs (e.g., curled dock, hawkweed, and bindweed).

D5.1.8 Area H (Harbor Patrol)

Area H, the Harbor Patrol facility, is located on the west side of the Site (Figure D-3) and occupies approximately 1 acre. No former MGP operations were located in this area (Figure D-4).

The major portion of Area H is currently covered by asphalt or concrete and contains several buildings used by the Harbor Patrol (Figure D-3). An aerial photograph from 1965[11] shows a similar area of pavement. A row of Scotch pine trees line the northern border of Area H and the ground beneath the trees is virtually devoid of plants.

D5.2 Site-specific Exposure Pathways Evaluation

Important elements of the ecological exposure pathways of the Site are described in the following sections.

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[10] Personal communication with Mr. David Graves (Seattle Department of Parks and Recreation) on November 16, 2010.

[11] Seattle Parks and Recreation, Gas Works Park web site at http://www.seattle.gov/parks/park_detail.asp?ID=293.

D5.2.1 Rooting Depths of Plants

Plants growing on the Gas Works Park site are divided into grasses and shrubs/trees for the purpose of describing their rooting depths.

The primary turfgrass planted at the Gas Works Park site is perennial ryegrass (*Lolium perenne*). Perennial ryegrass is a cool season grass that can become drought dormant during the summer if insufficient water is applied. Grasses typically have fibrous root systems that are limited to relatively shallow soil depths. However, the depth of rooting of any particular grass species can vary with soil characteristics such as soil moisture. For example, a shallow hardpan can limit rooting to depths above the hardpan.

Warm season grasses typically produce deep root systems, while cool season grasses produce shallow root systems (Harivandi 1985). Perennial ryegrass has a relatively shallow root system and has relatively low drought tolerance. Harivandi et al. (2009) reported the root depth of perennial ryegrass grown in California to range from 0.5 to 1.5 feet depending on site conditions. Evans (1978) reported that 81 percent of roots of perennial ryegrass were found in the upper 0.75 feet of soil at a pasture site with a sandy silt soil extending to four meters deep. Few roots were found below a depth of 1.25 feet. In a rhizosphere study, Kechavarzi et al. (2007) reported roots of perennial ryegrass extended to a depth of 0.8 feet when grown for 51 days in a 0.8 foot wide by 1.2 foot high container filled with sandy loam soil with adequate soil moisture. Regional turfgrass experts[12] were also contacted concerning the rooting depth of perennial ryegrass in the Seattle area. The experts' consensus was that most and possibly all roots would be limited to the top 0.7 to 0.8 feet of the soil profile. One expert noted that if soil quality was adequate at depth and infrequent deep irrigation was practiced, some roots could extend to a depth greater than 1 foot. However, grass roots would tend to concentrate in the high quality surface soil layer (upper 1 foot) that is present over much of the park and would have limited growth into the poorer quality underlying soil.

A survey of Gas Works Park conducted on September 23 and 24, 2010, confirmed that the rooting depth of turfgrass does not exceed one foot (Attachment D-1).

The most common shrub species at the Site is Himalayan blackberry (*Rubus armeniacus*). According to the Washington State Noxious Weed Control

[12] Regional turfgrass experts contacted on August 31, 2010 were Mr. Bill Payne, AGRI Turf Inc., Arlington, Washington, and Mr. Dennis Cadman, Country Green Turf Farms, Olympia, Washington.

Board[13], the roots of Himalayan blackberry can extend as deep as 5 feet below ground surface. Many tree species have taproot root systems that can extend several feet below the ground surface given suitable soil conditions.

D5.2.2 Burrowing Depth of Soil Invertebrates

The American robin, European starling, American crow, and northern flicker have been observed foraging on soil invertebrates at the Gas Works Park site[14]. The primary prey of these bird species in the Seattle area includes earthworms, crane fly larvae, ants, and beetles.

The crane fly species most often encountered in turfgrass habitats in the Seattle area is the European crane fly (*Tipula paludosa*). The European crane fly is native to northwestern Europe and was first discovered in British Columbia in 1965 (Jackson and Campbell 1975). It quickly spread up and down the Pacific coast and is a pest of lawns, pastures, and hayfields in northwestern Washington, where it feeds on the roots and aboveground tender tissue of grasses and forbs. Larvae in the soil experience four instar growth stages with the fourth instar being present from mid-April through mid-August. The fourth instar larvae are 3 to 4 cm long and weight 300 to 400 mg. The lifecycle of the European crane fly is (Jackson and Campbell 1975):

- Eggs are laid in the soil by adult crane flies in August and September; the nonfeeding adults live for only 2 to 3 weeks
- The eggs hatch within 2 weeks and the larvae feed ravenously for about two months while going through two instar stages
- Larva overwinter as third instars and are relatively inactive during mid-November through early April
- The larva grow to fourth instar stage in April and feed ravenously again until mid-June when they enter a resting state
- Larva pupate to produce adults from late August to early September

European crane fly larvae are always found in the upper four inches of the soil profile and are able to survive freezing soil temperatures (Jackson and Campbell 1975).

Crane flies were not observed during the September 23-24, 2010, field survey (Attachment D-1) probably because the survey took place after adults had completed egg laying and had died. In addition, eggs and first instar larval

[13] Information available at http://www.nwcb.wa.gov/.

[14]Field observations by Dr. Dana Houkal (DH Environmental Consulting) on June 15, June 30, and August 27, 2010.

stages are small and difficult to see with the naked eye. Therefore, it is likely that the presence of crane flies could not be readily discerned during the late September period.

Earthworm burrow depths vary among species and with soil characteristics. Two common groups of earthworms found in the Pacific Northwest are those that burrow in the shallow soil (endogenic species) and those that burrow into deep soil (anecic species). Both groups are dominated by nonnative earthworm species introduced from Europe. Shallow soil species common to the Northwest (e.g., *Lumbricus rubellus, Aporrectodea calignosa, Aporrectodea longa, Octolasion cyaneum*) feed on organic matter in the shallow soil by creating temporary vertical and horizontal tunnels. Francis et al. (2001) studied the burrowing characteristics of three of these species, *L. rubellus, A. calignosa, and O. cyaneum*. Cylinders (25 cm diameter by 60 cm deep) were filled with topsoil and subsoil from a silt loam soil type that had been augmented with organic matter (ground clover and ryegrass) and then planted with ryegrass. Earthworms were introduced to the soil cylinders within a growth chamber where soil moisture, temperature, and photoperiod were maintained at suitable levels. At the end of the 60-day test, burrow formation was evaluated using CT scanning and image analysis. Burrows of *L. rubellus* were concentrated at 5 cm with little burrow formation below 10 cm. Burrows of *A. caliginosa* were concentrated in the upper 10 cm, with little burrow formation below 15 cm. Burrows of *O. cyaneum* were uniformly distributed in the upper 20 cm with few burrows below 20 cm. Although *A. caliginosa* and *O. cyaneum* have been reported to burrow as deep as 45 cm, presumably this is due to seasonally unfavorable conditions near the soil surface (e.g., drought, freezing soil). Turfgrass areas at Gas Works Park are irrigated and the soil frost depth in Seattle does not exceed 10 inches. Therefore, populations of endogenic earthworms would be expected to reside in the upper 1 foot of the soil profile throughout the year.

Deep burrowing earthworm species, such as the night crawler (*Lumbricus terrestris*), typically form vertical burrows from which they emerge at night to feed on surface litter. Night crawlers are common in the Seattle area. Several studies have shown that under certain soil conditions, night crawlers can form burrows extending to 1 m deep or more (Shipitalo and Gibbs 2000; Hawkins et al. 2008).

Earthworms were observed at all 23 locations during the September 23-24, 2010, field survey (Attachment D-1). Earthworms were present in all six ecological exposure areas (A, B, C, D, E, F, and G). Both deep-burrowing night crawlers and shallow-burrowing species were present in all six ecological exposure areas. However, the burrowing depth of the night crawlers could not be determined because the surface soil in Areas A and E consisted of imported

loamy soil and did not provide the structure needed to allow proper excavation of earthworm burrows.

D5.2.3 Burrowing Wildlife

The most common burrowing mammal potentially occurring at the Gas Works Park site is the Townsend's mole (*Scapanus townsendii*). These moles leave conspicuous soil mounds and near-surface tunnels that indicate their presence. No mounds or tunnels were observed on the Site during four visits conducted in 2010 and park maintenance staff have not observed burrowing mammals at Gas Works Park[15]. Other mammal and bird species observed or potentially occurring at the Site do not normally burrow.

D5.2.4 Wildlife Exposure to Soil

Several species of birds and mammals observed or potentially occurring at the Site may forage on the ground for soil invertebrates and/or vegetation. While foraging on the ground, they may incidentally ingest soil that enters their mouths, is attached to their prey, or is contained inside their prey (e.g., soil in the gut of earthworms). Birds often seek out open soil areas and use them as dusting areas to help control parasites and maintain their plumage. Wildlife often preen or clean themselves and may consume soil attached to feathers or fur. Therefore, direct wildlife contact to soil is expected to be limited to the upper foot of the soil profile, unless they consume earthworms that contain gut soil originating from deeper soil strata. The potential for wildlife exposure to subsurface soil through foraging on earthworms that burrow into subsurface soil is considered remote, because once night crawlers construct their permanent burrows, they are unlikely to ingest soil.

D5.3 Bioaccumulation of Chemicals of Potential Concern

The two chemicals of potential concern identified for this simplified TEE for the Gas Works Park site are arsenic and benzo(a)pyrene (BaP) (See Section 6.1). The bioaccumulation potential of these chemicals is described in the following sections.

[15] Field visits conducted by Dr. Dana Houkal (DH Environmental Consulting) on June 15, June 30, August 27, and September 23-24, 2010. Personal communication with Mr. David Graves (Seattle Department of Parks and Recreation) on 11/16/2010.

D5.3.1 Arsenic

The two most commonly occurring forms of arsenic in the natural soil environment are arsenic V (arsenate) and arsenic III (arsenite) (Grafe et al. 2001; Zhang and Selim 2008). Arsenite has been found to be the more mobile and toxic form in soil environments. Arsenite dominates under reducing soil conditions (e.g., flooded soils), whereas arsenate dominates under oxidizing soil conditions (well-drained soils) (Ascar et al. 2008; Kabata-Pendias and Pendias 1984; Zhang and Selim 2008). The long-term fate of arsenite in mineral soils under aerobic/oxidizing conditions begins with its rapid adsorption to iron oxides (Manning and Suarez 2000). The arsenite is then oxidized to arsenate by manganese oxides. Arsenate will then partition between solid and liquid phases, but most of the arsenate will become strongly adsorbed to iron oxides. Under reducing conditions, arsenate is reduced to arsenite, which is more soluble than arsenate due to the dissolution of iron oxides and release of sorbed and coprecipitated arsenite (Grafe et al. 2001). The distribution and transformation between arsenate and arsenite is largely controlled by the redox condition of the soil environment (Zhang and Selim, 2008). For the Gas Works Park site, it is assumed the soil in the 0 to 1 foot strata is well oxygenated and the arsenate form of arsenic dominates. Arsenic in subsurface soil (> 1 foot below ground surface) is assumed to be dominated by the arsenite form due to reducing conditions.

The default bioaccumulation factors (BAFs) for arsenic in MTCA (Table 749-5) are the same for the arsenate and arsenite forms, namely, 0.06 for plants and 1.16 for earthworms.

D5.3.2 Benzo(a)pyrene

Benzo(a)pyrene (BAP) is a high molecular weight PAH (molecular weight = 252.31) that is highly insoluble in water (solubility = 0.00162 mg/L at 25° C) and has low volatility (Henry's law constant = 4.57 x 10^{-7} atm-cu m/mole)[16]. It is expected to have very low to no mobility in soil based upon measured K_{oc} values of 930 to 6,300. The persistence of BaP in soil is expected to vary depending upon the nature of compounds accompanying it and the nature and previous history of the soil. Half-lives of BaP in soil have been reported to range from 229 to 309 days.

The default plant BAF for BaP used in MTCA (Table 749-5) is 0.011. This BAF was calculated using a relationship between the log octanol-water partition

[16] Chemical data obtained from the online Hazardous Substance Database at http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB

coefficient on nonionic organic compounds and plant uptake that was developed by Travis and Arms (1988)[17].

Lipophilic organic compounds with low water solubility tend to sorb strongly to the soil and root uptake is not expected to be a major pathway of vegetation contamination (Briggs et al. 1982). For example, Fismes et al. (2002) studied accumulation of PAHs from soils (total PAH concentration ranging from 4 to 2,526 mg/kg) in crop plants. The mean BAFs for aerial plant parts (leaves and stems) grown on five test soils for 25 days were 0.00081 for lettuce, 0.0039 for potato, and 0.0046 for carrot, which demonstrates a very low potential for translocation of PAHs from the roots to the aerial plants parts. These BAFs are somewhat lower than the MTCA plant BAF value of 0.011. Interestingly, plants such as perennial ryegrass have been shown to enhance biodegradation of petroleum-impacted soils by stimulating the microbial soil community, which actually degrades the petroleum (Kechavarzi et al. 2007). In particular, grasses have been shown to enhance the degradation of highly absorbed, recalcitrant BaP in soil (Banks et al. 1998).

The default BaP earthworm BAF used in MTCA is 0.43 (MTCA Table 749-5). This BAF is the mean of mean earthworm BAF values empirically derived and reported by Beyer and Stafford (1993) and Marquenie et al. (1987) for several confined disposal facilities located in the eastern USA.

Bioavailability of hydrophobic organic constituents in soil is greatly reduced by weathering (Alexander 2000). In addition, the characteristics of the soil can influence the bioavailability of hydrophobic organic constituents such as PAHs. Kreitinger et al. (2007) evaluated the bioavailability of PAHs in soils collected from 16 coal and oil MGP sites in the US that had been closed for approximately 50 years. Soils at MGPs have manmade sources of hard or black carbon (e.g., charcoal, coal, coal tar pitch, coke, and soot) that strongly sorb and reduce the bioavailability of hydrophobic organic compounds. Earthworms were found to bioaccumulate much lower levels of PAHs from weathered soils at MGP sites then in soils freshly spiked with PAHs.

D5.4 Points of Compliance

The conditional point of compliance for soil under the TEE process is 0 to 6 feet bgs (WAC 173-340-7490(4)), which represents the maximum depth at which plants and animals will become exposed to soil-borne chemicals. However,

[17] Travis and Arms (1988) developed the relationship ($BAF_{plant} = 10^{(1.588-(0.578 * \log Kow))}$) based on an empirical study of plant uptake of a variety of nonionic organic compounds.

potential exposures of ecological receptors at the Gas Works Park site is expected to mainly occur in the upper 1 foot of soil. The rationale for this shallower exposure scenario is:

- Most open areas in Gas Works Park are landscaped with turfgrass that has root systems concentrated in the upper 1 foot of soil.
- No burrowing animals have been observed at Gas Works Park, so direct exposure of wildlife to soil is limited to the upper 1 foot of soil.
- Most soil macroinvertebrates at Gas Works Park that are foraged upon by wildlife inhabit the upper 1 foot of soil.
- Many of the shrub and tree species that have been planted at Gas Works Park have limited value as a wildlife food source.

However, the exposure pathway to subsurface soil cannot be completely discounted because of two reasons:

- Some shrub and tree species have root systems that likely extend into the subsurface soil and are also food sources for wildlife (e.g., Himalayan blackberry)
- Deep-burrowing earthworms (i.e., night crawler) are present and may be exposed to subsurface soil and, in turn, be consumed by wildlife

Therefore, the 0- to 6-foot conditional point of compliance will be used in this simplified TEE. In addition, ecological exposure to chemicals in surface soil (0 to 1 foot depth) will also be evaluated as a more likely exposure scenario.

D5.5 Upwelling Tar

Intermittent seepage of small amounts of tar through the ground or through asphalt walkways had been a regular occurrence at Gas Works Park (Parametrix and Key Environmental 1998). The most frequent seeps were formerly observed north of Kite Hill in the area of the former American Tar Company facility. The Department of Parks and Recreation consistently checks for tar seeps and promptly removes any tar that presents a concern for park users.

Known and suspected tar seeps were characterized in 1997 by excavating 12 test pits in 10 locations in Gas Works Park (Parametrix and Key Environmental 1998). These test pits were located in Areas A, E, and G. Tar was present in 3 of the 10 locations: one location along the asphalt pathway north of Kite Hill, one along the asphalt pathway on the northeast side of Kite Hill, and one along the Lake Union shoreline south of the Play Barn. Subsequently, tar was removed to the extent possible from the shallow test pits located north of Kite Hill and along the Lake Union shoreline. A total of 22 drums of semisolid tar and

approximately 24 cubic yards of tar-contaminated soil were removed from the location north of Kite Hill. One drum of semisolid tar was removed from the Lake Union shoreline location.

A small semisolid tar mass is located in Area C on the Lake Union shoreline. The area is surrounding by a chain-link fence to control human exposure to the material.

The Department of Parks and Recreation still maintains park inspections for tar[18]. Tar seeps observed along the Lake union shoreline have been addressed by removal and the addition of gravel cover. In addition, tar observed seeping from pipes located at the Prow was addressed by plugging the pipes with concrete.

Although the tar contains high concentrations of chemicals, such as PAHs, the spatial and temporal extent of contamination associated with tar seeps is quite small. These tar seeps are not considered to present a significant ecological exposure pathway.

D5.6 Conclusions of Pathways Analysis

An ecological conceptual site model for the Gas Works Park site is shown on Figure D-5. Ecological exposure areas with complete exposure pathways are identified in Table D-3. Ecological exposure areas A, C, E, F, and G require further evaluation and were carried into the contaminants analysis (Section 6.0).

D6.0 CONTAMINANTS ANALYSIS

This contaminants analysis consists of three steps: identifying suitably protective ecological risk-based soil screening values (SSVs), estimating reasonable maximum exposure (RME) point concentrations in soil, and comparing the RMEs to the SSVs. If the RME concentration is less than the SSV, it can be concluded that the chemical does not pose an ecological hazard.

D6.1 Soil Screening Values

No direct observations of ecotoxic effects (e.g., plant dieback, overt signs of plant stress, or wildlife morbidity/mortality) associated with exposure to residual chemical concentrations in soil have been observed at the Gas Works Park

[18] Personal communication with Ms.Nina J. Sinclair, Seattle Department of Parks and Recreation on September 17, 2010.

site[19]. The one exception is the observation in the late 1980s of an area located on the south side of the berm northeast of Kite Hill, which was unable to support vegetation (HDR 1988). Several attempts at seeding grass, including the placement of new soil in the area, had failed. In addition, invasive vegetation failed to become established in the area. It was hypothesized that plant establishment was being inhibited by chemicals leaching from the berm. Some waste material from park redevelopment had been used to form the base of the berm, which was subsequently covered with imported fill (HDR 1988). Soil samples were collected from the unvegetated area and adjacent vegetated area and analyzed for pH and cyanide. The pH and cyanide concentrations were similar in samples from vegetated and unvegetated areas suggesting they were not responsible for inhibiting plant establishment. No definitive reason for the lack of vegetation in this area was identified. This area was included in the 2001 vegetative soil cover placement (ThermoRetec 2001). Turfgrass was observed to cover this area in 2010 and was similar to other areas vegetated in 2001[20].

This TEE uses literature-based values to estimate the potential toxicity of chemicals to ecological receptors. Default ecological SSVs for this simplified TEE are provided in MTCA (Table 749-2) and represent soil concentrations below which adverse effects are unlikely to occur. For plants and soil biota, the SSVs are typically based upon results of laboratory toxicity tests where test organisms are grown in soils containing a range of chemical concentrations. For wildlife, the SSVs are derived using food-chain models that consist of an estimate of the daily oral dose of a chemical from the site and a toxicity reference value. Wildlife toxicity reference values represent a daily dose of chemical below which adverse effects are unlikely to occur and are typically based on laboratory toxicity tests where animals were dosed with a range of chemical concentrations. Wildlife food-chain model parameter values and the toxic reference value are obtained from the literature. The default SSVs presented in Table 749-2 of MTCA are the lowest of the plant, soil biota, and wildlife SSVs (Ecology 2000).

The wildlife SSVs for this simplified TEE were developed using food-chain models that estimate exposure of birds and mammals via incidental ingestion of soil and ingestion of biota that have accumulated chemicals from the soil (Ecology 2000). Two surrogate wildlife species, the shrew (mammalian insectivore) and the robin (avian insectivore), were used in food-chain modeling. These surrogate species

[19] Field visits conducted by Dr. Dana Houkal (DH Environmental Consulting) on June 15, June 30, August 27, and September 23-24, 2010. Personal communication with Mr. David Graves (Seattle Department of Parks and Recreation) on 11/16/2010.

[20] Field visit conducted by Dr. Dana Houkal (DH Environmental Consulting) on September 23-24, 2010.

were selected because they consume soil invertebrates that tend to accumulate higher concentrations of chemicals from the soil than plants.

The chemicals of concern in soil at the Gas Works Park site were identified in the Revised Cleanup Action Plan (Parametrix and ThermoRetec 2005) and include arsenic and 10 PAHs (Table D-4). This simplified TEE process focuses on a list of priority ecological contaminants that were selected based upon their persistence in the environment, tendency to bioaccumulate, or relatively high toxicity (Ecology 2000). Priority ecological contaminants for this simplified TEE are listed in Table 749-2 of MTCA. Chemicals that are both chemicals of concern at the Site and priority ecological contaminants are arsenic and benzo(a)pyrene (BaP).

Soil screening values (SSVs) for unrestricted land use (Table 749-2 of MTCA) are the most applicable for use at the Gas Works Park site and were derived to be protective of soil biota, plants, and wildlife (Ecology 2000). However, protection of the nonnative landscape plants and invasive plants is not a goal of this TEE (see Section 2.0), so SSVs protective of plants are not used in this toxicity assessment. The SSVs selected and developed for this simplified TEE are described in the following sections.

D6.1.1 Arsenic

Arsenic SSVs for this simplified TEE (MTCA Table 749-2) are provided for two chemical forms of arsenic: arsenite and arsenate. For unrestricted land use, the SSVs are 20 mg/kg for arsenite and 95 mg/kg for arsenate. The technical bases of these SSVs are explained in the technical addendum to the Sections 7490 through 7493 of MTCA (Ecology 2000). While no SSVs were derived for the protection of soil biota due to a lack of sufficient toxicity information, SSVs were derived for plants, birds, and mammals. The plant SSV is 95 mg/kg for total arsenic, the bird SSV is 260 mg/kg for total arsenic, and the mammal SSVs are 20 mg/kg for arsenate and 260 mg/kg for arsenite (Ecology 2000). The reason there are unique mammalian SSVs for arsenate and arsenite is that arsenite is believed to be the more toxic form and there was sufficient toxicological data to support the derivation of unique mammalian SSVs for arsenate and arsenite. An earthworm bioaccumulation factor of 1.16 was used to estimate exposure to wildlife species (i.e., robin and shrew).

The distribution and transformation between arsenate and arsenite, described in Section 5.3.1, is largely controlled by the redox condition of the soil environment. For purposes of this simplified TEE, oxidizing soil conditions are assumed to dominate in the upper 1 foot of soil, while reducing conditions are assumed to dominate in subsurface soil below a depth of 1 foot. In addition,

since protection of ornamental and invasive plants is not a goal of this TEE, the SSV for plants (95 mg/kg total arsenic) will not be used. Therefore, the arsenic SSVs selected for this TEE are 260 mg/kg in surface soil (0- to 1-foot depth) and 20 mg/kg in subsurface soil (1- to 6-foot depth). Since the conditional point of compliance is 0 to 6 feet below ground surface (Section 2.0), a soil depth weighted average SSV of 60 mg/kg was selected to assess ecological hazards from arsenic in this soil strata[21].

D6.1.2 Benzo(a)pyrene

The default ecological SSV for BaP (MTCA Table 749-2) is 30 mg/kg for unrestricted land use. This value is based upon the wildlife value derived for the shrew (insectivorous mammals) (Ecology 2000). Insufficient toxicity data were available to derive values for soil biota, plants, and birds.

Wildlife toxicity values used to derive the default SSVs in Table 749-2 of MTCA typically represent a lowest observed adverse effect level (LOAEL) toxicity value (Ecology 2000). However, in the case of BaP, a mammalian no observed adverse effect level (NOAEL) toxicity value was used because of uncertainties associated with the lack of toxicity data for birds, plants, and soil biota. The NOAEL value (1.2 mg/kg/d) was calculated as ten percent of the LOAEL value (11.9 mg/kg/d), but no explanation of this conversion factor was provided (Ecology 2000). In addition, the soil to earthworm bioaccumulation factor used to derive the default SSV for BaP is based on two published studies characterizing bioaccumulation on upland dredge spoils sites (Ecology 2000). The default BAF may not be representative of BAFs at MGP sites whose soils have unique characteristics associated with the industrial processes practiced at these sites. Consequently, confidence in the MTCA default SSV for BaP is relatively low because of uncertainties associated with the mammalian toxicity value and earthworm BAF. A literature search was conducted to identify more suitable toxicity and BAF information.

EPA has recently developed national ecological soil screening levels for PAHs (EPA 2007). EPA grouped PAHs into low molecular weight (LMW) and high molecular weight (HMW) compounds based upon similarities in toxicity and environmental fate. BaP is a HWM PAH. Seventeen NOAEL values for HMW PAHs met EPA's toxicity value selection criteria and were identified as acceptable mammalian toxicity values for growth, reproduction, and mortality endpoints (Table D-5) (EPA 2007). The NOAEL values ranged from 0.615 to 125 mg/kg/d. Data sets such as this one often contain outlier values at the lower

[21] The soil depth weighted average SSV for arsenic was calculated as [(260 mg/kg x 1) + (20 mg/kg x 5)]/6.

and upper ends of the distribution that may not be representative of the distribution and may bias estimates. For this reason, the 10th percentile value (4.24 mg/kg/d) was selected as a reasonable minimum mammalian NOAEL value for BaP. Since this toxicity value is based on reported NOAEL value and not extrapolated from a LOAEL value as was done in MTCA (Table 749-2), it is considered scientifically more defensible. Furthermore, the EPA (2007) toxicity data set contains more recent and comprehensive data than that used in MTCA, which also supports the use of the value derived from EPA.

Ecology's (2000) wildlife SSV methodology includes the allometric adjustment of mammalian toxicity values to account for differences in body weight between the test animal and the wildlife receptor species. This adjustment is made using Equation 1.

Equation 1: $$NOAEL_{wildlife\ species} = NOAEL_{test\ species} \times \left[\frac{BW_{test\ species}}{BW_{wildlife\ species}}\right]^{1/4}$$

Where:

$NOAEL_{wildlife\ species}$ = no adverse effects level for the surrogate wildlife species (mg/kg/d)

$NOAEL_{test\ species}$ = no adverse effects level for the test species (mg/kg/d)

$BW_{test\ species}$ = body weight for the test species (kg)

$BW_{wildlife\ species}$ = body weight for the surrogate wildlife species (kg)

Toxicity data presented in Table D-5 shows that the only test species with NOAEL values for HMW PAHs are the mouse and rat. The surrogate mammalian wildlife species used to derive simplified TEE SSVs is the shrew, which has a body weight of 0.015 kg. Since toxicity is inversely proportional to body weight, the closer the test species body weight is to the shrew body weight, the smaller (more conservative) the allometrically adjusted toxicity value will be. The mature mouse has a smaller body weight (0.03 kg) then the rat (0.35 kg), so using the mouse as the test species will yield a lower toxicity value. Solving Equation 1 using body weights for the mouse and shrew, and the 10th percentile NOAEL of 4.24 mg/kg/d, yields an adjusted toxicity value of 5.04 mg/kg/d.

Organic compounds, such as PAHs, become progressively less available for uptake by organisms as they persist or age in soil (Alexander 2000). This declining bioavailability often results in the overestimation of exposure and hazards from the compounds at contaminated sites. Chemicals present in soils at the Gas Works Park site have undergone considerable aging since cessation of industrial activities in 1956. In addition, soils at MGP sites have unique

characteristics which affect the bioavailability of organic chemicals. A study by Kreitinger et al. (2007) characterized the bioaccumulation of PAHs from soils at 16 MGP sites into earthworms and is particularly well suited as a source for developing a suitable BAF for use at the Gas Works Park site.

Kreitinger et al. (2007) found the bioavailability of PAHs to earthworms in weathered soils at 16 coal and oil gas MGP sites was 5- to 50-fold lower than the bioavailability of freshly added PAHs. Soils at these MPG sites contained high levels of manmade carbon (e.g., charcoal, coal, coal tar pitch, coke, and soot) and have undergone weathering for 50 years or more. Weathering has removed the more mobile fraction of PAHs from the soil and residual PAHs are in an advanced stage of sequestration within the manmade carbon matrix. Results of 14-day earthworm toxicity tests showed soils with total PAH concentrations as high as 42,100 mg/kg did not affect earthworm survival (Kreitinger et al. 2007). Soil characteristics at the Gas Works Park site are expected to be similar to the 16 MGP sites studied by Kreitinger et al. (2007).

Kreitinger et al. (2007) derived earthworm bioaccumulation factors (BAFs) for PAHs using two approaches: Field-collected earthworms and laboratory earthworm bioassays. The field-collected earthworm results were selected to derive a BAF for BaP for use at the Gas Works Park site because they represent natural exposure conditions, BaP concentrations in soil and earthworm tissues should be at equilibrium, and the BAFs derived using field collected earthworm data were somewhat higher than those derived using laboratory bioassays (i.e., more conservative).

The earthworm BAFs for BaP provided in Kreitinger et al. (2007) were based on using lipid-normalized earthworm concentrations and carbon-normalized soil concentrations. BAFs based on dry weight earthworm and soil concentrations were calculated as shown in Table D-6. The BAFs calculated from the Kreitinger et al. (2007) study range from 0.06 to 0.15 and are significantly below the MTCA default earthworm BAF of 0.43. The highest calculated BAF (0.15) was selected to derive the alternate SSV for BaP.

Use of the NOAEL of 5.04 mg/kg/d and BAF of 0.15 along with the standard MTCA exposure parameter values used in the food-chain model for the shrew (Ecology 2000) yields a SSV of 339.4 mg/kg for BaP (Table D-7). This SSV will be used to screen soil data at the Gas Works Park site.

D6.2 Estimation of Reasonable Maximum Exposure Concentrations

All historical soils data presented in the RI were considered for use in this simplified TEE. Some of these data were more than 25 years old and site

development activities subsequent to sample collection may have compromised the integrity of specific sample results. Nonetheless, these data were considered suitable for characterizing the general nature of soil chemical concentrations in the target ecological exposure areas.

RME soil concentrations for target ecological exposure areas were calculated for two soil depths, 0 to 6 feet and 0 to 1 foot below ground surface (see Section 4.5). The 0 to 6 foot strata is the conditional point of compliance (WAC 173-340-7490(4)) and includes potential exposures to subsurface soil representing the default biologically active zone. The 0 to 1 foot stratum represents exposures to surface soils and is the most likely ecological exposure zone at the Gas Works Park site. The designation of this surface soil exposure zone is based on the following observations:

- No burrowing mammals have been observed at the Site
- Direct soil exposure of surface-dwelling mammals and birds is limited to the upper few inches
- Turfgrass roots are likely limited to the upper foot of soil
- Most soil macroinvertebrates live in the upper foot of soil

Ecological exposure areas with known clean soil cover depths (i.e., Areas A and E) had the soil sample depths adjusted accordingly. For example, Area A had a 1 foot of clean soil cover placed over the area in 2005. If the soil sample depth at the time of collection (prior to placement of the soil cover) was 2.5 feet, the sample depth was adjusted to 3.5 feet. The soil sample depth for all other ecological exposure areas was assumed to be as recorded at the time of collection.

The following soils data were not used to estimate ecological exposures:

- Data from sample locations known to have been excavated and removed.
- Data collected for quality assurance/quality control purposes (e.g., field duplicate samples).
- Data from sample locations covered by an impermeable layer. (Note: Some samples were composites collected from a large area. For samples collected in the 1980s, the positional information is considered approximate. Therefore, data from sample locations potentially located under an impermeable layer were considered usable unless sufficient information was available to conclude otherwise.)

The soils data used to calculate RME concentrations are shown in Attachment D-2.

The RME concentrations were calculated using EPA's ProUCL version 4.0[22] statistical software using the upper confidence limit (UCL) option. The UCL option was run in the "full" mode for data sets containing all detected concentrations, while the UCL option was run in the "with NDs" mode for data set containing undetected values. The maximum detected concentration was used to represent the RME in data sets having insufficient samples to generate an RME estimate using ProUCL. ProUCL output files of summary statistics and UCL estimates are provided in Attachment D-3.

D6.3 Chemical Screening

Table D-8 presents the RME soil concentrations for COPCs and the SSVs for target ecological exposure areas. Since the RME soil concentrations in all areas are less than the SSVs, arsenic and BaP do not pose an ecological hazard.

D7.0 UNCERTAINTY ANALYSIS

Assumptions exist in virtually every step of the terrestrial ecological evaluation process that may lead to uncertainties in the evaluation. Understanding these uncertainties can help with interpreting the results of the evaluation and enhance remedial decision-making. The major sources of uncertainty in this simplified TEE for the Gas Works Park site are discussed below.

D7.1 Soils Data

The analytical soil data used in the TEE came from historical environmental studies some of which are more than 25 years old. Organic chemicals, such as PAHs, are subject to physical (e.g., leaching), biological (e.g., microbial mineralization), and chemical degradation over time which should result in a reduction in their concentrations. Inorganic chemicals can also leach from the soil reducing their concentrations in the soil. Therefore, it is likely that exposure point estimates, which are based in part on old data, overestimate exposures and hazards.

Redevelopment activities that occurred following the historical environmental studies probably disturbed many sample locations. For example, all soils data from Area A were collected prior to redevelopment of the area into a recreational area in 2005. During redevelopment, the pre-existing soil was regraded to form the rolling topography currently found in Area A. Regrading

[22] ProUCL version 4.0 software is available online at http://www.epa.gov/esd/tsc/software.htm.

tends to homogenize the soil so that the chemical concentrations become more uniform over the site. High concentrations associated with chemical hotspots would be reduced. Areas having the same mean soil chemical concentration may have very different RME concentrations because the RME is dependent of the amount of variation associated with the sample population. Sampling soil from an area having a more uniform spatial pattern of chemical concentrations will result in the calculation of a lower RME concentration than sampling an area with widely variable chemical concentrations. Therefore, it is likely that if an area was sampled after redevelopment the resulting RME estimate would be lower than if pre-development data were used.

The number of soil samples available for characterizing exposure at each target ecological exposure area was variable (Table D-9). Although the highest density of samples probably occurs in Area C, sample density appears to be adequate for characterizing each of the areas.

D7.2 Toxicity Values

In general, bird and mammal toxicity values used in ecological hazard assessment come from published laboratory studies where standard laboratory test species (e.g., mice, rats, Japanese quail, domestic chickens) are exposed to a chemical via the diet for a variable time (e.g., weeks to years) and then assessed for a variety of endpoints (e.g., survival, body weight gain/loss, reproductive capacity). How accurate a measure these laboratory tests are of toxicity to wild animals is largely unknown.

This TEE used default MTCA SSVs for arsenic (20 mg/kg for arsenite and 260 mg/kg for arsenate) to assess ecological hazards from arsenic. These SSVs were based on the following protective soil concentrations provided in Ecology (2000): Birds = 260 mg/kg as total arsenic, mammals = 20 mg/kg as arsenite, mammals = 260 mg/kg as arsenate. EPA (2005) developed national ecological risk-based soil concentrations for arsenic, but did not find sufficient information to distinguish mammalian toxicity based on the chemical form of arsenic. Therefore, EPA combined the toxicity data for all forms of arsenic to derive a mammalian toxicity reference value. Even though the method used to derive the mammalian toxicity value by EPA (2005) is more conservative than the method used in MTCA (Ecology 2000), it resulted in a higher toxicity value for arsenic than the mammalian toxicity value arsenite. This suggests that the use of the mammalian toxicity value for arsenite may overestimate ecological hazards.

Toxicity values for BaP were limited to mammals. In lieu of using the MTCA default mammalian toxicity values, this TEE derived a toxicity value from data provided in EPA's EcoSSL for PAHs (EPA 2007). This approach is considered

scientifically defensible because EPA provided a more comprehensive and updated mammalian data set than was that used by Ecology (2000).

D7.3 Bioaccumulation Factors

The default earthworm BAF of 1.6 used to derive the wildlife SSV for arsenic is based on a study of upland sediment disposal sites (Ecology 2000). EPA (2005) also developed earthworm bioaccumulation estimates for arsenic, but based their estimates on a regression equation that relates the accumulation of arsenic in earthworms to the concentration in soil (Equation 2). This equation was based upon 53 measurements of arsenic bioaccumulation in earthworms from four published studies.

Equation 2: $\ln(C_e) = 0.706 \times \ln(C_s) - 1.421$

Where:

C_e = concentration of chemical in the earthworm (mg/kg)
C_s = concentration of chemical in soil (mg/kg)

When substituting the arsenic RME soil concentrations for each target ecological exposure area (Table D-8) into Equation 2, the resulting BAFs are 8 to 16 times lower than the default BAF of 1.6. This information suggests that the default earthworm BAF used to derive SSVs for arsenic may overestimate exposure and hazards.

The earthworm BAF derived for this TEE was based upon a bioaccumulation study of 16 MGP sites (Kreitinger et al. 2007). Given the unique soil characteristics associated with MGP sites and their likely similarity to soils at the Gas Works Park site, use of BAFs derived from MGP sites is considered more appropriate than using BAFs derived using soils having very different characteristics.

D7.4 Wildlife Food-Chain Models

The robin and shrew are the default MTCA surrogate wildlife species used in food-chain modeling to derive SSVs. Robins has been observed at the Site, but shrews have not. Given the developed nature of the Site, shrews may not be present. Nevertheless, the shrew is a reasonable surrogate species to use in this screening-level hazard assessment because modeling results using the shrew are likely to be protective of most other mammals. There is some uncertainty associated with using the shrew as a surrogate wildlife species and this uncertainty is likely to overestimate hazards to mammals.

Insufficient toxicity data were available for BaP to develop an SSV for birds. Therefore, an SSV for wildlife could only be calculated for mammals (i.e., the shrew). A lower toxicity value was selected for calculating the SSV for the shrew which should account for uncertainties associated with the lack of toxicity data for birds.

The wildlife exposure parameter values used to derive wildlife SSVs are the default values used in MTCA (Ecology 2000). Although there is some uncertainty associated with using these values, it is considered relatively small.

D7.5 Ecological Goals

Although, the goal of this simplified TEE includes the protection of soil invertebrates, hazards to these receptors were not directly assessed because Ecology (2000) did not find sufficient toxicity information for arsenic or BaP to derive a SSV protective of soil invertebrates. Some of dominant soil macroinvertebrates at the Gas Works Park site are earthworms and crane flies, both of which are not native to the region. In addition, abundant and healthy earthworm populations were observed in all ecological exposure areas surveyed on September 23-24, 2010. This information suggests that chemicals in these areas do not pose a hazard to soil invertebrate populations.

A fundamental ecological unit is the population. Ecological hazard assessments typically focus on the protection of populations unless a threatened or endangered species is present that requires protection of individual organisms. The methods used in this simplified TEE estimate hazards to individual organisms. Although the definition of a population is debatable, the concept of a local population for assessing ecological hazards has been adopted by the Oregon Department of Environmental Quality (ODEQ) in their ecological risk assessment guidelines[23]. Basically, ODEQs population-level guidelines describe how to establish the boundaries of a local population and then how to determine if the acceptable risk level is exceeded. The acceptable risk level is defined as a 10 percent chance or less that 20 percent or more of a local population would have exposure greater than the ecological benchmark value for a contaminant of concern. Although this detailed analysis was not conducted for the Gas Works Park site, this discussion serves to demonstrate that is it acceptable to have a certain proportion of a local population affected by chemicals at a site and still not have an impact to the local population viability. This is because most populations have an innate amount of plasticity which enables them to incur

[23] Available online at http://www.deq.state.or.us/lq/pubs/docs/cu/GuidanceEcologicalRisk.pdf.

mortality, but offset this with a sufficient level of reproduction to offset these losses.

D7.6 Summary of Uncertainties

The uncertainties discussed above indicate that the methods used in this simplified TEE may overestimate exposure and hazards. Given that results of the TEE do not show residual soil concentrations of arsenic and BaP at the Gas Works Park site pose an ecological hazard, it can be safely concluded that this finding does not underestimate hazards.

D8.0 SUMMARY AND CONCLUSIONS

A simplified TEE was conducted on the terrestrial portion of the Gas Works Park site compliant with MTCA (WAC 173-340-7492). The MTCA TEE procedures are consistent with EPA ecological risk assessment guidelines (EPA 1997). This TEE consisted of four steps: an exposure analysis, a pathways analysis, a contaminants analysis, and an uncertainty analysis.

Results of the exposure analysis showed that there is a potential for substantial exposure of wildlife to residual soil chemicals. Therefore, further analysis was required.

In the pathways analysis, the Site was divided into eight ecological exposure areas based mainly on redevelopment activities at Gas Works Park. A significant portion of the Site is covered by concrete, asphalt, or compacted gravel that prohibits ecological exposures to underlying soil. Some exposure areas have been covered with a 1-foot layer of imported loam soil, which also reduce ecological exposure. Other areas have received some soil treatments, but still have residual chemical concentrations present in the surface soils. Exposure to residual chemicals present in subsurface soil is limited because the dominant plants and animals found on the Site are only exposed to surface soil. The dominant vegetation is turfgrass, which has a root system largely limited to the upper 1 foot of soil. Most soil invertebrates found at the site (e.g., endogenic earthworms and crane flies) inhabit the upper 1 foot of soil. No burrowing animals were observed at the Site, so direct wildlife contact with soil is restricted to shallow soils. However, limited ecological exposure to chemicals in subsurface soil was possible. One species of deep burrowing soil invertebrate (night crawler) and several species of shrubs and trees that have deeper root systems and are a food source to wildlife (e.g., Himalayan blackberry, beech tree) occur on the Site. Ecological exposure to soil-borne chemicals was determined to be potentially complete in five of eight ecological exposure areas.

Two ecological COPCs were identified in soil at the Gas Works Park site: Arsenic and BaP. As part of the contaminants analysis, appropriate toxicity values and bioaccumulation factors were identified and used to derive protective ecological SSVs. The SSVs were then compared to RME concentrations in soil in target ecological exposure areas. The RME concentrations were all below the SSVs indicating the COPCs do not pose an ecological hazard.

Major sources of uncertainty in the TEE were qualitatively described in the uncertainty analysis. Overall, these uncertainties suggest that the results of this simplified TEE do not underestimate ecological hazards from the COPCs.

Results of the pathways analysis, contaminants analysis, and uncertainty indicate that residual concentrations of COPCs in soils at the Gas Works Park site do not pose an ecological hazard.

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Table D-1 - Wildlife Observed at the Gas Works Park Site

Species Name		Introduced or Native
Common	Scientific	
Birds		
Mallard	*Anas platychynchos*	Native
Canada Goose	*Branta canadensis*	Native
Northern Flicker	*Colaptes auratus*	Native
Rock Dove	*Columba livia*	Introduced
American Crow	*Corvus brachyrhynchos*	Native
Barn Swallow	*Hirundo rustica*	Native
Herring Gull	*Larus argentatus*	Native
Song Sparrow	*Melospiza melodia*	Native
English Sparrow	*Passer domesticus*	Introduced
European Starling	*Sturnus vulgaris*	Introduced
American Robin	*Turdus migratorious*	Native
Mammals		
Eastern Gray Squirrel	*Sciurus carolinensis*	Introduced

Table D-2 - Results of Exposure Analysis

Parameter	Score
1) From the table below, find the number of points corresponding to the area of the site and enter this score. Area (acres) — Points 0.25 or less — 4 0.5 — 5 1.0 — 6 1.5 — 7 2.0 — 8 2.5 — 9 3.0 — 10 3.5 — 11 4.0 or more — 12	12
2) Is this an industrial or commercial property? See WAC 173-340-7490(3)(c). If yes, enter a score of 3. If no, enter a score of 1.	1
3) Enter a score for the habitat quality of the site, where high = 1, intermediate = 2, and low = 3.	3
4) Is the undeveloped land likely to attract wildlife? If yes, enter a score of 1. If no, enter a score of 2.	1
5) Are there any of the following soil contaminants present: chlorinated dioxins/furans, PCB mixtures, DDT, DDE, DDD, aldrin, chlordane, dieldrin, endosulfan, endrin, heptachlor, benzene hexachloride, toxaphene, hexachlorobenzene, pentachlorophenol, pentachlorobenzene? If yes, enter a score of 1. If no, enter a score of 4.	1
6) Add the numbers in the boxes from parameters 2 through 5 and enter the score. If this number is larger than the score in parameter 1, the simplified TEE may be ended under WAC 173-340-7492(2)(a)(ii).	6

Table D-3 - Ecological Exposure Areas Exposure Pathways Summary

Ecological Exposure Area	Further Evaluation Needed?	Description
A and E	Yes	A clean soil cover at least 1 foot thick exists over these areas. The areas are mostly covered by turfgrass with root systems limited to the upper 1 foot. Several ornamental trees and shrubs were planted on Area A, while invasive and planted species of shrubs and trees are found along the Lake Union shoreline of Area E. Roots of shrubs and trees probably extend into the subsurface soil, but PAHs do not readily accumulate in aboveground plant tissues. Although most soil invertebrates live in upper 1 foot of soil, one deep burrowing species (the night crawler) is present. No burrowing animals have been observed at the site. Therefore, the direct exposure pathway of wildlife to residual chemicals present in subsurface soil is largely incomplete.
B	No	This area is largely paved creating a physical exposure barrier. The Burke-Gilman Trail is covered by compacted gravel, effectively prohibiting ecological exposure to underlying soil. However, the berms located along either side of the Burke-Gilman Trail contain open ground supporting plants and soil macroinvertebrates. The berms were created by mounding imported fill brought to the park during redevelopment in the early 1970s. Trees growing on the berms have limited value as a wildlife food source. Although ecological exposure to soil-borne chemicals may be complete, it is considered to be minor and does not warrant further evaluation.
C and F	Yes	Although the soil in these areas was amended during initial park redevelopment, they are not covered by a layer of clean soil. Wildlife and soil biota may be exposed to residual chemical concentrations present in surface soil.
D	No	A clean soil cover of at least 1 foot thickness covers the area. An impermeable low-density polyethylene liner is also present at a depth of 1.5 feet that prohibits ecological exposure to underlying soil.
G	Yes	Although most of this area was covered by imported fill during park redevelopment in the early 1970s, the quality of the fill material was not verified. Soil conditions in the low area between Kite Hill and the Cracking Towers are similar to Areas C and F.
H	No	This area is largely paved. No industrial operations of the former MGP were located in this area.

Table D-4 - Priority Ecological Contaminants Present in Soil

Chemical of Potential Concern	Priority Ecological Contaminant?
Arsenic	Yes
Benzo(a)anthracene	No
Benzo(a)pyrene	Yes
Benzo(b)fluoranthene	No
Benzo(k)fluoranthene	No
Chrysene	No
Dibenzo(a,h)anthracene	No
Fluoranthene	No
Indeno(1,2,3-cd)pyrene	No
Naphthalene	No
Pyrene	No

Table D-5 - Mammalian Toxicity Data for High Molecular Weight Polycyclic Aromatic Hydrocarbons [a]

Chemical	Test Organism	Effect Type	NOAEL (mg/kg/d)
Benzo(a)pyrene	Mouse (*Mus musculus*)	Mortality	0.615
Benzo(a)pyrene	Mouse (*Mus musculus*)	Growth	3.09
Benzo(a)pyrene	Rat (*Rattus norvegicus*)	Growth	5
Benzo(a)pyrene	Mouse (*Mus musculus*)	Reproduction	10
Benzo(a)pyrene	Mouse (*Mus musculus*)	Growth	10
6-Aminochrysene	Rat (*Rattus norvegicus*)	Growth	11.8
6-Aminochrysene	Rat (*Rattus norvegicus*)	Reproduction	13.3
6-Aminochrysene	Rat (*Rattus norvegicus*)	Growth	13.3
6-Aminochrysene	Rat (*Rattus norvegicus*)	Mortality	13.3
Benzo(a)pyrene	Rat (*Rattus norvegicus*)	Growth	21.1
Benzo(a)pyrene	Mouse (*Mus musculus*)	Mortality	27.3
7,12-Dimethylbenz(a)anthracene	Mouse (*Mus musculus*)	Growth	28.5
Benzo(a)pyrene	Mouse (*Mus musculus*)	Growth	31.7
Benzo(a)pyrene	Mouse (*Mus musculus*)	Mortality	31.7
Benzo(a)pyrene	Rat (*Rattus norvegicus*)	Growth	49
Benzo(a)pyrene	Rat (*Rattus norvegicus*)	Growth	53.9
Benzo(a)pyrene	Mouse (*Mus musculus*)	Growth	125
		10th percentile	4.24

[a] Toxicity values are from EPA (2007)

NOAEL - no observed adverse effect level

Table D-6 - Derivation of Earthworm Bioaccumulation Factor for Benzo(a)pyrene

Soil Sample #	BaP BSAF[1]	BaP Conc. Earthworm[2] (ug/g lipid)	BaP Conc. Soil[3] (ug/g OC)	Soil Total Carbon[1] (%)	BaP Conc. Soil[4] (ug/g DW)	BaP Conc. Earthworm[5] (ug/g DW)	BAF[6]
CG12	0.065	200	3076.9	7.9	243.1	13.8	0.06
CG15	0.26	80	307.7	24.1	74.2	5.5	0.07
CG17	0.27	100	370.4	12.5	46.3	6.9	0.15

BSAF - biota soil accumulation factor calculated as earthworm concentration (ug/g lipid)/soil concentrations (ug/g carbon)

BaP - benzo(a)pyrene

OC – organic carbon

DW - dry weight

BAF - bioaccumulation factor calculated as earthworm concentration (ug/g DW)/soil concentration (ug/g DW)

[1] Source: Table 1 in Kreitinger et al. (2007)

[2] Source: Figure 2 in Kreitinger et al. (2007)

[3] Calculated as (BaP Conc. Earthworm (ug/g lipid))/(BaP BSAF)

[4] Calculated as (BaP Conc. Soil (ug/g OC))/(Soil Total Carbon/100)

[5] Calculated as (BaP Conc. Earthworm (ug/g lipid)/Earthworm lipid content (percent))/(100 - earthworm moisture content (percent)). Earthworm lipid content is 0.018 percent (Kreitinger et al. 2007) and earthworm moisture content is 0.83 percent (EPA 1993).

[6] Calculated as (BaP Conc. Earthworm (ug/g DW))/(BaP Conc. Soil (ug/g DW))

Table D-7 - Mammalian Soil Screening Value for Benzo(a)pyrene

$$SSV_{mammal} = \frac{T}{(FIR \times P \times BAP) + (SIR \times RGAF)}$$

Parameter		Value	Description	Source
SSV_{mammal}	=	339.4	BaP soil screening value for the shrew (mg/kg)	Calculated
T	=	5.04	Toxicity reference value for BaP for shrew (mg/kg body weight/day)	Allometrically adjusted 10th percentile mammalian NOAEL (see Section 6.1.2)
FIR	=	0.45	Food ingestion rate for the shrew (kg dry weight/kg body weight/day)	Ecology 2000
P	=	0.2	Proportion of contaminated food in the shrew diet (unitless)	Ecology 2000
BAF	=	0.15	BaP bioaccumulation factor for soil macroinvertebrates (kg biota dry weight/kg soil dry weight)	MTCA Table 749-5
SIR	=	0.0045	Soil ingestion rate for the shrew (kg soil dry weight/kg body weight/day)	Ecology 2000
RGAF	=	0.3	Gut absorption factor for BaP in soil (unitless)	Ecology 2000

Table D-8 Chemical Screening Results

Ecological Exposure Area	RME Soil Concentration (mg/kg)[a]			
	0 to 6 Foot Soil Strata		0 to 1 Foot Soil Strata	
	Arsenic	Benzo(a)pyrene	Arsenic	Benzo(a)pyrene
A	5.747	128.8	NR	NR
C	31.19	157.5	54.45	46.44
E	7.211	46.97	NR	NR
F	ND	36[b]	ND	36[b]
G	11.26	196.5	17.03	76.64
Soil Screening Value (mg/kg)	60	339.4	260	339.4

RME - reasonable maximum exposure point concentration

NR - not required; Areas A and E are covered with 1 foot of clean soil

ND - not detected

[a] RMEs were calculated using EPA's ProUCL software unless indicated otherwise.

[b] RME is the maximum detected concentration.

Table D-9 - Number of Soil Samples (0 to 6 feet) from Ecological Exposure Areas

Ecological Exposure Area	Number of Soil Samples	
	Arsenic	Benzo(a)pyrene
A	21	25
C	12	54
E	27	41
F	2	4
G	10	24

North Northlake Way

Parking Lot

Gravel Trail (Former Railroad Grade)

Concrete Trestles

Play Barn

Seattle Police Harbor Patrol

Kite Hill

Cracking Towers

The Prow

LAKE UNION

Boundary for Gasworks Park Uplands Site per 1999 Consent Decree

-20 Topography Contour (5 foot Interval)

Notes:

1. Topography lines created from King County interactive mapping tool (iMAP).
2. Figure and impacted areas based on Figure E5-3 by Parametrix, 1998.

Source: Base map prepared from aerial photo provided by Floyd/Snider, 2010.

0 100 200

Scale in Feet

N

Gas Works Park Site
Seattle, Washington

Site Features

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Figure
D-1

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LAKE UNION

Site Boundary

-20 Topography Contour (5 foot Interval)

Notes:

1. Topography lines created from King County interactive mapping tool (iMAP).
2. Based on Figure 6-1 by Parametrix and Key Environmental, 1998.

Source: Base map prepared from aerial photo provided by Floyd/Snider, 2010.

Gravel Pathways

Impervious Surfaces

Buildings and Structures

N

0 100 200

Scale in Feet

Gas Works Park Site
Seattle, Washington

Topography, Impervious Surfaces, and Gravel Pathways

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Figure **D-2**

EAL 06/1/11 1733020-063.dwg

Source: Base map prepared from aerial photo provided by Floyd/Snider, 2010.

Gas Works Park Site
Seattle, Washington

Ecological Exposure Areas

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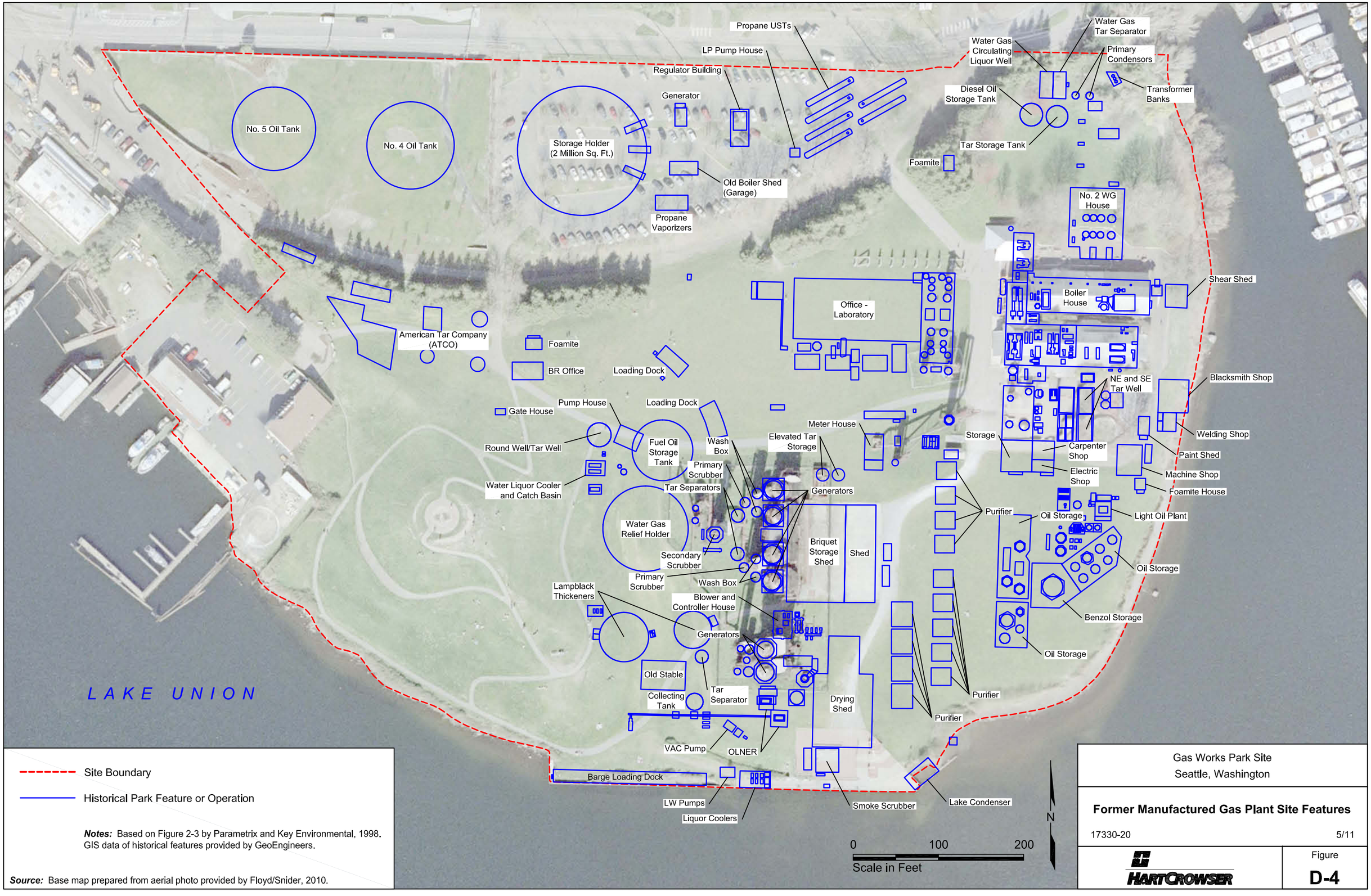
Figure
D-3

EAL 06/1/11 1733020-064.dwg


No. 5 Oil Tank
No. 4 Oil Tank
Storage Holder
(2 Million Sq. Ft.)
Propane USTs
LP Pump House
Regulator Building
Generator
Old Boiler Shed
(Garage)
Propane
Vaporizers
Water Gas
Tar Separator
Water Gas
Circulating
Liquor Well
Primary
Condensors
Transformer
Banks
Diesel Oil
Storage Tank
Tar Storage Tank
Foamite
No. 2 WG
House
Boiler
House
Shear Shed
Office -
Laboratory
American Tar Company
(ATCO)
Foamite
BR Office
Loading Dock
Gate House
Pump House
Loading Dock
Round Well/Tar Well
Fuel Oil
Storage
Tank
Wash
Box
Primary
Scrubber
Tar Separators
Water Liquor Cooler
and Catch Basin
Water Gas
Relief Holder
Secondary
Scrubber
Primary
Scrubber
Wash Box
Lampblack
Thickeners
Blower and
Controller House
Generators
Old Stable
Collecting
Tank
Tar
Separator
VAC Pump
OLNER
Barge Loading Dock
LW Pumps
Liquor Coolers
Meter House
Elevated Tar
Storage
Generators
Briquet
Storage
Shed
Shed
Drying
Shed
Smoke Scrubber
Lake Condenser
Purifier
Purifier
Purifier
Purifier
Storage
Blacksmith Shop
NE and SE
Tar Well
Welding Shop
Paint Shed
Carpenter
Shop
Electric
Shop
Machine Shop
Foamite House
Oil Storage
Light Oil Plant
Oil Storage
Benzol Storage
Oil Storage
LAKE UNION
Site Boundary
Historical Park Feature or Operation
Notes: Based on Figure 2-3 by Parametrix and Key Environmental, 1998.
GIS data of historical features provided by GeoEngineers.
Source: Base map prepared from aerial photo provided by Floyd/Snider, 2010.
0
100
200
Scale in Feet
N
Gas Works Park Site
Seattle, Washington
Former Manufactured Gas Plant Site Features
17330-20
5/11
HARTCROWSER
Figure
D-4
EAL 06/1/11 1733020-065.dwg

EAL 06/1/11 1733020-066.dwg

Gas Works Park Site
Seattle, Washington

Ecological Conceptual Site Model

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Figure **D-5**

ATTACHMENT D-1
SOIL INVERTEBRATE SURVEY REPORT FOR THE GAS WORKS PARK SITE

ATTACHMENT D-1
SOIL INVERTEBRATE SURVEY FOR THE GAS WORKS PARK SITE

1.0 INTRODUCTION

A simplified terrestrial ecological evaluation (TEE) was conducted for the upland portion of the Gas Works Park site (Site) following MTCA (WAC 173-340-9492). One component of this TEE is a pathways analysis where potentially complete exposure pathways from residual soil chemicals to ecological receptors are identified. One important exposure pathway is from soil to soil invertebrates to wildlife (e.g., robin consuming soil invertebrates). This pathway is particularly important for hydrophobic chemicals, such as polycyclic aromatic hydrocarbons, that tend to accumulate in the lipid fraction of soil macroinvertebrates. The purpose of this survey is to provide site-specific information for determining if this pathway is complete.

Birds (e.g., American robin, European starlings, American crow, and northern flicker) have been observed foraging on soil macroinvertebrates at the Site on several occasions. Two common soil macroinvertebrates in the Seattle area that are important food items for birds are earthworms and crane fly larvae.

Crane fly larvae inhabit the upper four inches of the soil profile (Jackson and Campbell 1975) and are not expected to be exposed to residual chemicals in soils at depths of one foot or greater. On the other hand, some earthworm species may burrow to depths in excess of one foot. Earthworm burrowing depth is affected by many factors including spatial and temporal soil variations in moisture, soil texture, soil stratification, and spatial distribution of food.

The objectives of this survey were to determine if earthworms are present on the Site and to refine our understanding of the potential exposure of earthworms to residual chemical concentrations in soil.

2.0 METHODS AND MATERIALS

Two *in situ* sampling methods were used to assess earthworm populations: liquid extraction sampling and hand excavation sampling. Liquid extraction sampling was used to determine if and what type of earthworms were present. If earthworms were present, selected locations were hand excavated to

determine the burrowing depth of the earthworms. Excavation sampling was only done in areas covered by a geogrid layer[1].

Liquid extraction sampling was conducted using a non-toxic fumigant (an aqueous solution of ground mustard seed) following the methods described by Gunn (1992) and the University of Minnesota[2]. Liquid extraction sampling does not require any intrusive soil activities. Approximately 1/3 cup of dry mustard powder was mixed into one gallon of tap water. To aid in visually locating emerging earthworms, turfgrass in the sample location was trimmed to a height of approximately 0.5 inch with a pair of hand shears. A 1- by 1-foot sample plot was delimited with an aluminum frame and wetted with the mustard solution. Approximately one-half gallon of mustard solution was applied to each plot and allowed to slowly percolate into the soil. From each sample plot, emerging earthworms were placed into a polyethylene zip-lock bag containing a small amount water and then placed in a cooler containing a reusable ice pack. Typically, some earthworms emerged from soil outside the 1 by 1 foot frame as the mustard powder solution often flowed past the frame. These earthworms typically emerged within 3 inches from the frame and were also collected and placed in ziplock bags[3]. Earthworm samples were later enumerated.

Specific liquid extraction sample locations were determined in the field. Samples were located in turfgrass areas because insect-eating birds were seen foraging in this habitat during site visits. Zones of low and high soil moisture were not sampled because earthworms avoid these conditions. Balled and burlapped ornamental shrub and tree plantings are likely sources of introduced earthworms into newly landscaped areas. Some liquid extraction samples in each area were located near shrub or tree landscape plantings.

Following completion of the liquid extraction sampling, hand excavation sample locations were selected. Hand excavation samples were located adjacent to liquid extraction sample locations with earthworms. A shovel was used to excavate a hole approximately 8 inches by 12 inches wide to a depth of no greater than 12 inches or to the depth of the geogrid layer. Care was taken to remove an intact turfgrass root mass so that it could be replaced with little

[1] This excavation sampling design insured that residual chemicals present in underlying soils are not exposed. In addition, underground irrigation pipes are buried across most of the Site and the potential for damaging this piping while excavating was a concern. Therefore, hand excavation was limited to areas with a buried geogrid identifier layer. The geogrid layer indicates the transition from clean cover soil to underlying soil. The geogrid layer was installed in Areas A and E during redevelopment activities and it is covered by 1-foot-thick layer of clean soil.

[2] Available online at http://www.nrri.umn.edu/worms/research/methods_worms.html.

[3] This survey was not intended to be a quantitative population survey, but a qualitative survey in which the presence and species composition of the population was assessed.

damage. Excavated soil and turfgrass masses were placed on a plastic sheet laid down near the excavation. Both the root mass and excavation side walls were visually examined to determine the burrow depth of earthworms. A knife was used to trim away soil to create a cleaner side wall. A ruler was used to measure burrow depths. After examining the excavation, loose soil was replaced in the excavation and then the turfgrass was replaced. The turfgrass root mass was brought to the original grade by tapping it down by foot.

The Site was divided into eight ecological exposure areas based on redevelopment history (i.e., current soil cover characteristics) (Figure D-1-1). Area D was not surveyed because an impermeable low-density polyethylene liner was installed below a 12-inch layer of sandy loam soil and a 6-inch layer of sand. This liner prohibits earthworms and turfgrass roots from contacting residual chemicals potentially present at greater depth. Area H was not surveyed because it is mostly covered by asphalt/concrete pavement or buildings and the small open area located on the western side of Area H is covered by compacted soil that is virtually devoid of vegetation and is not expected to support earthworm populations. Ecological exposure Areas A and E are covered by 12 inches of clean sandy loam soil that was placed within the past 10 years. Sample locations are also shown on Figure D-1-1.

3.0 RESULTS AND DISCUSSION

The liquid extraction sampling was conducted on September 23, 2010, between 11:30 a.m. and 1:45 p.m. for Areas A and F. The weather was cool and rainy. The liquid extraction sampling for Areas B, C, F, and G and hand excavation sampling at Areas A and E were conducted on September 24, 2010, between 7:00 a.m. and 11:50 a.m. The weather was cool and overcast. Results of the survey are shown in Tables D-1-1 and D-1-2.

Results of the liquid extraction sampling (Table D-1-1) show that earthworms were present in all 23 sample locations. Anecic species (e.g., *Lumbricus terrestris*) and endogenic species (*Lumbricus rubellus, Aporrectodea calignosa, Aporrectodea longa, and Octolasion cyaneum* are endogenic species common to western Washington) were present in all six ecological exposure areas. Neither crane fly larvae nor adults were observed. According to Jackson and Campbell (1975), crane flies typically emerge from the soil in Western Washington in late August through early September. So it is likely the crane flies had already emerged from the ground prior to the survey. This may explain why crane flies were not observed during the survey. Pot worms (family Enchytraeidae) were observed at several sample locations. Pot worms are very small white worms that are difficult to see with the naked eye and are too small

to be fed upon by birds and mammals. Small slugs were observed at a few sample locations and a single caterpillar was observed at one sample location.

In samples collected on September 23, mature night crawlers (*L. terrestris*) emerged relatively quickly from the saturated soil. However, in samples collected on September 24, mature night crawlers typically emerged after other earthworms (immature *L. terrestris* and endogenic species). The soil was more saturated on September 23 than on September 24 due to heavy rain. Two possible explanations for the delayed emergence of night crawlers observed on September 24 are that it took more time for the mustard solution to reach these earthworms in their deeper burrows, or possibly the night crawlers in areas sampled on September 24 simply lived in deeper burrows.

All earthworms collected appeared healthy and did not show any signs of chemical stress (e.g., lesions).

Results of the hand excavation sampling survey (Table D-1-2) were not useful for delimiting the burrowing depth of earthworms. The sandy loam surface soil covering Areas A and E had very little physical structure and was very friable when disturbed. This severely limited the ability to make visual inspections for earthworm burrows. Turfgrass roots were observed to be concentrated in the upper 6 to 8 inches of soil with a few roots extending to a maximum depth of 10 inches.

4.0 CONCLUSIONS

The primary conclusions of this survey are:

- Diverse and healthy earthworm populations are present in the turfgrass habitat in all six ecological exposure areas surveyed.

- Anecic earthworm species (*L. terrestris*) were found in all six ecological exposure areas surveyed. Anecic species live in permanent, relatively deep vertical burrows. Although it was not possible to confirm the burrowing depth of *L. terrestris* at the Site, they have been reported to burrow to depths in excess of 3 feet.

- Endogenic earthworm species were found in all six ecological exposure areas surveyed. These species create temporary horizontal and relatively shallow vertical burrows.

- Anecic earthworm species, endogenic earthworm species, and turfgrass are exposed to residual chemicals in soil in areas that do not have a 12-inch clean soil cover.

- Anecic earthworm species are likely to be exposed to residual chemicals in soil that occur below a 12-inch clean soil cover.

- Endogenic earthworm species are not likely to be exposed to residual chemicals in soil that occur below a 12-inch clean soil cover.

5.0 REFERENCES

Gunn, A., 1992. The use of mustard to estimate earthworm populations. Pedobiologia 36: 65-67.

Jackson, M.D., and R.L. Campbell, 1975. Biology of the European Crane Fly, *Tipula paludosa* Meigen, in Western Washington. Washington State University, College of Agricultural Research Center, Technical Bulletin 81. 23 pp.

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Table D-1-1 - Gas Works Park Soil Invertebrate Survey Results - Liquid Extraction Sampling Method

Area	Sample Location	Numbers of Invertebrates Observed					Comments
		Total Earthworms	Mature Night Crawlers	Mature Endogenic Earthworms	Immature Earthworms	Other Invertebrates	
A	A-1	11	--	7	4	many pot worms	
	A-2	12	--	4	8	many pot worms; few slugs	
	A-3	19	2	6	12	many pot worms; few slugs	
	A-4	31	--	8	23	some pot worms	
B	B-1	14	3	--	11	some pot worms	several night crawler middens present
	B-2	5	1	--	4	--	
C	C-1	14	2	3	9	some pot worms	several night crawler middens present
	C-2	22	--	5	17	some pot worms	several night crawler middens present
	C-3	19	4	4	11	--	several night crawler middens present
E	E-1	5	--	3	2	--	
	E-2	2	1	--	1	--	
	E-3	6	--	4	2	--	
	E-4	5	--	4	1	some pot worms	several night crawler middens present
	E-5	21	5	--	11	--	
	E-6	4	--	1	3	one caterpillar	several night crawler middens present
F	F-1	3	2	--	1	--	
	F-2	10	2	--	8	--	several night crawler middens present
	F-3	1	--	1	--	--	
G	G-1	6	2	2	2	--	
	G-2	22	--	5	17	--	
	G-3	4	2	--	2	some pot worms	several night crawler middens present
	G-4	16	2	2	12	--	
	G-5	47	--	11	36	--	

Notes: Middens are small piles of night crawler castings (feces) located around the surface opening of their burrows.

Table D-1-2 - Gas Works Park Soil Invertebrate Survey Results - Hand Ecavation Sampling Method

Area	Sample Location	Maximum Earthworm Burrow Depth (inches)	Maximum Turfrass Rooting Depth (inches)	Comments
A	A-2	NA	8	sandy loam soil - upper 0-8" moist and lower 8-12" dry; geogrid reached at 12" depth; most trufgrass roots extend to 6" depth with some extending to 8-10"; adjacent tree lateral roots running along top of geogrid; several worms noted on upper 2" of soil
	A-4	NA	11	sandy loam soil was moist throughout upper 12"; geogrid was reached at 12" depth; most turfgrass roots extend to 8-9" depth with a few extending to 10-11"; earthworms were observed to a depth of 6-7"
E	E-2	NA	11	sandy loam soil was moist throughout upper 12"; geogrid reached at 12" depth; most turfgrass roots extend to 6-8" depth with some extending to 10"
	E-4	NA	10	sandy loam soil was moist throughout upper 12"; geogrid reached at 12" depth; most turfgrass roots extend to 6-8" depth with some extending to 10"
	E-5	NA	10	sandy loam soil was moist throughout upper 12"; geogrid reached at 12" depth; most trufgrass roots extend to 6-8" depth with some extending to 10"

NA - not available

Source: Base map prepared from aerial photo provided by Floyd/Snider, 2010.

Gas Works Park Site
Seattle, Washington

Approximate Sample Locations for the Soil Invertebrate Survey

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Figure
D-1-1

EAL 06/1/11 1733020-067.dwg

ATTACHMENT D-2
ANALYTICAL SOILS DATA USED IN TERRESTRIAL ECOLOGICAL EVALUATION

Table D-2-1 - Analytical Soils Data Used in the Terrestrial Ecological Evaluation

Sample ID	Sampling Date	Depth	Area	Source	Arsenic		Benzo(a)pyrene	
					Conc. (mg/kg)	Qualifier	Conc. (mg/kg)	Qualifier
NWSS-1S	3/26/2004	0-0.3'	A	Parametrix, NW Corner, 2004	6		0.0077	U
NWSS-1D	3/26/2004	2.6-2.8'	A	Parametrix, NW Corner, 2004	7		0.68	
NWSS-2S	3/26/2004	0-0.3'	A	Parametrix, NW Corner, 2004	7		1	
NWSS-2D	3/26/2004	1.3-1.6'	A	Parametrix, NW Corner, 2004	6		0.29	
NWSS-3S	3/26/2004	0-0.3'	A	Parametrix, NW Corner, 2004	6	U	0.028	
NWSS-3D	3/26/2004	2.2-2.5'	A	Parametrix, NW Corner, 2004	7		290	
NWSS-4S	3/26/2004	0-0.3'	A	Parametrix, NW Corner, 2004	6		0.029	
NWSS-4D	3/26/2004	2.3-2.5'	A	Parametrix, NW Corner, 2004	5	U	0.05	
NWSS-5S	3/26/2004	0-0.3'	A	Parametrix, NW Corner, 2004	6		0.21	
NWSS-6S	3/26/2004	0-0.3'	A	Parametrix, NW Corner, 2004	5	U	2.5	
NWSS-7S	3/26/2004	0-0.3'	A	Parametrix, NW Corner, 2004	5	U	0.0072	U
NWSS-8S	3/26/2004	0-0.3'	A	Parametrix, NW Corner, 2004	5	U	0.025	
NWSS-9S	3/26/2004	0-0.3'	A	Parametrix, NW Corner, 2004	6	U	0.076	
NWSS-10S	3/26/2004	0-0.3'	A	Parametrix, NW Corner, 2004	6		0.29	
NWSS-11S	3/26/2004	0-0.3'	A	Parametrix, NW Corner, 2004	12		0.032	
NWSS-12S	3/26/2004	0-0.3'	A	Parametrix, NW Corner, 2004	6		0.078	
EPA1	4/17/1984	0.5'	A	E&E 1984/ Parametrix 1999 CAP	2.9		2.7	
EPA1	4/17/1984	3'	A	E&E 1984/ Parametrix 1999 CAP	2.8		1.798	U
EPA2	4/17/1984	0.5'	A	E&E 1984/ Parametrix 1999 CAP	3.3		16	
EPA2	4/17/1984	3'	A	E&E 1984/ Parametrix 1999 CAP	1.4		0.0714	U
B6	3/15/1985	2"	A	TT 1985 SUPP/ Parametrix 1999 CAP	--		10	
C11	3/15/1985	2"	A	TT 1985 SUPP/ Parametrix 1999 CAP	--		0.04	
D8	3/15/1985	2"	A	TT 1985 SUPP/ Parametrix 1999 CAP	--		0.01	U
S-10	10/23/1997	Surface	A	Parametrix and Key, 1998	10	U	0.0269	
B-35	5/15/1998	2-3'	A	Parametrix and Key, 1998	--		0.1	U
SB 6	9/18/2007	1-2.0'	C	F|S 2008	--		810	
SB 13	9/20/2007	2.5-4.0'	C	F|S 2008	--		510	
SL14	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		1.8	
SL14	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		1.5	
SL14	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		1.9	
SL14	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		1.8	
SL7	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		85	
SL7	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		130	
SL7	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		84	
SL7	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		130	
SL7	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		22	
SL7	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		74	
SL7	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		4.1	
SL7	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		22	
SL7	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		33	
SL7	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		4.7	
SL7	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		7.5	
SL7	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		16	
SL7	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		4.5	
SL8	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		4.2	
SL8	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		3	
SL8	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		3.1	
SL8	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		3.1	
SL8	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		3.4	
SL8	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		5.1	
SL8	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		6	
SL8	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		2.1	
SL8	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		6.2	
SL8	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		2.3	
SL8	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		16	
SL8	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		8.5	
SL8	10/13/2009	0-2"	C	F|S NE Corner Soil Summary Table	--		6.7	
84EPA100	4/2/1984	0.08'	C	EPA 1984/ Parametrix 1999 CAP	--		44	
84EPA200	4/2/1984	0.08'	C	EPA 1984/ Parametrix 1999 CAP	--		63	
84EPA300	4/2/1984	0.08'	C	EPA 1984/ Parametrix 1999 CAP	--		19	
84EPA400	4/2/1984	0.08'	C	EPA 1984/ Parametrix 1999 CAP	--		6.9	
EPA20	4/19/1984	0.5'	C	E&E 1984/ Parametrix 1999 CAP	26.9		20	
EPA20	4/19/1984	3'	C	E&E 1984/ Parametrix 1999 CAP	30.4		0.042	U

Table D-2-1 - Analytical Soils Data Used in the Terrestrial Ecological Evaluation

Sample ID	Sampling Date	Depth	Area	Source	Arsenic		Benzo(a)pyrene	
					Conc. (mg/kg)	Qualifier	Conc. (mg/kg)	Qualifier
EPA21	4/19/1984	0.5'	C	E&E 1984/ Parametrix 1999 CAP	47.5		150	
EPA21	4/19/1984	3'	C	E&E 1984/ Parametrix 1999 CAP	15		0.046	U
EPA22	4/19/1984	0.5'	C	E&E 1984/ Parametrix 1999 CAP	6.1		46	
EPA22	4/19/1984	3'	C	E&E 1984/ Parametrix 1999 CAP	5.5		0.047	U
EPA23	4/19/1984	0.5'	C	E&E 1984/ Parametrix 1999 CAP	4.8		30	
EPA23	4/19/1984	3'	C	E&E 1984/ Parametrix 1999 CAP	3.7		61.436	
EPA24	4/19/1984	0.5'	C	E&E 1984/ Parametrix 1999 CAP	3.7		10	
EPA24	4/19/1984	3'	C	E&E 1984/ Parametrix 1999 CAP	2.7		16.927	
UW9	5/24/1984	1"	C	UW 1984	--		24.3	
B30	3/15/1985	2"	C	TT 1985 SUPP/ Parametrix 1999 CAP	--		2	
B36	3/15/1985	2"	C	TT 1985 SUPP/ Parametrix 1999 CAP	--		16	
C27	3/15/1985	2"	C	TT 1985 SUPP/ Parametrix 1999 CAP	--		0.7	
C37	3/15/1985	2"	C	TT 1985 SUPP/ Parametrix 1999 CAP	--		3.8	
D32	3/15/1985	2"	C	TT 1985 SUPP/ Parametrix 1999 CAP	--		14	
S-1	10/23/1997	Surface	C	Parametrix and Key, 1998	10	U	11	
84EPA31	3/21/1984	0.08'	C/D	EPA 1984/ Parametrix 1999 CAP/Ongerth	5.7		0.76	
MW-09	10/31/1986	2.5'	E	TT 1987, Turney & Goerlitz 1989	--		15	
S-2	10/23/1997	Surface	E	Parametrix and Key, 1998	10.9		7.55	
84EPA33	3/21/1984	0.08'	E	EPA 1984/ Parametrix 1999 CAP/Ongerth	6.7		22	
EPA3	4/17/1984	0.5'	E	E&E 1984/ Parametrix 1999 CAP	4.7		5.1	
EPA8	4/17/1984	0.5'	E	E&E 1984/ Parametrix 1999 CAP	7.6		36	
EPA8	4/17/1984	3'	E	E&E 1984/ Parametrix 1999 CAP	5.7		1.761	
EPA9	4/17/1984	0.5'	E	E&E 1984/ Parametrix 1999 CAP	9		15	
EPA9	4/17/1984	3'	E	E&E 1984/ Parametrix 1999 CAP	9.2		1.234	
EPA10	4/17/1984	0.5'	E	E&E 1984/ Parametrix 1999 CAP	5.4		0.2	U
EPA10	4/17/1984	3'	E	E&E 1984/ Parametrix 1999 CAP	2.5		0.952	U
EPA11	4/17/1984	0.5'	E	E&E 1984/ Parametrix 1999 CAP	3.7		3.6	
EPA11	4/17/1984	3'	E	E&E 1984/ Parametrix 1999 CAP	4		0.915	
EPA12	4/17/1984	0.5'	E	E&E 1984/ Parametrix 1999 CAP	3.5		5	
EPA12	4/17/1984	3'	E	E&E 1984/ Parametrix 1999 CAP	3.5		0.562	JT
EPA13	4/17/1984	0.5'	E	E&E 1984/ Parametrix 1999 CAP	9		100	
EPA13	4/17/1984	3'	E	E&E 1984/ Parametrix 1999 CAP	7.5		3.9	
EPA14	4/18/1984	0.5'	E	E&E 1984/ Parametrix 1999 CAP	5.9		37	
EPA14	4/18/1984	3'	E	E&E 1984/ Parametrix 1999 CAP	2.6		0.0227	U
EPA17	4/19/1984	0.5'	E	E&E 1984/ Parametrix 1999 CAP	3.1		17	
EPA17	4/19/1984	3'	E	E&E 1984/ Parametrix 1999 CAP	3.3		0.0213	U
EPA18	4/19/1984	0.5'	E	E&E 1984/ Parametrix 1999 CAP	7.7		23	
EPA18	4/19/1984	3'	E	E&E 1984/ Parametrix 1999 CAP	8.1		0.044	U
EPA19	4/19/1984	0.5'	E	E&E 1984/ Parametrix 1999 CAP	10.4		190	
EPA19	4/19/1984	3'	E	E&E 1984/ Parametrix 1999 CAP	13.2		0.217	JT
UW6	5/24/1984	1"	E	UW 1984	--		14.3	
E17	3/15/1985	2"	E	TT 1985 SUPP/ Parametrix 1999 CAP	--		0.75	
E25	3/15/1985	2"	E	TT 1985 SUPP/ Parametrix 1999 CAP	--		18	
F10	3/15/1985	2"	E	TT 1985 SUPP/ Parametrix 1999 CAP	--		1.1	
F16	3/15/1985	2"	E	TT 1985 SUPP/ Parametrix 1999 CAP	--		2.9	
F24	3/15/1985	2"	E	TT 1985 SUPP/ Parametrix 1999 CAP	--		6.2	
G19	3/15/1985	2"	E	TT 1985 SUPP/ Parametrix 1999 CAP	--		0.33	
G27	3/15/1985	2"	E	TT 1985 SUPP/ Parametrix 1999 CAP	--		1.3	
H22	3/15/1985	2"	E	TT 1985 SUPP/ Parametrix 1999 CAP	--		1.9	
I29	3/15/1985	2"	E	TT 1985 SUPP/ Parametrix 1999 CAP	--		19	
L28	3/15/1985	2"	E	TT 1985 SUPP/ Parametrix 1999 CAP	--		1.6	
M31	3/15/1985	2"	E	TT 1985 SUPP/ Parametrix 1999 CAP	--		4.7	
N26	3/15/1985	2"	E	TT 1985 SUPP/ Parametrix 1999 CAP	--		4.2	
95EPA33	1/23/1995	0.08'	E	EPA 1995/ Parametrix 1999 CAP	5.69		1.75	
S-4	10/23/1997	Surface	E	Parametrix and Key, 1998	10	U	2.71	
S-9	10/23/1997	Surface	E	Parametrix and Key, 1998	10	U	30.9	
EPA3	4/17/1984	3'	E	E&E 1984/ Parametrix 1999 CAP	4.6		1.905	U
I21	3/15/1985	2"	F	TT 1985 SUPP/ Parametrix 1999 CAP	--		15	
L20	3/15/1985	2"	F	TT 1985 SUPP/ Parametrix 1999 CAP	--		23	
S-5	10/23/1997	Surface	F	Parametrix and Key, 1998	10	U	36	
S-6	10/23/1997	Surface	F	Parametrix and Key, 1998	10	U	8.67	
EPA4	4/17/1984	0.5'	G	E&E 1984/ Parametrix 1999 CAP	5.3		130	
EPA4	4/17/1984	3'	G	E&E 1984/ Parametrix 1999 CAP	2.6		1.86	U

Table D-2-1 - Analytical Soils Data Used in the Terrestrial Ecological Evaluation

Sample ID	Sampling Date	Depth	Area	Source	Arsenic		Benzo(a)pyrene	
					Conc. (mg/kg)	Qualifier	Conc. (mg/kg)	Qualifier
EPA5	4/17/1984	0.5'	G	E&E 1984/ Parametrix 1999 CAP	6		43	
EPA5	4/17/1984	3'	G	E&E 1984/ Parametrix 1999 CAP	2.5		5.04	
EPA6	4/17/1984	0.5'	G	E&E 1984/ Parametrix 1999 CAP	4.1		17	
EPA6	4/17/1984	3'	G	E&E 1984/ Parametrix 1999 CAP	2.4		1.267	
EPA7	4/17/1984	0.5'	G	E&E 1984/ Parametrix 1999 CAP	28.7		180	
EPA7	4/17/1984	3'	G	E&E 1984/ Parametrix 1999 CAP	3		0.046	U
UW21	5/24/1984	1"	G	UW 1984	--		16.3	
H10	3/15/1985	2"	G	TT 1985 SUPP/ Parametrix 1999 CAP	--		13	
I13	3/15/1985	2"	G	TT 1985 SUPP/ Parametrix 1999 CAP	--		7.1	
J14	3/15/1985	2"	G	TT 1985 SUPP/ Parametrix 1999 CAP	--		16	
K17	3/15/1985	2"	G	TT 1985 SUPP/ Parametrix 1999 CAP	--		2.4	
L12	3/15/1985	2"	G	TT 1985 SUPP/ Parametrix 1999 CAP	--		13	
M10	3/15/1985	2"	G	TT 1985 SUPP/ Parametrix 1999 CAP	--		35	
M17	3/15/1985	2"	G	TT 1985 SUPP/ Parametrix 1999 CAP	--		16	
N18	3/15/1985	2"	G	TT 1985 SUPP/ Parametrix 1999 CAP	--		1.9	
P19	3/15/1985	2"	G	TT 1985 SUPP/ Parametrix 1999 CAP	--		16	
MW-10	10/28/1986	3.4'	G	TT 1987, Turney & Goerlitz 1989	--		0.33	U
MW-14	10/29/1986	6'	G	TT 1987, Turney & Goerlitz 1989	--		0.37	U
S-7	10/23/1997	Surface	G	Parametrix and Key, 1998	10	U	11.8	
S-8	10/23/1997	Surface	G	Parametrix and Key, 1998	10	U	4.12	
MW-22	2/1/1998	3'	G	EPRI	--		191	
MW-23	2/1/1998	3'	G	EPRI	--		289	

ATTACHMENT D-3
SUMMARY STATISTICS AND UPPER CONFIDENCE LIMITS
PROUCL OUTPUT FILES

Table D-3-1 - Summary Statistics for Soil Chemcicals of Potential Concern[a]

Ecological Exposure Area	Chemical	Number of Observations	Percent Detect	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	Mean Concentration (mg/kg)	Median Concentration (mg/kg)	Standard Deviation (mg/kg)	Coefficient of Variation (mg/kg)
0- to 6-foot Soil Strata									
A	Arsenic	21	67	1.4	12	5.671	6	2.569	0.453
	Benzo(a)pyrene	25	76	0.025	290	17.06	0.21	66.23	3.883
C	Arsenic	12	92	2.7	47.5	13.82	5.7	14.79	1.07
	Benzo(a)pyrene	54	94	0.7	810	50.07	10	132.9	2.654
E	Arsenic	27	93	2.5	13.2	6.3	5.7	2.882	0.457
	Benzo(a)pyrene	41	85	0.217	190	17.04	4.7	35.33	2.073
F	Arsenic	2	0	N/A	N/A	N/A	N/A	N/A	N/A
	Benzo(a)pyrene	4	100	8.67	36	20.67	19	11.78	0.57
G	Arsenic	10	80	2.4	28.7	6.825	3.55	8.942	1.31
	Benzo(a)pyrene	24	83	1.267	289	50.45	16	80.58	1.597
0- to 1-foot Soil Strata[b]									
C	Arsenic	7	86	3.7	47.5	15.78	5.9	17.84	1.13
	Benzo(a)pyrene	47	100	0.7	150	24.57	7.5	36.61	1.49
F	Arsenic	2	0	N/A	N/A	N/A	N/A	N/A	N/A
	Benzo(a)pyrene	4	100	8.67	36	20.67	19	11.78	0.57
G	Arsenic	6	67	4.1	28.7	11.03	5.65	11.81	1.071
	Benzo(a)pyrene	16	100	1.9	180	32.66	16	49.79	1.524

a Summary statistics were generated using EPA's ProUCL statistical software which uses detected concentrations to generate statistics. ProUCL was run in the "full" mode for data sets with all detected values and in the "with NDs" mode for data sets containing undetected values.

b Summary statistics were not generated for areas A and E in the 0- to 1-foot soil strata because these

N/A - not available because there were no detected concentrations on which to base the statistics.

General UCL Statistics for Data Sets with Non-Detects

User Selected Options

From File	C:\Users\admin\Desktop\GWP soil data 0-6'.wst
Full Precision	OFF
Confidence Coefficient	95%
nber of Bootstrap Operations	2000

Area A - Arsenic (0- to 6-foot soil strata)

General Statistics

Number of Valid Data	21	Number of Detected Data	14
Number of Distinct Detected Data	7	Number of Non-Detect Data	7
		Percent Non-Detects	33.33%

Raw Statistics		**Log-transformed Statistics**	
Minimum Detected	1.4	Minimum Detected	0.336
Maximum Detected	12	Maximum Detected	2.485
Mean of Detected	5.671	Mean of Detected	1.621
SD of Detected	2.569	SD of Detected	0.536
Minimum Non-Detect	5	Minimum Non-Detect	1.609
Maximum Non-Detect	10	Maximum Non-Detect	2.303

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	20
Number treated as Detected	1
Single DL Non-Detect Percentage	95.24%

UCL Statistics

Normal Distribution Test with Detected Values Only		**Lognormal Distribution Test with Detected Values Only**	
Shapiro Wilk Test Statistic	0.869	Shapiro Wilk Test Statistic	0.854
5% Shapiro Wilk Critical Value	0.874	5% Shapiro Wilk Critical Value	0.874
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	4.781	Mean	1.437
SD	2.491	SD	0.527
95% DL/2 (t) UCL	5.718	95% H-Stat (DL/2) UCL	6.379
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	1.434
		SD in Log Scale	0.528
		Mean in Original Scale	4.767
		SD in Original Scale	2.481
		95% Percentile Bootstrap UCL	5.669
		95% BCA Bootstrap UCL	5.829

Gamma Distribution Test with Detected Values Only		**Data Distribution Test with Detected Values Only**	
k star (bias corrected)	3.615	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	1.569		
nu star	101.2		
A-D Test Statistic	1	**Nonparametric Statistics**	
5% A-D Critical Value	0.739	Kaplan-Meier (KM) Method	
K-S Test Statistic	0.739	Mean	4.732
5% K-S Critical Value	0.23	SD	2.512
Data not Gamma Distributed at 5% Significance Level		SE of Mean	0.595
		95% KM (t) UCL	5.758
Assuming Gamma Distribution		95% KM (z) UCL	5.711
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	5.769
Minimum	1.4	95% KM (bootstrap t) UCL	5.792
Maximum	12	95% KM (BCA) UCL	5.747
Mean	5.507	95% KM (Percentile Bootstrap) UCL	5.762
Median	6	95% KM (Chebyshev) UCL	7.327
SD	2.197	97.5% KM (Chebyshev) UCL	8.449
k star	5.128	99% KM (Chebyshev) UCL	10.65
Theta star	1.074		
Nu star	215.4	**Potential UCLs to Use**	
AppChi2	182.4	95% KM (BCA) UCL	5.747
95% Gamma Approximate UCL	6.502		
95% Adjusted Gamma UCL	6.586		

Note: DL/2 is not a recommended method.

Area A - Benzo(a)pyrene (0- to 6-foot soil strata)

General Statistics

Number of Valid Data	25	Number of Detected Data	19

Number of Distinct Detected Data	18	Number of Non-Detect Data	6
		Percent Non-Detects	24.00%

Raw Statistics		**Log-transformed Statistics**	
Minimum Detected	0.025	Minimum Detected	-3.689
Maximum Detected	290	Maximum Detected	5.67
Mean of Detected	17.06	Mean of Detected	-1.104
SD of Detected	66.23	SD of Detected	2.644
Minimum Non-Detect	0.0072	Minimum Non-Detect	-4.934
Maximum Non-Detect	1.798	Maximum Non-Detect	0.587

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	20
Number treated as Detected	5
Single DL Non-Detect Percentage	80.00%

UCL Statistics

Normal Distribution Test with Detected Values Only		**Lognormal Distribution Test with Detected Values Only**	
Shapiro Wilk Test Statistic	0.279	Shapiro Wilk Test Statistic	0.875
5% Shapiro Wilk Critical Value	0.901	5% Shapiro Wilk Critical Value	0.901
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	13	Mean	-1.756
SD	57.82	SD	2.758
95% DL/2 (t) UCL	32.79	95% H-Stat (DL/2) UCL	70.09
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE yields a negative mean		Mean in Log Scale	-2.121
		SD in Log Scale	3.05
		Mean in Original Scale	12.97
		SD in Original Scale	57.83
		95% Percentile Bootstrap UCL	35.92
		95% BCA Bootstrap UCL	47.72

Gamma Distribution Test with Detected Values Only		**Data Distribution Test with Detected Values Only**	
k star (bias corrected)	0.194	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	88		
nu star	7.365		
A-D Test Statistic	2.681	**Nonparametric Statistics**	
5% A-D Critical Value	0.892	Kaplan-Meier (KM) Method	
K-S Test Statistic	0.892	Mean	12.97
5% K-S Critical Value	0.22	SD	56.66
Data not Gamma Distributed at 5% Significance Level		SE of Mean	11.64
		95% KM (t) UCL	32.89
Assuming Gamma Distribution		95% KM (z) UCL	32.12
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	32.76
Minimum	0.000000001	95% KM (bootstrap t) UCL	364.1
Maximum	290	95% KM (BCA) UCL	36.18
Mean	12.96	95% KM (Percentile Bootstrap) UCL	36.02
Median	0.05	95% KM (Chebyshev) UCL	63.72
SD	57.83	97.5% KM (Chebyshev) UCL	85.68
k star	0.112	99% KM (Chebyshev) UCL	128.8
Theta star	115.4		
Nu star	5.615	**Potential UCLs to Use**	
AppChi2	1.446	99% KM (Chebyshev) UCL	128.8
95% Gamma Approximate UCL	50.32		
95% Adjusted Gamma UCL	55.63		

Note: DL/2 is not a recommended method.

Area C - Arsenic (0- to 6-foot soil strata)

General Statistics

Number of Valid Data	12	Number of Detected Data	11
Number of Distinct Detected Data	10	Number of Non-Detect Data	1
		Percent Non-Detects	8.33%

Raw Statistics		**Log-transformed Statistics**	
Minimum Detected	2.7	Minimum Detected	0.993
Maximum Detected	47.5	Maximum Detected	3.861
Mean of Detected	13.82	Mean of Detected	2.155
SD of Detected	14.79	SD of Detected	0.986
Minimum Non-Detect	10	Minimum Non-Detect	2.303
Maximum Non-Detect	10	Maximum Non-Detect	2.303

UCL Statistics

Normal Distribution Test with Detected Values Only		**Lognormal Distribution Test with Detected Values Only**	
Shapiro Wilk Test Statistic	0.757	Shapiro Wilk Test Statistic	0.879
5% Shapiro Wilk Critical Value	0.85	5% Shapiro Wilk Critical Value	0.85
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	13.08	Mean	2.11
SD	14.33	SD	0.953
95% DL/2 (t) UCL	20.51	95% H-Stat (DL/2) UCL	32.09
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE yields a negative mean		Mean in Log Scale	2.113
		SD in Log Scale	0.951
		Mean in Original Scale	13.1
		SD in Original Scale	14.32
		95% Percentile Bootstrap UCL	19.78
		95% BCA Bootstrap UCL	21.54
Gamma Distribution Test with Detected Values Only		**Data Distribution Test with Detected Values Only**	
k star (bias corrected)	0.934	**Data appear Lognormal at 5% Significance Level**	
Theta Star	14.79		
nu star	20.56		
A-D Test Statistic	0.861	**Nonparametric Statistics**	
5% A-D Critical Value	0.748	Kaplan-Meier (KM) Method	
K-S Test Statistic	0.748	Mean	13.05
5% K-S Critical Value	0.261	SD	13.74
Data not Gamma Distributed at 5% Significance Level		SE of Mean	4.162
		95% KM (t) UCL	20.52
Assuming Gamma Distribution		95% KM (z) UCL	19.9
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	20.49
Minimum	2.7	95% KM (bootstrap t) UCL	25.79
Maximum	47.5	95% KM (BCA) UCL	20.88
Mean	13.29	95% KM (Percentile Bootstrap) UCL	20.03
Median	5.9	95% KM (Chebyshev) UCL	31.19
SD	14.22	97.5% KM (Chebyshev) UCL	39.04
k star	1.006	99% KM (Chebyshev) UCL	54.46
Theta star	13.21		
Nu star	24.14	**Potential UCLs to Use**	
AppChi2	13.96	95% KM (Chebyshev) UCL	31.19
95% Gamma Approximate UCL	22.98		
95% Adjusted Gamma UCL	25.08		

Note: DL/2 is not a recommended method.

Area C - Benzo(a)pyrene (0- to 6-foot soil strata)

General Statistics

Number of Valid Data	54	Number of Detected Data	51
Number of Distinct Detected Data	45	Number of Non-Detect Data	3
		Percent Non-Detects	5.56%
Raw Statistics		**Log-transformed Statistics**	
Minimum Detected	0.7	Minimum Detected	-0.357
Maximum Detected	810	Maximum Detected	6.697
Mean of Detected	50.07	Mean of Detected	2.477
SD of Detected	132.9	SD of Detected	1.601
Minimum Non-Detect	0.042	Minimum Non-Detect	-3.17
Maximum Non-Detect	0.047	Maximum Non-Detect	-3.058
Note: Data have multiple DLs - Use of KM Method is recommended		Number treated as Non-Detect	3
For all methods (except KM, DL/2, and ROS Methods),		Number treated as Detected	51
Observations < Largest ND are treated as NDs		Single DL Non-Detect Percentage	5.56%

UCL Statistics

Normal Distribution Test with Detected Values Only		**Lognormal Distribution Test with Detected Values Only**	
Lilliefors Test Statistic	0.355	Lilliefors Test Statistic	0.0844
5% Lilliefors Critical Value	0.124	5% Lilliefors Critical Value	0.124
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	47.29	Mean	2.129
SD	129.6	SD	2.127

95% DL/2 (t) UCL	76.8	95% H-Stat (DL/2) UCL	138.6
Maximum Likelihood Estimate(MLE) Method		Log ROS Method	
Mean	42.16	Mean in Log Scale	2.268
SD	133	SD in Log Scale	1.782
95% MLE (t) UCL	72.47	Mean in Original Scale	47.3
95% MLE (Tiku) UCL	69.52	SD in Original Scale	129.5
		95% Percentile Bootstrap UCL	79.94
		95% BCA Bootstrap UCL	96.32

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	0.436
Theta Star	114.7
nu star	44.5
A-D Test Statistic	2.96
5% A-D Critical Value	0.827
K-S Test Statistic	0.827
5% K-S Critical Value	0.132

Data not Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data	
Minimum	0.000000001
Maximum	810
Mean	47.28
Median	8
SD	129.6
k star	0.262
Theta star	180.7
Nu star	28.25
AppChi2	17.12
95% Gamma Approximate UCL	78.01
95% Adjusted Gamma UCL	79.11

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only

Data appear Lognormal at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method	
Mean	47.32
SD	128.3
SE of Mean	17.64
95% KM (t) UCL	76.85
95% KM (z) UCL	76.33
95% KM (jackknife) UCL	76.83
95% KM (bootstrap t) UCL	148.6
95% KM (BCA) UCL	79.72
95% KM (Percentile Bootstrap) UCL	79.26
95% KM (Chebyshev) UCL	124.2
97.5% KM (Chebyshev) UCL	157.5
99% KM (Chebyshev) UCL	222.8

Potential UCLs to Use

97.5% KM (Chebyshev) UCL	157.5

Area E - Arsenic (0- to 6-foot soil strata)

General Statistics

Number of Valid Data	27	Number of Detected Data	25
Number of Distinct Detected Data	23	Number of Non-Detect Data	2
		Percent Non-Detects	7.41%

Raw Statistics

Minimum Detected	2.5
Maximum Detected	13.2
Mean of Detected	6.3
SD of Detected	2.882
Minimum Non-Detect	10
Maximum Non-Detect	10

Log-transformed Statistics

Minimum Detected	0.916
Maximum Detected	2.58
Mean of Detected	1.737
SD of Detected	0.473
Minimum Non-Detect	2.303
Maximum Non-Detect	2.303

UCL Statistics

Normal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.943
5% Shapiro Wilk Critical Value	0.918

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

DL/2 Substitution Method	
Mean	6.203
SD	2.79
95% DL/2 (t) UCL	7.119
Maximum Likelihood Estimate(MLE) Method	
Mean	11.9
SD	1.219
95% MLE (t) UCL	12.3
95% MLE (Tiku) UCL	13.07

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	4.402
Theta Star	1.431
nu star	220.1

Lognormal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.963
5% Shapiro Wilk Critical Value	0.918

Data appear Lognormal at 5% Significance Level

Assuming Lognormal Distribution

DL/2 Substitution Method			
Mean	1.727		
SD	0.456		
95% H-Stat (DL/2) UCL	8.265		
Log ROS Method			
Mean in Log Scale	1.73		
SD in Log Scale	0.458		
Mean in Original Scale	6.225		
SD in Original Scale	2.795		
95% Percentile Bootstrap UCL	7.137		
95% BCA Bootstrap UCL	7.137		

Data Distribution Test with Detected Values Only

Data appear Normal at 5% Significance Level

A-D Test Statistic	0.318	**Nonparametric Statistics**	
5% A-D Critical Value	0.747	Kaplan-Meier (KM) Method	
K-S Test Statistic	0.747	Mean	6.247
5% K-S Critical Value	0.175	SD	2.786
Data appear Gamma Distributed at 5% Significance Level		SE of Mean	0.56
		95% KM (t) UCL	7.203
Assuming Gamma Distribution		95% KM (z) UCL	7.169
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	7.203
Minimum	2.5	95% KM (bootstrap t) UCL	7.229
Maximum	13.2	95% KM (BCA) UCL	7.232
Mean	6.313	95% KM (Percentile Bootstrap) UCL	7.211
Median	5.7	95% KM (Chebyshev) UCL	8.69
SD	2.788	97.5% KM (Chebyshev) UCL	9.747
k star	4.727	99% KM (Chebyshev) UCL	11.82
Theta star	1.336		
Nu star	255.2	**Potential UCLs to Use**	
AppChi2	219.3	95% KM (t) UCL	7.203
95% Gamma Approximate UCL	7.349	95% KM (Percentile Bootstrap) UCL	7.211
95% Adjusted Gamma UCL	7.421		

Note: DL/2 is not a recommended method.

Area E - Benzo(a)pyrene (0- to 6-foot soil strata)

General Statistics

Number of Valid Data	41	Number of Detected Data	35
Number of Distinct Detected Data	34	Number of Non-Detect Data	6
		Percent Non-Detects	14.63%

Raw Statistics		**Log-transformed Statistics**	
Minimum Detected	0.217	Minimum Detected	-1.528
Maximum Detected	190	Maximum Detected	5.247
Mean of Detected	17.04	Mean of Detected	1.641
SD of Detected	35.33	SD of Detected	1.594
Minimum Non-Detect	0.0213	Minimum Non-Detect	-3.849
Maximum Non-Detect	1.905	Maximum Non-Detect	0.644

Note: Data have multiple DLs - Use of KM Method is recommended		Number treated as Non-Detect	18
For all methods (except KM, DL/2, and ROS Methods),		Number treated as Detected	23
Observations < Largest ND are treated as NDs		Single DL Non-Detect Percentage	43.90%

UCL Statistics

Normal Distribution Test with Detected Values Only		**Lognormal Distribution Test with Detected Values Only**	
Shapiro Wilk Test Statistic	0.486	Shapiro Wilk Test Statistic	0.982
5% Shapiro Wilk Critical Value	0.934	5% Shapiro Wilk Critical Value	0.934
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	14.59	Mean	1.012
SD	33.12	SD	2.235
95% DL/2 (t) UCL	23.3	95% H-Stat (DL/2) UCL	136.3
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE yields a negative mean		Mean in Log Scale	1.169
		SD in Log Scale	1.885
		Mean in Original Scale	14.59
		SD in Original Scale	33.12
		95% Percentile Bootstrap UCL	23.35
		95% BCA Bootstrap UCL	28

Gamma Distribution Test with Detected Values Only		**Data Distribution Test with Detected Values Only**	
k star (bias corrected)	0.501	**Data appear Lognormal at 5% Significance Level**	
Theta Star	34		
nu star	35.08		
A-D Test Statistic	1.157	**Nonparametric Statistics**	
5% A-D Critical Value	0.81	Kaplan-Meier (KM) Method	
K-S Test Statistic	0.81	Mean	14.6
5% K-S Critical Value	0.157	SD	32.71
Data not Gamma Distributed at 5% Significance Level		SE of Mean	5.183
		95% KM (t) UCL	23.33
Assuming Gamma Distribution		95% KM (z) UCL	23.13
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	23.3
Minimum	0.000000001	95% KM (bootstrap t) UCL	38.8
Maximum	190	95% KM (BCA) UCL	24.13

Mean	14.55	95% KM (Percentile Bootstrap) UCL	23.89
Median	3.6	95% KM (Chebyshev) UCL	37.19
SD	33.14	97.5% KM (Chebyshev) UCL	46.97
k star	0.178	99% KM (Chebyshev) UCL	66.17
Theta star	81.77		
Nu star	14.59	**Potential UCLs to Use**	
AppChi2	6.976	97.5% KM (Chebyshev) UCL	46.97
95% Gamma Approximate UCL	30.42		
95% Adjusted Gamma UCL	31.29		

Note: DL/2 is not a recommended method.

Area F - Arsenic (0- to 6-soil strata)

General Statistics

Number of Valid Data	2	Number of Detected Data	0
Number of Distinct Detected Data	0	Number of Non-Detect Data	2
		Percent Non-Detects	100.00%

Warning: This data set only has 2 observations!
Data set is too small to compute reliable and meaningful statistics and estimates!
The data set for variable F-As was not processed!

It is suggested to collect at least 8 to 10 observations before using these statistical methods!
If possible, compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Area G - Arsenic (0- to 6-foot soil strata)

General Statistics

Number of Valid Data	10	Number of Detected Data	8
Number of Distinct Detected Data	8	Number of Non-Detect Data	2
		Percent Non-Detects	20.00%

Raw Statistics		**Log-transformed Statistics**	
Minimum Detected	2.4	Minimum Detected	0.875
Maximum Detected	28.7	Maximum Detected	3.357
Mean of Detected	6.825	Mean of Detected	1.509
SD of Detected	8.942	SD of Detected	0.824
Minimum Non-Detect	10	Minimum Non-Detect	2.303
Maximum Non-Detect	10	Maximum Non-Detect	2.303

Warning: There are only 8 Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough tp draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

UCL Statistics

Normal Distribution Test with Detected Values Only		**Lognormal Distribution Test with Detected Values Only**	
Shapiro Wilk Test Statistic	0.551	Shapiro Wilk Test Statistic	0.775
5% Shapiro Wilk Critical Value	0.818	5% Shapiro Wilk Critical Value	0.818
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	6.46	Mean	1.529
SD	7.924	SD	0.728
95% DL/2 (t) UCL	11.05	95% H-Stat (DL/2) UCL	20.03
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	1.475
		SD in Log Scale	0.746
		Mean in Original Scale	6.264
		SD in Original Scale	7.996
		95% Percentile Bootstrap UCL	11.09
		95% BCA Bootstrap UCL	13.8

Gamma Distribution Test with Detected Values Only		**Data Distribution Test with Detected Values Only**	
k star (bias corrected)	0.932	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	7.323		
nu star	14.91		
A-D Test Statistic	1.12	**Nonparametric Statistics**	
5% A-D Critical Value	0.73	Kaplan-Meier (KM) Method	
K-S Test Statistic	0.73	Mean	6.2

5% K-S Critical Value	0.3	SD	7.609
Data not Gamma Distributed at 5% Significance Level		SE of Mean	2.583
		95% KM (t) UCL	10.93
Assuming Gamma Distribution		95% KM (z) UCL	10.45
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	10.87
Minimum	2.4	95% KM (bootstrap t) UCL	25.68
Maximum	28.7	95% KM (BCA) UCL	11.26
Mean	6.814	95% KM (Percentile Bootstrap) UCL	10.99
Median	4.7	95% KM (Chebyshev) UCL	17.46
SD	7.89	97.5% KM (Chebyshev) UCL	22.33
k star	1.231	99% KM (Chebyshev) UCL	31.9
Theta star	5.536		
Nu star	24.62	**Potential UCLs to Use**	
AppChi2	14.32	95% KM (BCA) UCL	11.26
95% Gamma Approximate UCL	11.71		
95% Adjusted Gamma UCL	12.93		

Note: DL/2 is not a recommended method.

Area G - Benzo(a)pyrene (o- to 6-foot soil strata)

General Statistics

Number of Valid Data	24	Number of Detected Data	20
Number of Distinct Detected Data	17	Number of Non-Detect Data	4
		Percent Non-Detects	16.67%

Raw Statistics		**Log-transformed Statistics**	
Minimum Detected	1.267	Minimum Detected	0.237
Maximum Detected	289	Maximum Detected	5.666
Mean of Detected	50.45	Mean of Detected	2.829
SD of Detected	80.58	SD of Detected	1.537
Minimum Non-Detect	0.046	Minimum Non-Detect	-3.079
Maximum Non-Detect	1.86	Maximum Non-Detect	0.621

Note: Data have multiple DLs - Use of KM Method is recommended		Number treated as Non-Detect	5
For all methods (except KM, DL/2, and ROS Methods),		Number treated as Detected	19
Observations < Largest ND are treated as NDs		Single DL Non-Detect Percentage	20.83%

UCL Statistics

Normal Distribution Test with Detected Values Only		**Lognormal Distribution Test with Detected Values Only**	
Shapiro Wilk Test Statistic	0.634	Shapiro Wilk Test Statistic	0.945
5% Shapiro Wilk Critical Value	0.905	5% Shapiro Wilk Critical Value	0.905
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	42.09	Mean	2.052
SD	75.69	SD	2.324
95% DL/2 (t) UCL	68.57	95% H-Stat (DL/2) UCL	288.2
Maximum Likelihood Estimate(MLE) Method		Log ROS Method	
Mean	29.86	Mean in Log Scale	2.259
SD	86.87	SD in Log Scale	1.911
95% MLE (t) UCL	60.25	Mean in Original Scale	42.13
95% MLE (Tiku) UCL	59.83	SD in Original Scale	75.66
		95% Percentile Bootstrap UCL	68.87
		95% BCA Bootstrap UCL	76.28

Gamma Distribution Test with Detected Values Only		**Data Distribution Test with Detected Values Only**	
k star (bias corrected)	0.518	**Data appear Lognormal at 5% Significance Level**	
Theta Star	97.38		
nu star	20.72		
A-D Test Statistic	1.231	**Nonparametric Statistics**	
5% A-D Critical Value	0.796	Kaplan-Meier (KM) Method	
K-S Test Statistic	0.796	Mean	42.25
5% K-S Critical Value	0.204	SD	74.01
Data not Gamma Distributed at 5% Significance Level		SE of Mean	15.5
		95% KM (t) UCL	68.81
Assuming Gamma Distribution		95% KM (z) UCL	67.74
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	68.61
Minimum	0.000000001	95% KM (bootstrap t) UCL	89.83
Maximum	289	95% KM (BCA) UCL	71.08
Mean	42.04	95% KM (Percentile Bootstrap) UCL	68.17
Median	13	95% KM (Chebyshev) UCL	109.8
SD	75.72	97.5% KM (Chebyshev) UCL	139
k star	0.166	99% KM (Chebyshev) UCL	196.5

Theta star	253.5		
Nu star	7.961	**Potential UCLs to Use**	
AppChi2	2.712	99% KM (Chebyshev) UCL	196.5
95% Gamma Approximate UCL	123.4		
95% Adjusted Gamma UCL	133.8		

Note: DL/2 is not a recommended method.

General UCL Statistics for Full Data Sets

User Selected Options

From File	C:\Users\admin\Desktop\GWP soil data 0-6'.wst
Full Precision	OFF
Confidence Coefficient	95%
nber of Bootstrap Operations	2000

Area F - Benzo(a)pyrene (0- to 6-foot soil strata)

General Statistics

Number of Valid Observations 4 Number of Distinct Observations 4

Warning: This data set only has 4 observations!
Data set is too small to compute reliable and meaningful statistics and estimates!
The data set for variable F-BaP was not processed!

It is suggested to collect at least 8 to 10 observations before using these statistical methods!
If possible, compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

General UCL Statistics for Data Sets with Non-Detects

User Selected Options

From File	C:\Users\admin\Desktop\GWP soil data 0-1'.wst
Full Precision	OFF
Confidence Coefficient	95%
nber of Bootstrap Operations	2000

Area C - Arsenic (0- to 1-foot soil strata)

General Statistics

Number of Valid Data	7	Number of Detected Data	6
Number of Distinct Detected Data	6	Number of Non-Detect Data	1
		Percent Non-Detects	14.29%

Raw Statistics		**Log-transformed Statistics**	
Minimum Detected	3.7	Minimum Detected	1.308
Maximum Detected	47.5	Maximum Detected	3.861
Mean of Detected	15.78	Mean of Detected	2.263
SD of Detected	17.84	SD of Detected	1.047
Minimum Non-Detect	10	Minimum Non-Detect	2.303
Maximum Non-Detect	10	Maximum Non-Detect	2.303

Warning: There are only 6 Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough tp draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

UCL Statistics

Normal Distribution Test with Detected Values Only		**Lognormal Distribution Test with Detected Values Only**	
Shapiro Wilk Test Statistic	0.744	Shapiro Wilk Test Statistic	0.828
5% Shapiro Wilk Critical Value	0.788	5% Shapiro Wilk Critical Value	0.788
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	14.24	Mean	2.17
SD	16.79	SD	0.988
95% DL/2 (t) UCL	26.57	95% H-Stat (DL/2) UCL	79.18
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	2.19
		SD in Log Scale	0.975
		Mean in Original Scale	14.35
		SD in Original Scale	16.72
		95% Percentile Bootstrap UCL	23.7
		95% BCA Bootstrap UCL	29.31

Gamma Distribution Test with Detected Values Only		**Data Distribution Test with Detected Values Only**	
k star (bias corrected)	0.684	**Data appear Lognormal at 5% Significance Level**	
Theta Star	23.07		
nu star	8.211		
A-D Test Statistic	0.716	**Nonparametric Statistics**	
5% A-D Critical Value	0.713	Kaplan-Meier (KM) Method	
K-S Test Statistic	0.713	Mean	14.25
5% K-S Critical Value	0.34	SD	15.54
Data not Gamma Distributed at 5% Significance Level		SE of Mean	6.437
		95% KM (t) UCL	26.76
Assuming Gamma Distribution		95% KM (z) UCL	24.84
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	26.59
Minimum	3.7	95% KM (bootstrap t) UCL	165.7
Maximum	47.5	95% KM (BCA) UCL	23.79
Mean	15.02	95% KM (Percentile Bootstrap) UCL	23.54
Median	6.1	95% KM (Chebyshev) UCL	42.31
SD	16.41	97.5% KM (Chebyshev) UCL	54.45
k star	0.834	99% KM (Chebyshev) UCL	78.3
Theta star	18.02		
Nu star	11.67	**Potential UCLs to Use**	
AppChi2	5.01	97.5% KM (Chebyshev) UCL	54.45
95% Gamma Approximate UCL	34.98		
95% Adjusted Gamma UCL	46.4		

Warning: Recommended UCL exceeds the maximum observation

Note: DL/2 is not a recommended method.

Area F - Arsenic (0- to 1-foot soil strata)

General Statistics

Number of Valid Data	2	Number of Detected Data	0
Number of Distinct Detected Data	0	Number of Non-Detect Data	2
		Percent Non-Detects	100.00%

Warning: This data set only has 2 observations!
Data set is too small to compute reliable and meaningful statistics and estimates!
The data set for variable F-As was not processed!

It is suggested to collect at least 8 to 10 observations before using these statistical methods!
If possible, compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Area G - Arsenic (0- to 1-foot soil strata)

General Statistics

Number of Valid Data	6	Number of Detected Data	4
Number of Distinct Detected Data	4	Number of Non-Detect Data	2
		Percent Non-Detects	33.33%

Raw Statistics		**Log-transformed Statistics**	
Minimum Detected	4.1	Minimum Detected	1.411
Maximum Detected	28.7	Maximum Detected	3.357
Mean of Detected	11.03	Mean of Detected	2.057
SD of Detected	11.81	SD of Detected	0.881
Minimum Non-Detect	10	Minimum Non-Detect	2.303
Maximum Non-Detect	10	Maximum Non-Detect	2.303

Warning: There are only 4 Distinct Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough tp draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

UCL Statistics

Normal Distribution Test with Detected Values Only		**Lognormal Distribution Test with Detected Values Only**	
Shapiro Wilk Test Statistic	0.693	Shapiro Wilk Test Statistic	0.792
5% Shapiro Wilk Critical Value	0.748	5% Shapiro Wilk Critical Value	0.748
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	9.017	Mean	1.908
SD	9.662	SD	0.721
95% DL/2 (t) UCL	16.97	95% H-Stat (DL/2) UCL	48.81

Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	1.94
		SD in Log Scale	0.736
		Mean in Original Scale	9.282
		SD in Original Scale	9.607
		95% Percentile Bootstrap UCL	16.78
		95% BCA Bootstrap UCL	20.68

Gamma Distribution Test with Detected Values Only		**Data Distribution Test with Detected Values Only**	
k star (bias corrected)	0.567	**Data appear Lognormal at 5% Significance Level**	
Theta Star	19.43		
nu star	4.539		
A-D Test Statistic	0.683	**Nonparametric Statistics**	
5% A-D Critical Value	0.662	Kaplan-Meier (KM) Method	
K-S Test Statistic	0.662	Mean	9.061
5% K-S Critical Value	0.399	SD	8.812
Data not Gamma Distributed at 5% Significance Level		SE of Mean	4.163
		95% KM (t) UCL	17.45
Assuming Gamma Distribution		95% KM (z) UCL	15.91
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	17.04
Minimum	4.1	95% KM (bootstrap t) UCL	78.47
Maximum	28.7	95% KM (BCA) UCL	17.03
Mean	10.83	95% KM (Percentile Bootstrap) UCL	16.88
Median	6.721	95% KM (Chebyshev) UCL	27.21
SD	9.345	97.5% KM (Chebyshev) UCL	35.06
k star	1.214	99% KM (Chebyshev) UCL	50.48
Theta star	8.917		
Nu star	14.57	**Potential UCLs to Use**	
AppChi2	6.962	95% KM (BCA) UCL	17.03
95% Gamma Approximate UCL	22.65		
95% Adjusted Gamma UCL	N/A		

Note: DL/2 is not a recommended method.

General UCL Statistics for Full Data Sets

User Selected Options

From File	C:\Users\admin\Desktop\GWP soil data 0-1'.wst
Full Precision	OFF
Confidence Coefficient	95%
nber of Bootstrap Operations	2000

Area C - Benzo(a)pyrene (0- to 1-foot soil strata)

General Statistics

Number of Valid Observations 47 Number of Distinct Observations 41

Raw Statistics		**Log-transformed Statistics**	
Minimum	0.7	Minimum of Log Data	-0.357
Maximum	150	Maximum of Log Data	5.011
Mean	24.57	Mean of log Data	2.265
Median	7.5	SD of log Data	1.409
SD	36.61		
Coefficient of Variation	1.49		
Skewness	2.176		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.659	Shapiro Wilk Test Statistic	0.96
Shapiro Wilk Critical Value	0.946	Shapiro Wilk Critical Value	0.946
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	33.54	95% H-UCL	46.44
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	53.93
95% Adjusted-CLT UCL	35.17	97.5% Chebyshev (MVUE) UCL	66.47
95% Modified-t UCL	33.82	99% Chebyshev (MVUE) UCL	91.08
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.624	**Data appear Lognormal at 5% Significance Level**	
Theta Star	39.36		
nu star	58.69		
Approximate Chi Square Value (.05)	42.08	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0449	95% CLT UCL	33.36
Adjusted Chi Square Value	41.63	95% Jackknife UCL	33.54
		95% Standard Bootstrap UCL	33.42

Anderson-Darling Test Statistic	1.573	95% Bootstrap-t UCL	35.83
Anderson-Darling 5% Critical Value	0.8	95% Hall's Bootstrap UCL	34.34
Kolmogorov-Smirnov Test Statistic	0.152	95% Percentile Bootstrap UCL	33.53
Kolmogorov-Smirnov 5% Critical Value	0.135	95% BCA Bootstrap UCL	34.8
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	47.85
		97.5% Chebyshev(Mean, Sd) UCL	57.93
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	77.71
95% Approximate Gamma UCL	34.28		
95% Adjusted Gamma UCL	34.64		
Potential UCL to Use		Use 95% H-UCL	46.44

Area F - Benzo(a)pyrene (0- to 1-foot soil strata)

General Statistics

Number of Valid Observations 4 — Number of Distinct Observations 4

Warning: This data set only has 4 observations!
Data set is too small to compute reliable and meaningful statistics and estimates!
The data set for variable F-BaP was not processed!

It is suggested to collect at least 8 to 10 observations before using these statistical methods!
If possible, compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Area G - Benzo(a)pyrene (0- to 1-foot soil strata)

General Statistics

Number of Valid Observations 16 — Number of Distinct Observations 13

Raw Statistics		**Log-transformed Statistics**	
Minimum	1.9	Minimum of Log Data	0.642
Maximum	180	Maximum of Log Data	5.193
Mean	32.66	Mean of log Data	2.738
Median	16	SD of log Data	1.229
SD	49.79		
Coefficient of Variation	1.524		
Skewness	2.456		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.593	Shapiro Wilk Test Statistic	0.936
Shapiro Wilk Critical Value	0.887	Shapiro Wilk Critical Value	0.887
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	54.48	95% H-UCL	87.14
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	76.64
95% Adjusted-CLT UCL	61.3	97.5% Chebyshev (MVUE) UCL	96.59
95% Modified-t UCL	55.76	99% Chebyshev (MVUE) UCL	135.8
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.687	**Data appear Lognormal at 5% Significance Level**	
Theta Star	47.55		
nu star	21.98		
Approximate Chi Square Value (.05)	12.32	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0335	95% CLT UCL	53.14
Adjusted Chi Square Value	11.51	95% Jackknife UCL	54.48
		95% Standard Bootstrap UCL	52.17
Anderson-Darling Test Statistic	1.076	95% Bootstrap-t UCL	115.4
Anderson-Darling 5% Critical Value	0.773	95% Hall's Bootstrap UCL	152.1
Kolmogorov-Smirnov Test Statistic	0.303	95% Percentile Bootstrap UCL	54.66
Kolmogorov-Smirnov 5% Critical Value	0.223	95% BCA Bootstrap UCL	62.9
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	86.92
		97.5% Chebyshev(Mean, Sd) UCL	110.4
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	156.5
95% Approximate Gamma UCL	58.26		
95% Adjusted Gamma UCL	62.4		
Potential UCL to Use		Use 95% Chebyshev (MVUE) UCL	76.64

ATTACHMENT 4D-4
ProUCL Output

UCL Statistics for Data Sets with Non-Detects

User Selected Options	Cracking Tower Area
Date/Time of Computation	ProUCL 5.110/31/2019 11:40:15 AM
From File	ProUCL_Data_CT_Area(Oct2019)_COI.xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

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General Statistics

Total Number of Observations	8	Number of Distinct Observations	8
		Number of Missing Observations	0
Minimum	0.32	Mean	17.68
Maximum	48.34	Median	12.65
SD	18.63	Std. Error of Mean	6.587
Coefficient of Variation	1.054	Skewness	1.06

Note: Sample size is small (e.g., <10), if data are collected using ISM approach, you should use guidance provided in ITRC Tech Reg Guide on ISM (ITRC, 2012) to compute statistics of interest. For example, you may want to use Chebyshev UCL to estimate EPC (ITRC, 2012). Chebyshev UCL can be computed using the Nonparametric and All UCL Options of ProUCL 5.1

Normal GOF Test

Shapiro Wilk Test Statistic	0.823	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.818	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.267	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.283	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	30.16	95% Adjusted-CLT UCL (Chen-1995)	31.15
		95% Modified-t UCL (Johnson-1978)	30.57

Gamma GOF Test

A-D Test Statistic	0.238	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.745	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.153	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.304	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics			
k hat (MLE)	0.757	k star (bias corrected MLE)	0.557
Theta hat (MLE)	23.34	Theta star (bias corrected MLE)	31.76
nu hat (MLE)	12.12	nu star (bias corrected)	8.906
MLE Mean (bias corrected)	17.68	MLE Sd (bias corrected)	23.69
		Approximate Chi Square Value (0.05)	3.271
Adjusted Level of Significance	0.0195	Adjusted Chi Square Value	2.469
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	48.14	95% Adjusted Gamma UCL (use when n<50)	63.78
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.915	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.818	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.208	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.283	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	-1.14	Mean of logged Data	2.083
Maximum of Logged Data	3.878	SD of logged Data	1.666
Assuming Lognormal Distribution			
95% H-UCL	848.9	90% Chebyshev (MVUE) UCL	65.57
95% Chebyshev (MVUE) UCL	84.5	97.5% Chebyshev (MVUE) UCL	110.8
99% Chebyshev (MVUE) UCL	162.4		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	28.51	95% Jackknife UCL	30.16
95% Standard Bootstrap UCL	27.7	95% Bootstrap-t UCL	44.96
95% Hall's Bootstrap UCL	107.8	95% Percentile Bootstrap UCL	28.9
95% BCA Bootstrap UCL	30.55		
90% Chebyshev(Mean, Sd) UCL	37.44	95% Chebyshev(Mean, Sd) UCL	46.39
97.5% Chebyshev(Mean, Sd) UCL	58.81	99% Chebyshev(Mean, Sd) UCL	83.22
Suggested UCL to Use			
95% Student's-t UCL	30.16		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			

UCL Statistics for Data Sets with Non-Detects

User Selected Options	**Exposed Unstable Bank Areas**
Date/Time of Computation	ProUCL 5.110/31/2019 11:49:54 AM
From File	ProUCL_Data_EUB_Area(Oct2019)_COPC.xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

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General Statistics

Total Number of Observations	12	Number of Distinct Observations	11
		Number of Missing Observations	9
Number of Detects	11	Number of Non-Detects	1
Number of Distinct Detects	10	Number of Distinct Non-Detects	1
Minimum Detect	2.4	Minimum Non-Detect	10
Maximum Detect	25.5	Maximum Non-Detect	10
Variance Detects	43.41	Percent Non-Detects	8.333%
Mean Detects	6.6	SD Detects	6.589
Median Detects	4.1	CV Detects	0.998
Skewness Detects	2.789	Kurtosis Detects	8.331
Mean of Logged Detects	1.626	SD of Logged Detects	0.671

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.616	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.85	Detected Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.27	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.251	Detected Data Not Normal at 5% Significance Level

Detected Data Not Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	6.443	KM Standard Error of Mean	1.846
KM SD	6.066	95% KM (BCA) UCL	9.717
95% KM (t) UCL	9.758	95% KM (Percentile Bootstrap) UCL	9.658
95% KM (z) UCL	9.479	95% KM Bootstrap t UCL	15.89
90% KM Chebyshev UCL	11.98	95% KM Chebyshev UCL	14.49
97.5% KM Chebyshev UCL	17.97	99% KM Chebyshev UCL	24.81

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.876	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.739	Detected Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.235	**Kolmogorov-Smirnov GOF**
5% K-S Critical Value	0.258	Detected data appear Gamma Distributed at 5% Significance Level

Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics on Detected Data Only			
k hat (MLE)	2.066	k star (bias corrected MLE)	1.563
Theta hat (MLE)	3.194	Theta star (bias corrected MLE)	4.222
nu hat (MLE)	45.45	nu star (bias corrected)	34.39
Mean (detects)	6.6		
Gamma ROS Statistics using Imputed Non-Detects			
GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs			
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)			
For such situations, GROS method may yield incorrect values of UCLs and BTVs			
This is especially true when the sample size is small.			
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates			
Minimum	2.4	Mean	6.44
Maximum	25.5	Median	4.35
SD	6.307	CV	0.979
k hat (MLE)	2.206	k star (bias corrected MLE)	1.71
Theta hat (MLE)	2.919	Theta star (bias corrected MLE)	3.766
nu hat (MLE)	52.95	nu star (bias corrected)	41.04
Adjusted Level of Significance (β)	0.029		
Approximate Chi Square Value (41.04, α)	27.36	Adjusted Chi Square Value (41.04, β)	25.67
95% Gamma Approximate UCL (use when n>=50)	9.661	95% Gamma Adjusted UCL (use when n<50)	10.3
Estimates of Gamma Parameters using KM Estimates			
Mean (KM)	6.443	SD (KM)	6.066
Variance (KM)	36.79	SE of Mean (KM)	1.846
k hat (KM)	1.128	k star (KM)	0.902
nu hat (KM)	27.07	nu star (KM)	21.64
theta hat (KM)	5.711	theta star (KM)	7.146
80% gamma percentile (KM)	10.45	90% gamma percentile (KM)	15.22
95% gamma percentile (KM)	20.02	99% gamma percentile (KM)	31.27
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (21.64, α)	12.07	Adjusted Chi Square Value (21.64, β)	10.99
95% Gamma Approximate KM-UCL (use when n>=50)	11.55	95% Gamma Adjusted KM-UCL (use when n<50)	12.68
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.881	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.85	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.196	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.251	Detected Data appear Lognormal at 5% Significance Level	
Detected Data appear Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	6.434	Mean in Log Scale	1.618
SD in Original Scale	6.308	SD in Log Scale	0.641
95% t UCL (assumes normality of ROS data)	9.705	95% Percentile Bootstrap UCL	9.743
95% BCA Bootstrap UCL	11.47	95% Bootstrap t UCL	16.62
95% H-UCL (Log ROS)	9.705		

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	1.613	KM Geo Mean	5.015
KM SD (logged)	0.625	95% Critical H Value (KM-Log)	2.306
KM Standard Error of Mean (logged)	0.193	95% H-UCL (KM -Log)	9.421
KM SD (logged)	0.625	95% Critical H Value (KM-Log)	2.306
KM Standard Error of Mean (logged)	0.193		

DL/2 Statistics			
DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	6.467	Mean in Log Scale	1.625
SD in Original Scale	6.299	SD in Log Scale	0.64
95% t UCL (Assumes normality)	9.732	95% H-Stat UCL	9.761

DL/2 is not a recommended method, provided for comparisons and historical reasons

Nonparametric Distribution Free UCL Statistics

Detected Data appear Approximate Gamma Distributed at 5% Significance Level

Suggested UCL to Use			
95% KM Adjusted Gamma UCL	12.68	95% GROS Adjusted Gamma UCL	10.3

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test

When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.

Recommendations are based upon data size, data distribution, and skewness.

These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).

However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

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General Statistics			
Total Number of Observations	20	Number of Distinct Observations	19
Number of Detects	18	Number of Non-Detects	2
Number of Distinct Detects	17	Number of Distinct Non-Detects	2
Minimum Detect	0.76	Minimum Non-Detect	0.015
Maximum Detect	120	Maximum Non-Detect	0.03
Variance Detects	1382	Percent Non-Detects	10%
Mean Detects	28.29	SD Detects	37.17
Median Detects	9.8	CV Detects	1.314
Skewness Detects	1.735	Kurtosis Detects	2.286
Mean of Logged Detects	2.405	SD of Logged Detects	1.55

Normal GOF Test on Detects Only			
Shapiro Wilk Test Statistic	0.732	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.897	Detected Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.244	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.202	Detected Data Not Normal at 5% Significance Level	

Detected Data Not Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs			
KM Mean	25.46	KM Standard Error of Mean	8.123
KM SD	35.3	95% KM (BCA) UCL	39.44
95% KM (t) UCL	39.5	95% KM (Percentile Bootstrap) UCL	40.01
95% KM (z) UCL	38.82	95% KM Bootstrap t UCL	48.77
90% KM Chebyshev UCL	49.83	95% KM Chebyshev UCL	60.87
97.5% KM Chebyshev UCL	76.19	99% KM Chebyshev UCL	106.3

Gamma GOF Tests on Detected Observations Only		
A-D Test Statistic	0.41	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.787	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.167	**Kolmogorov-Smirnov GOF**
5% K-S Critical Value	0.213	Detected data appear Gamma Distributed at 5% Significance Level
Detected data appear Gamma Distributed at 5% Significance Level		

Gamma Statistics on Detected Data Only			
k hat (MLE)	0.652	k star (bias corrected MLE)	0.58
Theta hat (MLE)	43.41	Theta star (bias corrected MLE)	48.77
nu hat (MLE)	23.46	nu star (bias corrected)	20.88
Mean (detects)	28.29		

Gamma ROS Statistics using Imputed Non-Detects			
GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs			
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)			
For such situations, GROS method may yield incorrect values of UCLs and BTVs			
This is especially true when the sample size is small.			
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates			
Minimum	0.01	Mean	25.46
Maximum	120	Median	7.1
SD	36.22	CV	1.423
k hat (MLE)	0.425	k star (bias corrected MLE)	0.395
Theta hat (MLE)	59.88	Theta star (bias corrected MLE)	64.5
nu hat (MLE)	17.01	nu star (bias corrected)	15.79
Adjusted Level of Significance (β)	0.038		
Approximate Chi Square Value (15.79, α)	7.813	Adjusted Chi Square Value (15.79, β)	7.372
95% Gamma Approximate UCL (use when n>=50)	51.45	95% Gamma Adjusted UCL (use when n<50)	54.53

Estimates of Gamma Parameters using KM Estimates			
Mean (KM)	25.46	SD (KM)	35.3
Variance (KM)	1246	SE of Mean (KM)	8.123
k hat (KM)	0.52	k star (KM)	0.475
nu hat (KM)	20.8	nu star (KM)	19.02
theta hat (KM)	48.95	theta star (KM)	53.55
80% gamma percentile (KM)	41.71	90% gamma percentile (KM)	69.59
95% gamma percentile (KM)	99.57	99% gamma percentile (KM)	173.6

Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (19.02, α)	10.13	Adjusted Chi Square Value (19.02, β)	9.619
95% Gamma Approximate KM-UCL (use when n>=50)	47.8	95% Gamma Adjusted KM-UCL (use when n<50)	50.34
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.961	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.897	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.0985	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.202	Detected Data appear Lognormal at 5% Significance Level	
Detected Data appear Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	25.49	Mean in Log Scale	2.043
SD in Original Scale	36.2	SD in Log Scale	1.843
95% t UCL (assumes normality of ROS data)	39.48	95% Percentile Bootstrap UCL	39.48
95% BCA Bootstrap UCL	43.71	95% Bootstrap t UCL	46.72
95% H-UCL (Log ROS)	231		
Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	1.745	KM Geo Mean	5.725
KM SD (logged)	2.443	95% Critical H Value (KM-Log)	5.117
KM Standard Error of Mean (logged)	0.562	95% H-UCL (KM -Log)	1994
KM SD (logged)	2.443	95% Critical H Value (KM-Log)	5.117
KM Standard Error of Mean (logged)	0.562		
DL/2 Statistics			
DL/2 Normal		**DL/2 Log-Transformed**	
Mean in Original Scale	25.46	Mean in Log Scale	1.71
SD in Original Scale	36.22	SD in Log Scale	2.596
95% t UCL (Assumes normality)	39.46	95% H-Stat UCL	4019
DL/2 is not a recommended method, provided for comparisons and historical reasons			
Nonparametric Distribution Free UCL Statistics			
Detected Data appear Gamma Distributed at 5% Significance Level			
Suggested UCL to Use			
a Adjusted KM-UCL (use when k<=1 and 15 < n < 50 but k<=1)	50.34		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			

UCL Statistics for Data Sets with Non-Detects

User Selected Options	**Limited Use Areas**
Date/Time of Computation	ProUCL 5.110/31/2019 11:41:52 AM
From File	ProUCL_Data_LU_Area(Oct2019)_COI.xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

cPAH TEQ

General Statistics

Total Number of Observations	5	Number of Distinct Observations	5
		Number of Missing Observations	0
Minimum	1.038	Mean	1.766
Maximum	3.764	Median	1.317
SD	1.127	Std. Error of Mean	0.504
Coefficient of Variation	0.638	Skewness	2.133

Note: Sample size is small (e.g., <10), if data are collected using ISM approach, you should use guidance provided in ITRC Tech Reg Guide on ISM (ITRC, 2012) to compute statistics of interest. For example, you may want to use Chebyshev UCL to estimate EPC (ITRC, 2012). Chebyshev UCL can be computed using the Nonparametric and All UCL Options of ProUCL 5.1

Normal GOF Test

Shapiro Wilk Test Statistic	0.683	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.762	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.407	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.343	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	2.841	95% Adjusted-CLT UCL (Chen-1995)	3.109
		95% Modified-t UCL (Johnson-1978)	2.921

Gamma GOF Test

A-D Test Statistic	0.774	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.681	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.386	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.358	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics			
k hat (MLE)	4.303	k star (bias corrected MLE)	1.854
Theta hat (MLE)	0.41	Theta star (bias corrected MLE)	0.952
nu hat (MLE)	43.03	nu star (bias corrected)	18.54
MLE Mean (bias corrected)	1.766	MLE Sd (bias corrected)	1.297
		Approximate Chi Square Value (0.05)	9.786
Adjusted Level of Significance	0.0086	Adjusted Chi Square Value	7.173
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	3.346	95% Adjusted Gamma UCL (use when n<50)	4.566
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.78	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.762	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.354	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.343	Data Not Lognormal at 5% Significance Level	
Data appear Approximate Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	0.0369	Mean of logged Data	0.448
Maximum of Logged Data	1.325	SD of logged Data	0.506
Assuming Lognormal Distribution			
95% H-UCL	3.767	90% Chebyshev (MVUE) UCL	2.895
95% Chebyshev (MVUE) UCL	3.422	97.5% Chebyshev (MVUE) UCL	4.154
99% Chebyshev (MVUE) UCL	5.592		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	2.595	95% Jackknife UCL	2.841
95% Standard Bootstrap UCL	2.5	95% Bootstrap-t UCL	7.445
95% Hall's Bootstrap UCL	7.695	95% Percentile Bootstrap UCL	2.716
95% BCA Bootstrap UCL	2.772		
90% Chebyshev(Mean, Sd) UCL	3.278	95% Chebyshev(Mean, Sd) UCL	3.963
97.5% Chebyshev(Mean, Sd) UCL	4.914	99% Chebyshev(Mean, Sd) UCL	6.782
Suggested UCL to Use			
95% H-UCL	3.767		
Recommended UCL exceeds the maximum observation			
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

UCL Statistics for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.11/31/2020 5:27:01 PM
From File	ProUCL_Data_NE_Area(Oct2019)_COPC_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Arsenic

General Statistics

Total Number of Observations	12	Number of Distinct Observations	11
		Number of Missing Observations	15
Number of Detects	11	Number of Non-Detects	1
Number of Distinct Detects	11	Number of Distinct Non-Detects	1
Minimum Detect	3.7	Minimum Non-Detect	10
Maximum Detect	26.9	Maximum Non-Detect	10
Variance Detects	41.56	Percent Non-Detects	8.333%
Mean Detects	11.95	SD Detects	6.447
Median Detects	10.5	CV Detects	0.539
Skewness Detects	1.21	Kurtosis Detects	1.945
Mean of Logged Detects	2.351	SD of Logged Detects	0.545

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.919	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.85	Detected Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.195	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.251	Detected Data appear Normal at 5% Significance Level

Detected Data appear Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	11.5	KM Standard Error of Mean	1.857
KM SD	6.103	95% KM (BCA) UCL	14.73
95% KM (t) UCL	14.83	95% KM (Percentile Bootstrap) UCL	14.71
95% KM (z) UCL	14.55	95% KM Bootstrap t UCL	15.92
90% KM Chebyshev UCL	17.07	95% KM Chebyshev UCL	19.59
97.5% KM Chebyshev UCL	23.09	99% KM Chebyshev UCL	29.98

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.149	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.733	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.135	**Kolmogorov-Smirnov GOF**
5% K-S Critical Value	0.256	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only			
k hat (MLE)	4.013	k star (bias corrected MLE)	2.979
Theta hat (MLE)	2.979	Theta star (bias corrected MLE)	4.013
nu hat (MLE)	88.28	nu star (bias corrected)	65.54
Mean (detects)	11.95		
Gamma ROS Statistics using Imputed Non-Detects			
GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs			
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)			
For such situations, GROS method may yield incorrect values of UCLs and BTVs			
This is especially true when the sample size is small.			
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates			
Minimum	3.7	Mean	11.44
Maximum	26.9	Median	10.25
SD	6.404	CV	0.56
k hat (MLE)	3.838	k star (bias corrected MLE)	2.934
Theta hat (MLE)	2.979	Theta star (bias corrected MLE)	3.897
nu hat (MLE)	92.12	nu star (bias corrected)	70.42
Adjusted Level of Significance (β)	0.029		
Approximate Chi Square Value (70.42, α)	52.1	Adjusted Chi Square Value (70.42, β)	49.7
95% Gamma Approximate UCL (use when n>=50)	15.46	95% Gamma Adjusted UCL (use when n<50)	16.2
Estimates of Gamma Parameters using KM Estimates			
Mean (KM)	11.5	SD (KM)	6.103
Variance (KM)	37.25	SE of Mean (KM)	1.857
k hat (KM)	3.548	k star (KM)	2.716
nu hat (KM)	85.14	nu star (KM)	65.19
theta hat (KM)	3.24	theta star (KM)	4.232
80% gamma percentile (KM)	16.59	90% gamma percentile (KM)	20.84
95% gamma percentile (KM)	24.83	99% gamma percentile (KM)	33.52
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (65.19, α)	47.61	Adjusted Chi Square Value (65.19, β)	45.33
95% Gamma Approximate KM-UCL (use when n>=50)	15.74	95% Gamma Adjusted KM-UCL (use when n<50)	16.53
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.989	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.85	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.116	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.251	Detected Data appear Lognormal at 5% Significance Level	
Detected Data appear Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	11.47	Mean in Log Scale	2.306
SD in Original Scale	6.376	SD in Log Scale	0.543
95% t UCL (assumes normality of ROS data)	14.77	95% Percentile Bootstrap UCL	14.54
95% BCA Bootstrap UCL	15.42	95% Bootstrap t UCL	15.76
95% H-UCL (Log ROS)	16.66		

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	2.307	KM Geo Mean	10.04
KM SD (logged)	0.528	95% Critical H Value (KM-Log)	2.175
KM Standard Error of Mean (logged)	0.163	95% H-UCL (KM -Log)	16.31
KM SD (logged)	0.528	95% Critical H Value (KM-Log)	2.175
KM Standard Error of Mean (logged)	0.163		
DL/2 Statistics			
DL/2 Normal		**DL/2 Log-Transformed**	
Mean in Original Scale	11.38	Mean in Log Scale	2.29
SD in Original Scale	6.466	SD in Log Scale	0.562
95% t UCL (Assumes normality)	14.73	95% H-Stat UCL	16.84
DL/2 is not a recommended method, provided for comparisons and historical reasons			
Nonparametric Distribution Free UCL Statistics			
Detected Data appear Normal Distributed at 5% Significance Level			
Suggested UCL to Use			
95% KM (t) UCL	14.83		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
cPAHs			
General Statistics			
Total Number of Observations	24	Number of Distinct Observations	24
		Number of Missing Observations	4
Minimum	0.186	Mean	12.05
Maximum	56.26	Median	9.239
SD	13.15	Std. Error of Mean	2.683
Coefficient of Variation	1.091	Skewness	1.809
Normal GOF Test			
Shapiro Wilk Test Statistic	0.808	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.916	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.183	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.177	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	16.65	95% Adjusted-CLT UCL (Chen-1995)	17.52
		95% Modified-t UCL (Johnson-1978)	16.81

Gamma GOF Test			
A-D Test Statistic	0.437	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.781	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.163	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.185	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.786	k star (bias corrected MLE)	0.716
Theta hat (MLE)	15.32	Theta star (bias corrected MLE)	16.83
nu hat (MLE)	37.75	nu star (bias corrected)	34.36
MLE Mean (bias corrected)	12.05	MLE Sd (bias corrected)	14.24
		Approximate Chi Square Value (0.05)	21.95
Adjusted Level of Significance	0.0392	Adjusted Chi Square Value	21.26
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50)	18.86	95% Adjusted Gamma UCL (use when n<50)	19.48
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.925	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.916	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.159	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.177	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	-1.684	Mean of logged Data	1.733
Maximum of Logged Data	4.03	SD of logged Data	1.498
Assuming Lognormal Distribution			
95% H-UCL	48.26	90% Chebyshev (MVUE) UCL	33.78
95% Chebyshev (MVUE) UCL	41.88	97.5% Chebyshev (MVUE) UCL	53.13
99% Chebyshev (MVUE) UCL	75.21		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	16.46	95% Jackknife UCL	16.65
95% Standard Bootstrap UCL	16.23	95% Bootstrap-t UCL	18.15
95% Hall's Bootstrap UCL	20.17	95% Percentile Bootstrap UCL	16.62
95% BCA Bootstrap UCL	17.3		
90% Chebyshev(Mean, Sd) UCL	20.1	95% Chebyshev(Mean, Sd) UCL	23.75
97.5% Chebyshev(Mean, Sd) UCL	28.81	99% Chebyshev(Mean, Sd) UCL	38.75

Suggested UCL to Use			
95% Adjusted Gamma UCL	19.48		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			

	General Statistics on Uncensored Data	
Date/Time of Computation	ProUCL 5.110/31/2019 11:04:05 AM	
User Selected Options	**Cracking Tower Area**	
From File	ProUCL_Data_CT_Area(Oct2019)_COI.xls	
Full Precision	OFF	

From File: ProUCL_Data_CT_Area(Oct2019)_COI.xls

General Statistics for Censored Data Set (with NDs) using Kaplan Meier Method

Variable	NumObs	# Missing	Num Ds	NumNDs	% NDs	Min ND	Max ND	KM Mean	KM Var	KM SD	KM CV
Aroclor 1254	6	0	0	6	100.00%	0.2	0.2	N/A	N/A	N/A	N/A
Aroclor 1260	6	0	0	6	100.00%	0.2	0.2	N/A	N/A	N/A	N/A
Arsenic	8	0	1	7	87.50%	2	10	2.683	2.335	1.528	0.569
Benzene	8	0	0	8	100.00%	0.05	0.05	N/A	N/A	N/A	N/A
Benzo(a)anthracene	8	0	8	0	0.00%	N/A	N/A	10.83	135.1	11.62	1.073
Benzo(a)pyrene	8	0	8	0	0.00%	N/A	N/A	12.89	187.4	13.69	1.062
Benzo(b)fluoranthene	8	0	8	0	0.00%	N/A	N/A	13.15	191	13.82	1.051
Benzo(k)fluoranthene	8	0	8	0	0.00%	N/A	N/A	10.96	163.4	12.78	1.166
cPAH TEQ	8	0	8	0	0.00%	N/A	N/A	17.68	347.1	18.63	1.054
Chrysene	8	0	8	0	0.00%	N/A	N/A	11.83	170.2	13.04	1.103
Dibenzo(a,h)anthracene	8	0	7	1	12.50%	0.1	0.1	1.556	2.894	1.701	1.093
Ethylbenzene	8	0	0	8	100.00%	0.05	0.05	N/A	N/A	N/A	N/A
Fluoranthene	8	0	8	0	0.00%	N/A	N/A	29.08	1103	33.21	1.142
Indeno(1,2,3-cd)pyrene	8	0	8	0	0.00%	N/A	N/A	10.21	210.8	14.52	1.422
thalenes (1 and 2), Total	2	6	2	0	0.00%	N/A	N/A	4.07	6.48	2.546	0.625
Pyrene	8	0	8	0	0.00%	N/A	N/A	42.25	2401	49	1.16
Toluene	6	0	0	6	100.00%	0.05	0.05	N/A	N/A	N/A	N/A
Total PCBs (Aroclor)	6	0	0	6	100.00%	0.2	0.2	N/A	N/A	N/A	N/A
Xylenes (mixed isomers)	6	0	0	6	100.00%	0.05	0.05	N/A	N/A	N/A	N/A

General Statistics for Raw Data Sets using Detected Data Only

Variable	NumObs	# Missing	Minimum	Maximum	Mean	Median	Var	SD	MAD/0.675	Skewness	CV
Aroclor 1254	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aroclor 1260	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Arsenic	1	0	6.1	6.1	6.1	6.1	N/A	N/A	0	N/A	N/A
Benzene	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(a)anthracene	8	0	0.14	32	10.83	8.015	135.1	11.62	10.25	0.991	1.073
Benzo(a)pyrene	8	0	0.24	36	12.89	9.085	187.4	13.69	9.985	1.101	1.062
Benzo(b)fluoranthene	8	0	0.21	35.4	13.15	9.725	191	13.82	11.38	0.993	1.051
Benzo(k)fluoranthene	8	0	0.26	39	10.96	7.4	163.4	12.78	8.673	1.74	1.166
cPAH TEQ	8	0	0.32	48.34	17.68	12.65	347.1	18.63	14.14	1.06	1.054
Chrysene	8	0	0.09	35	11.83	7.515	170.2	13.04	9.489	1.059	1.103
Dibenzo(a,h)anthracene	7	0	0.15	5.57	1.764	1.1	3.455	1.859	0.949	1.755	1.054
Ethylbenzene	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fluoranthene	8	0	0.2	91	29.08	17.56	1103	33.21	24.32	1.065	1.142
Indeno(1,2,3-cd)pyrene	8	0	0.13	44.4	10.21	5.45	210.8	14.52	6.931	2.329	1.422
thalenes (1 and 2), Total	2	6	2.27	5.87	4.07	4.07	6.48	2.546	2.669	N/A	0.625
Pyrene	8	0	0.27	130	42.25	25.8	2401	49	32.25	1.101	1.16
Toluene	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total PCBs (Aroclor)	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Xylenes (mixed isomers)	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	General Statistics on Uncensored Data	
Date/Time of Computation	ProUCL 5.110/31/2019 11:05:36 AM	
User Selected Options	**Limited Use Areas**	
From File	ProUCL_Data_LU_Area(Oct2019)_COI.xls	
Full Precision	OFF	

From File: ProUCL_Data_LU_Area(Oct2019)_COI.xls

General Statistics for Censored Data Set (with NDs) using Kaplan Meier Method

Variable	NumObs	# Missing	Num Ds	NumNDs	% NDs	Min ND	Max ND	KM Mean	KM Var	KM SD	KM CV
Benzo(a)anthracene	3	0	3	0	0.00%	N/A	N/A	1.063	0.662	0.814	0.765
Benzo(a)pyrene	5	0	5	0	0.00%	N/A	N/A	1.336	0.78	0.883	0.661
Benzo(b)fluoranthene	3	0	3	0	0.00%	N/A	N/A	1.277	0.799	0.894	0.7
Benzo(k)fluoranthene	3	0	3	0	0.00%	N/A	N/A	0.56	0.147	0.383	0.684
cPAH TEQ	5	0	5	0	0.00%	N/A	N/A	1.766	1.271	1.127	0.638
Chrysene	3	0	3	0	0.00%	N/A	N/A	1.477	0.948	0.974	0.66
Dibenzo(a,h)anthracene	3	0	1	2	66.67%	0.4	0.4	0.427	0.00142	0.0377	0.0884
Fluoranthene	3	0	3	0	0.00%	N/A	N/A	2.333	4.203	2.05	0.879
Indeno(1,2,3-cd)pyrene	3	0	3	0	0.00%	N/A	N/A	1.7	0.63	0.794	0.467
thalenes (1 and 2), Total	3	0	1	2	66.67%	1	1	1	0	0	N/A
Pyrene	3	0	3	0	0.00%	N/A	N/A	3.933	11.25	3.355	0.853

General Statistics for Raw Data Sets using Detected Data Only

Variable	NumObs	# Missing	Minimum	Maximum	Mean	Median	Var	SD	MAD/0.675	Skewness	CV
Benzo(a)anthracene	3	0	0.53	2	1.063	0.66	0.662	0.814	0.193	1.682	0.765
Benzo(a)pyrene	5	0	0.75	2.9	1.336	0.99	0.78	0.883	0.163	2.12	0.661
Benzo(b)fluoranthene	3	0	0.65	2.3	1.277	0.88	0.799	0.894	0.341	1.604	0.7
Benzo(k)fluoranthene	3	0	0.3	1	0.56	0.38	0.147	0.383	0.119	1.647	0.684
cPAH TEQ	5	0	1.038	3.764	1.766	1.317	1.271	1.127	0.213	2.133	0.638
Chrysene	3	0	0.87	2.6	1.477	0.96	0.948	0.974	0.133	1.715	0.66
Dibenzo(a,h)anthracene	1	0	0.48	0.48	0.48	0.48	N/A	N/A	0	N/A	N/A
Fluoranthene	3	0	1.1	4.7	2.333	1.2	4.203	2.05	0.148	1.727	0.879
Indeno(1,2,3-cd)pyrene	3	0	1.1	2.6	1.7	1.4	0.63	0.794	0.445	1.458	0.467
thalenes (1 and 2), Total	1	0	1	1	1	1	N/A	N/A	0	N/A	N/A
Pyrene	3	0	1.8	7.8	3.933	2.2	11.25	3.355	0.593	1.704	0.853

	General Statistics on Uncensored Data	
Date/Time of Computation	ProUCL 5.110/31/2019 11:00:28 AM	
User Selected Options	**Northeast Corner**	
From File	ProUCL_Data_NE_Area(Oct2019)_COI.xls	
Full Precision	OFF	

From File: ProUCL_Data_NE_Area(Oct2019)_COI.xls

General Statistics for Censored Data Set (with NDs) using Kaplan Meier Method

Variable	NumObs	# Missing	Num Ds	NumNDs	% NDs	Min ND	Max ND	KM Mean	KM Var	KM SD	KM CV
Aroclor 1254	10	17	6	4	40.00%	0.013	0.033	0.141	0.0323	0.18	1.278
Aroclor 1260	10	17	6	4	40.00%	0.031	0.033	0.0764	0.00558	0.0747	0.978
Arsenic	12	15	11	1	8.33%	10	10	11.5	37.25	6.103	0.531
Benzene	4	7	1	3	75.00%	0.0055	0.0064	0.0046	0	0	N/A
Benzo(a)anthracene	24	4	24	0	0.00%	N/A	N/A	5.46	31.13	5.579	1.022
Benzo(a)pyrene	24	4	24	0	0.00%	N/A	N/A	9.322	113.7	10.66	1.144
Benzo(b)fluoranthene	18	10	18	0	0.00%	N/A	N/A	4.226	21.09	4.592	1.087
Benzo(k)fluoranthene	18	10	18	0	0.00%	N/A	N/A	3.229	13.57	3.684	1.141
cPAH TEQ	24	4	24	0	0.00%	N/A	N/A	12.03	173.7	13.18	1.096
Chrysene	24	4	24	0	0.00%	N/A	N/A	9.038	93.83	9.687	1.072
Dibenzo(a,h)anthracene	24	4	16	8	33.33%	0.058	4	3.318	27.96	5.287	1.593
Ethylbenzene	4	7	3	1	25.00%	0.0013	0.0013	0.0048	4.1850E-6	0.00205	0.426
Fluoranthene	24	4	24	0	0.00%	N/A	N/A	12.46	143.6	11.98	0.962
Indeno(1,2,3-cd)pyrene	24	4	24	0	0.00%	N/A	N/A	7.911	105.6	10.28	1.299
m, p-Xylene	1	10	1	0	0.00%	N/A	N/A	N/A	N/A	N/A	N/A
thalenes (1 and 2), Total	23	5	16	7	30.43%	0.058	10	6.789	197.1	14.04	2.068
o-Xylene	1	10	0	1	100.00%	0.0013	0.0013	N/A	N/A	N/A	N/A
Pyrene	24	4	24	0	0.00%	N/A	N/A	18.81	393.9	19.85	1.055
Toluene	3	8	3	0	0.00%	N/A	N/A	0.00517	4.2033E-6	0.00205	0.397
Total PCBs (Aroclor)	10	17	7	3	30.00%	0.031	0.033	0.207	0.0648	0.255	1.228
Xylenes (mixed isomers)	1	10	1	0	0.00%	N/A	N/A	N/A	N/A	N/A	N/A

General Statistics for Raw Data Sets using Detected Data Only

Variable	NumObs	# Missing	Minimum	Maximum	Mean	Median	Var	SD	MAD/0.675	Skewness	CV
Aroclor 1254	6	17	0.042	0.516	0.226	0.139	0.0429	0.207	0.124	0.78	0.917
Aroclor 1260	6	17	0.014	0.2	0.113	0.12	0.00716	0.0846	0.113	-0.121	0.751
Arsenic	11	15	3.7	26.9	11.95	10.5	41.56	6.447	5.189	1.21	0.539
Benzene	1	7	0.0046	0.0046	0.0046	0.0046	N/A	N/A	0	N/A	N/A
Benzo(a)anthracene	24	4	0.1	17.6	5.46	3.8	31.13	5.579	4.589	1.027	1.022
Benzo(a)pyrene	24	4	0.13	46	9.322	6.65	113.7	10.66	8.354	1.953	1.144
Benzo(b)fluoranthene	18	10	0.14	15	4.226	1.5	21.09	4.592	1.987	1.194	1.087
Benzo(k)fluoranthene	18	10	0.14	15	3.229	1.4	13.57	3.684	1.742	2.064	1.141
cPAH TEQ	24	4	0.186	56.26	12.03	9.536	173.7	13.18	11.65	1.793	1.096
Chrysene	24	4	0.17	31	9.038	5.7	93.83	9.687	6.82	1.051	1.072
Dibenzo(a,h)anthracene	16	4	0.12	18.6	4.833	1.7	37.26	6.104	2.187	1.269	1.263
Ethylbenzene	3	7	0.0055	0.0064	0.00597	0.006	2.0333E-7	4.5092E-4	5.9303E-4	-0.331	0.0756
Fluoranthene	24	4	0.28	34.8	12.46	9.35	143.6	11.98	11.27	0.737	0.962
Indeno(1,2,3-cd)pyrene	24	4	0.12	47	7.911	4.91	105.6	10.28	6.056	2.581	1.299
m, p-Xylene	1	10	0.0011	0.0011	0.0011	0.0011	N/A	N/A	0	N/A	N/A
thalenes (1 and 2), Total	16	5	0.249	59.2	9.356	1.4	277.5	16.66	1.706	2.296	1.78
o-Xylene	0	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pyrene	24	4	0.31	56	18.81	11	393.9	19.85	14.01	0.912	1.055
Toluene	3	8	0.0028	0.0064	0.00517	0.0063	4.2033E-6	0.00205	1.4826E-4	-1.727	0.397
Total PCBs (Aroclor)	7	17	0.014	0.708	0.29	0.156	0.0814	0.285	0.211	0.654	0.983
Xylenes (mixed isomers)	1	10	0.0011	0.0011	0.0011	0.0011	N/A	N/A	0	N/A	N/A

ATTACHMENT 4D-5
Simplified Terrestrial Ecological Evaluation: Exposure Analysis Procedure

WAC 173-340-900: Table 749-1. Simplified Terrestrial Ecological Evaluation – Exposure Analysis Procedure under WAC 173-3407492(2)(a)(ii).

Estimate the area of contiguous (connected) undeveloped land on or within 500 feet of any area of the contaminated soil to the nearest ½ acre (1/4 acre if the area is less than 0.5 acre). "Undeveloped land" means land that is not covered by existing buildings, roads, paved areas or other barriers that will prevent wildfire from feeding on plants, earthworms, insects or other food in or on the soil.	
1) From the table below, find the number of points corresponding to the area and enter this number in the box to the right.	
Area (acres) Points 0.25 or less 4 0.5 5 1.0 6 1.5 7 2.0 8 2.5 9 3.0 10 3.5 11 4.0 or more 12	**7***
2) Is this an industrial or commercial property? See the definition in WAC 173-340-200. If yes, enter a score of 3 in the box to the right. If no, enter a score of 1.	**1**
3) Enter a score in the box to the right for the habitat quality of the contaminated soil and surrounding area, using the rating system shown below[b]. (High = 1, Intermediate = 2, Low = 3)	**3**
4) Is the undeveloped land likely to attract wildlife? If yes, enter a score of 1 in the box to the right. If no, enter a score of 2[c].	**1**
5) Are there any of the following soil hazardous substances present: Chlorinated dioxins/furans, PCB mixtures, DDT, DDE, DDD, aldrin, chlordane, dieldrin, endosulfan, endrin, heptachlor, benzene hexachloride, toxaphene, hexachlorobenzene, pentachlorophenol, or pentachlorobenzene? If yes, enter a score of 1 in the box to the right. If no, enter a score of 4.	**4****
Add the numbers in the boxes on lines 2 through 5 and enter this number to the right. If this number is larger than the number in the box on line 1, the simplified TEE may be ended under WAC 173-340-7292(2) (a) (ii).	**9**

*Note: Soils capped under the 1999 Cleanup Action Plan and Consent Decree are not considered undeveloped land. Capped areas, which include Areas A, D, E, and G and part of C, include 0.5 to 4 feet of topsoil underlain by an impermeable low-density polyethylene liner, geotextile, and/ or a compacted gravel layer. In addition, Area B is largely paved or covered with constructed landscape berms that include a layer of organic duff. Area H is paved. Remaining contiguous undeveloped land includes two areas totaling 1.6 acres: Area C (1.0 acres) and Area F (0.52 acres) – (See Figure 4D-4).

**Note: The maximum detected Total PCBs and 4,4'-DDT concentrations in undeveloped land are less than the simplified TEE risk-based soil concentrations from MTCA Table 749-2. None of the other hazardous substances have been detected in undeveloped land. Therefore, a score of 4 was retained.

Reference

Hart Crowser. 2012. Appendix D: Simplified Terrestrial Ecological Evaluation of the Gas Works Park Site (See Attachment 4D-3).

Footnotes: It is expected that this habitat evaluation will be undertaken by an experienced field biologist. If this is not the case, enter a conservative score (1) for questions 3 and 4.

[b] Habitat rating system. Rate the quality of the habitat as high, intermediate, or low based on your professional judgment as a field biologist. The following are suggested factors to consider in making this evaluation:

- Low: Early successional vegetative stands; vegetation predominantly noxious, non-native, exotic plant species or weeds. Areas severely disturbed by human activity, including intensively cultivated croplands. Areas isolated from other habitat used by wildlife.
- High: Area is ecologically significant for one or more of the following reasons: Late successional native plant communities present; relatively high species diversity; used by an uncommon or rare species; priority habitat (as defined by the Washington Department of Fish and Wildlife); part of a larger area of habitat where size or fragmentation may be important for the retention of some species.
- Intermediate: Area does not rate as either high or low.

[c] Indicate "yes" if the area attracts wildlife or is likely to do so. Examples include, birds frequently visit the area to feed, evidence of high use by mammals (tracks, scat, etc…), habitat "island" in an industrial area, unusual features of an area that make it important for feeding animals, heavy use during seasonal migrations, areas adjacent to wildlife corridors (i.e. greenbelts and waterways).

APPENDIX 4E
Identification of Direct Contact and Bioaccumulative Chemicals of Concern in Surface Sediment

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Technical Memorandum

From: Priscilla Tomlinson, Washington State Department of Ecology

To: Lucy McInerney, Washington State Department of Ecology

Date: April 7, 2020

Re: Gas Works Park Site direct contact and bioaccumulative chemicals of concern in surface sediment

This memo describes the screening process for identifying direct contact and bioaccumulative chemicals of concern (COCs) in surface sediment at the Gas Works Park Site (GWPS) in Seattle, Washington. The identification of benthic COCs is discussed in Section 4.2.3.1 of the Remedial Investigation (RI) report.

The facility site identification number for the GWPS is 139 and the cleanup site identification number is 2876.

The process for identifying sediment COCs involved two steps (RI report, Figure 4-2). In the first step, chemicals of potential concern (COPCs) were identified based on sediment chemistry results and background concentrations. In the second step, COPCs were evaluated further by considering protection of humans contacting sediment (RI Report, Figure 4-5) and protection of humans and upper trophic level ecological receptors consuming fish or shellfish (collectively referred to as seafood; RI Report, Figure 4-6).

The screening process used information from Appendix 4C of the RI report, Gas Works Sediment Area Supplement to the Cleanup Standards Document (SCSD) (AECOM et al., 2012).

Step 1: Chemicals of Potential Concern

COPCs were identified as those chemicals with detected concentrations in surface sediment (RI Report, Figure 4-3). Maximum sediment concentrations were obtained from the SCSD, except for carcinogenic PAH toxicity equivalents (cPAH TEQ) which was obtained from Table 5-4 of the RI report.

The following chemicals were detected in GWPS surface sediment (Table 4E-1):

- 25 metals and inorganic chemicals
- Tributyltin
- 7 low molecular weight polycyclic aromatic hydrocarbons (LPAHs) and total LPAHs
- 11 high molecular weight PAHs (HPAHs), total HPAHs, total PAHs, and cPAH TEQ
- 6 phthalates
- 6 phenols
- 8 additional semi-volatile organic chemicals (SVOCs)
- 19 volatile organic chemicals (VOCs)
- 5 pesticides
- 3 Aroclors.

Natural background concentrations for marine sediments are available for nine metals in Table 10-1 of the Sediment Cleanup User's Manual (SCUM). The natural background concentration listed for PCBs is for total congeners, which is not comparable to total Aroclors, so PCBs were not compared to background.

The use of marine sediment background as a proxy for freshwater sediment background introduces some uncertainty, as discussed in Appendix 4A-2. However, the maximum sediment concentration for each of the metals is greater than its natural background concentration (Table 4E-1), so this comparison provided no reason to eliminate any of the metals as a COPC.

All of the chemicals detected in sediment were identified as COPCs.

Step 2: Chemicals of Concern

COPCs were evaluated further by considering the following two endpoints, consistent with the Sediment Management Standards (RI report, Figures 4-5 and 6):

- Protection of human health via direct contact with sediment (direct contact COCs)
- Protection of humans and upper trophic level ecological receptors consuming seafood that has become contaminated via bioaccumulation from sediment (bioaccumulative COCs).

Each of the two endpoints was considered separately.

Direct Contact Chemicals of Concern

Identification of direct contact COCs involved answering the following two questions (RI report, Figure 4-5):

- Does the chemical exceed soil screening levels (SLs) for residential land use?
- Do human health risks from sediment contact exceed target levels?

Residential Screening Levels

This step relied on screening evaluations of sediment data presented in SCSD Table 3-4. In the SCSD table, maximum concentrations detected in sediment are compared with SLs based on MTCA Method B soil direct contact and EPA regional SLs for soil. These SLs are conservative when applied to sediment because they assume exposure on a daily basis in a residential setting.

The results of screening for cancer and noncancer health effects are combined into one column for each of the two sources of SLs in Table 4E-2. If the maximum sediment concentration measured at the GWPS exceeded any of the SLs, the chemical was identified as a preliminary direct contact COC. Otherwise it was eliminated from further consideration as a direct contact COC.

Total cPAH TEQ was not calculated for the SCSD. Each of the individual carcinogenic PAHs exceeded its direct contact SLs, so it was concluded that cPAH TEQ qualified as a preliminary direct contact COC.

Thirteen chemicals that were detected in five percent or fewer of the sediment samples analyzed were not compared with their SLs in SCSD Table 3-4. However, SCUM does not recognize frequency of detection as a factor for eliminating COCs. The maximum detected concentrations of the 13 chemicals, provided in SCSD Table 3-2, were compared to their direct contact SLs, provided in SCSD Table 3-3 (Table 4E-3). The maximum concentration of hexachlorobenzene exceeded its SL based on cancer effects, so it was retained as a preliminary direct contact COC.

A total of 20 chemicals were identified as preliminary direct contact COCs, including four metals, five noncarcinogenic PAHs, cPAH TEQ[1], three SVOCs, four VOCs, two individual Aroclors, and total PCBs (Table 4E-2). These chemicals were evaluated further in the next step.

Sediment Direct Contact Risk Assessment

This step relied on the results of the HHRA presented in Tables 4-13, 4-14, 4-17, and 4-18 of the SCSD. These tables show cancer risks and noncancer hazards for the adult beach play, child beach play, and adult netfishing scenarios. Because the risk assessments used maximum sediment concentrations, they were appropriate for identifying direct contact COCs.

The HHRA in the SCSD used exposure assumptions similar to, but not exactly the same as, default exposure assumptions in SCUM. To evaluate the differences, sediment SLs for three chemicals were calculated consistent with SCUM Equations 9-1a and 9-3 using parameter values for the RME child beach play and adult net fishing scenarios in SCSD Tables 4-5, 4-6, 4-9, and 4-10 (Table 4E-4). The three chemicals were arsenic, tributyltin, and total DDTs. The parameter values for the adult beach play scenario were not compared to SCUM because there is no adult beach play scenario in SCUM.

The SLs calculated per SCSD were compared to the default SLs in SCUM Table 9-3 (Table 4E-5). The child beach play SLs per SCSD were lower (more conservative) than the SLs per SCUM by a factor of 0.6 for the carcinogens arsenic and DDT. Any chemical with a cancer risk greater than 2×10^{-6} for the RME child beach play scenario in SCSD Table 4-13 was considered to be of concern for cancer risk (Table 4E-6).

The child beach play SL per SCSD was lower (more conservative) than the SL per SCUM by a factor of 0.6 for the noncarcinogen tributyltin (Table 4E-5). Any chemical with a noncancer hazard greater than 2 for the RME child beach play scenario in SCSD Table 4-14 was considered to be of concern for noncancer hazard (Table 4E-6).

The adult net fishing SLs per SCSD were higher (less conservative) than the SLs per SCUM by a factor of 6 for the carcinogens arsenic and DDT (Table 4E-5). Any chemical with a cancer risk greater than 2×10^{-7} for the RME adult net fishing scenario in Appendix 4C, Table 4-17 was considered to be of concern for cancer risk (Table 4E-6).

The adult net fishing SL per SCSD was higher (less conservative) than the SL per SCUM by a factor of 3 for the noncarcinogen tributyltin (Table 4E-5). Any chemical with a noncancer hazard greater than 0.3 for the RME adult net fishing scenario in SCSD Table 4-18 was considered to be of concern for noncancer hazard (Table 4E-6).

Because there is no SCUM scenario for adult beach play, the risk results for this scenario were considered without adjustment. Any chemical with a cancer risk greater than 1×10^{-6} for the adult beach play scenario in SCSD Table 4-13 was considered to be of concern for cancer risk. Any chemical with a noncancer hazard greater than 1 for the adult beach play scenario in SCSD Table 4-14 was considered to be of concern for noncancer hazard.

If the chemical was of concern for either cancer risk or noncancer hazard, it was considered a direct contact COC (Table 4E-6). Otherwise it was eliminated from the list of direct contact COCs.

[1] cPAH TEQ includes seven carcinogenic PAHs. These seven PAHs are not listed separately.

Total cPAH TEQ was not calculated for the SCSD. The cancer risks for each of the individual cPAHs exceeded at least one level of concern, so it was concluded that the cancer risks for cPAH TEQ would also exceed levels of concern.

Aluminum, lead, hexachlorobenzene, and chloroform were not included in the human health risk assessment in the SCSD. The risks and hazards associated with aluminum, hexachlorobenzene, and chloroform were evaluated by calculating sediment direct contact SLs per SCUM for the child beach play and adult net fishing scenarios (Table 4E-7). No SLs were calculated for the adult beach play scenario, which is not included in SCUM.

Lead has none of the toxicity values necessary for calculating SLs, so MTCA Method A soil cleanup levels were adjusted to derive SLs. The SL for the child beach play scenario was calculated by adjusting the Method A unrestricted soil cleanup level of 250 mg/kg. The Method A value assumes exposure to a child for 365 days per year, while the beach play scenarios assumes 41 days per year, so the Method A unrestricted soil value was adjusted by 365/41 to yield 2,200 mg/kg (Table 4E-8).

The lead SL for the adult net fishing scenario was calculated by adjusting the Method A industrial soil cleanup level of 1,000 mg/kg. The MTCA Method C industrial exposure scenario assumes a unitless exposure frequency of 0.4, which equates to 146 days per year, while the net fishing scenario assumes 119 days per year. The Method A industrial soil value was adjusted by 146/119 to yield 1,200 mg/kg (Table 4E-8).

The maximum concentrations of aluminum, lead, hexachlorobenzene, and chloroform detected on site were compared with their sediment direct contact SLs (Table 4E-8). The maximum concentration of hexachlorobenzene exceeded both of the sediment SLs, so it was retained as a direct contact COC (Table 4E-6). The other chemicals were eliminated as direct contact COCs.

The lead SLs are associated with a high level of uncertainty. The Method A soil lead cleanup levels were calculated by modeling blood lead concentrations. The adjustments for sediment SLs used simple ratios rather than blood lead modeling. However, it is not necessary to refine the sediment SLs further because remediation decisions for lead are driven by the freshwater sediment benthic criterion of 360 mg/kg, which is considered sufficiently protective for human contact.

List of Direct Contact Chemicals of Concern

The chemicals identified as direct contact COCs are arsenic, cPAH TEQ, and hexachlorobenzene (Table 4E-6). Arsenic and cPAHs are known to be related to operations at the GWPS, while hexachlorobenzene is not.

Hexachlorobenzene was included on the COC list because it didn't meet any of the criteria for exclusion, but there is uncertainty as to whether it truly qualifies as a COC. It was detected in two of the 286 sediment samples analyzed at concentrations of 0.0022 and 4.5 mg/kg; the maximum reporting limit was 16 mg/kg. The results of sediment testing conducted during remedy design will determine whether it remains on the list of direct contact COCs.

Bioaccumulative Chemicals of Concern

Identification of bioaccumulative COCs involved answering the following three questions (RI report, Figure 4-6):

- Is the chemical considered potentially bioaccumulative?
- Is there evidence of bioaccumulation at the GWPS, based on crayfish tissue data?
- Do human health or ecological risks from crayfish consumption exceed target levels?

Potentially Bioaccumulative

A chemical was considered potentially bioaccumulative if it was listed in 173-333-310 WAC (Persistent Bioaccumulative Toxins, PBTs) or included on List 1 (primary bioaccumulative COCs) or List 2 (candidate bioaccumulative chemicals) in the *Dredged Material Evaluation and Disposal Procedures User Manual* (DMMP) (ACOE et al., 2016).

The list of bioaccumulative COPCs includes seven metals, tributyltin, three noncarcinogenic PAHs, cPAH TEQ, pentachlorophenol, hexachlorobenzene, chlordane, DDT, and total PCBs (Table 4E-9). Each of the individual carcinogenic PAHs is listed as bioaccumulative chemical in PBT. They were addressed cumulatively as cPAH TEQ.

If a chemical did not appear on the PBT list or on DMMP Lists 1 or 2, it was not considered to be potentially bioaccumulative and was not identified as a bioaccumulative COC.

Hexavalent chromium is listed as bioaccumulative by the DMMP. Total chromium was detected in GWPS sediments but it was not speciated. Chromium was conservatively identified as a bioaccumulative COC for the site, based on the possibility that it is hexavalent, but there is uncertainty about the form present.

Dioxins and furans are bioaccumulative and are commonly detected in sediment, but they were not analyzed at the GWPS. This is a source of uncertainty.

Evidence of Bioaccumulation at GWPS

This step relied on screening evaluations of crayfish tissue presented in Table 3-6a of the SCSD, in which maximum concentrations detected in crayfish tissue are compared with SLs from the Oregon Department of Environmental Quality (ODEQ) for consumption by birds, wildlife, recreational fishers, and tribal members; regional SLs from EPA for fish consumption; and target tissue levels from the Northwest Regional Sediment Evaluation Team for protection of aquatic-dependent wildlife and human health.

The comparisons shown in SCSD Table 3-6a with ODEQ's critical tissue levels were not considered for the purpose of selecting bioaccumulative COCs because the critical tissue levels are for protection of aquatic organisms rather than seafood consumption. Comparison of maximum finfish tissue concentrations with SLs are provided in SCSD Table 3-6b, but these data were not used in the COC evaluation. The finfish tissue concentrations are considered to be a less reliable indicator of bioaccumulation at the GWPS because finfish have less site fidelity than crayfish.

If the maximum crayfish tissue concentration measured at the GWPS exceeded any of the SLs for fish consumption, the chemical was evaluated further (Table 4E-10). If there were one or more SLs for fish consumption and the maximum crayfish tissue concentration did not exceed any of them, the chemical was eliminated from further consideration as a bioaccumulative COC.

Methylmercury and hexachlorobenzene were not analyzed in crayfish tissue, so they were retained for further evaluation. There were no SLs for benzo(g,h,i)perylene, so it was retained for further evaluation. Total cPAH TEQ was not calculated for the SCSD. Each of the individual carcinogenic PAHs except chrysene exceeded its SL, so it was concluded that there is evidence of bioaccumulation of cPAH TEQ.

Crayfish Risk Assessment

This step relied on the results of the risk assessments conducted for human health (HHRA) and ecological receptors (ERA), presented in Tables 4-15, 4-16, and 4-27 of the SCSD. Because the risk assessments used maximum tissue concentrations, they were appropriate for identifying bioaccumulative COCs.

The ecological risk assessment results for the great blue heron, American mallard, northern river otter, and juvenile Chinook salmon (SCSD Table 4-27) were considered. The hazard quotient (HQ) for the lowest observed adverse effect level was used for the first three receptors. The HQ for the no observed adverse effect level, a more conservative endpoint, was used for salmon because it is an endangered species. If the HQ exceeded 1 for any of the receptors, the chemical was considered to be of concern for the ERA (Table 4E- 10).

The human health cancer risk (SCSD Table 4-15) and noncancer hazard (SCSD Table 4-16) assessment results for the reasonable maximum exposure (RME) scenario for tribal members were also considered. The HHRA in the SCSD used exposure assumptions similar to, but not exactly the same as, default exposure assumptions in the SCUM. To evaluate the differences, risk-based concentrations (RBCs) for five chemicals were calculated consistent with SCUM Equations 9-6a and 9-8 using parameter values for RME tribal fish consumption in SCSD Table 4-8 (Table 4E-11). The five chemicals were arsenic, cadmium, methylmercury, tributyltin, and total DDTs. RBCs were calculated separately for an adult and a child, consistent with SCSD.

The RBCs calculated per SCSD were compared to the RBCs calculated according to SCUM Appendix K, except that the fish consumption rate was adjusted to 97.5 g/day (Table 4E-12). This is the fish consumption rate assumed for the Lower Duwamish Waterway, based on the Tulalip Tribe excluding salmon.

The adult RBCs per SCSD were a factor of 1.1 higher (less conservative) than the RBCs per SCUM (Table 4E-12). Any chemical with a cancer risk of 9×10^{-7} or greater for the RME tribal adult in SCSD Table 4-15 was considered to be of concern for cancer risk (Table 4E-10). Any chemical with a noncancer hazard of

0.9 or greater for the RME tribal adult in SCSD Table 4-16 was considered to be of concern for noncancer hazard.

The child RBCs per SCSD were a factor of 6 higher (less conservative) than the RBCs per SCUM for the carcinogens arsenic and total DDTs (Table 4E-12). Any chemical with a cancer risk of 2×10^{-7} or greater for the RME tribal child in SCSD Table 4-15 was considered to be of concern for cancer risk (Table 4E-10).

The child RBCs per SCSD were approximately half of the RBCs per SCUM (more conservative) for the noncarcinogens cadmium, methylmercury, and tributyltin (Table 4E-12). Any chemical with a noncancer hazard of 2 or greater for the RME tribal child in SCSD Table 4-16 was considered to be of concern for noncancer hazard (Table 4E-10).

If the chemical was of concern for the ERA or for the HHRA (cancer risk or noncancer hazard), it was considered a bioaccumulative COC (Table 4E-10). Otherwise it was eliminated from the list of bioaccumulative COCs.

Methylmercury and hexachlorobenzene were not included in the risk assessments so they were retained as bioaccumulative COCs. Total cPAH TEQ was not calculated for the SCSD. The cancer risks for each of the individual cPAHs except chrysene exceeded levels of concern, so it was concluded that the cancer risks for cPAH TEQ would also exceed a level of concern.

List of Bioaccumulative COCs

The chemicals identified as bioaccumulative COCs are cPAH TEQ, arsenic, chromium, methylmercury, hexachlorobenzene, pentachlorophenol, chlordane, and total PCBs (Table 4E-10). cPAHs and arsenic are known to be related to operations at the GWPS. The remaining bioaccumulative COCs are not likely related to historic industrial site activities, but they are present at levels of concern in site sediment.

Methylmercury and hexachlorobenzene were included on the COC list because they didn't meet any of the criteria for exclusion, but there is uncertainty as to whether they truly qualify as COCs.

Hexachlorobenzene was detected in two of the 286 sediment samples analyzed at concentrations of 0.0022 and 4.5 mg/kg; the maximum reporting limit was 16 mg/kg. Methylmercury was detected in the single sediment sample analyzed at 0.0012 mg/kg. Methylmercury and hexachlorobenzene were not analyzed in crayfish tissue and were not included in the risk assessments. The results of sediment testing conducted during remedy design will determine whether methylmercury and hexachlorobenzene remain on the list of bioaccumulative COCs.

Chromium was included on the COC list because the form present in GWPS sediments is not known. If it is present as trivalent chromium, it is not bioaccumulative. The results of speciation tests conducted during remedy design will determine whether chromium remains on the list of bioaccumulative COCs.

Dioxins and furans are not included on the COC list because they were not analyzed in GWPS sediment. If they are present, they should be added to the list of COCs. The results of sediment testing conducted during remedy design will determine whether dioxins/furans are added to the list of bioaccumulative COCs.

References

ACOE et al., 2016. Dredged Material Evaluation and Disposal Procedures User Manual. U.S. Army Corps of Engineers, Seattle District; U.S. EPA, Region 10; Washington State Departments of Natural Resources and Ecology. August.

AECOM et al., 2012. Gas Works Sediment Area Supplemental to the Cleanup Standards Document. Draft final. Prepared by AECOM, WR Consulting, Inc., and Floyd|Snider for Puget Sound Energy and Seattle Public Utilities. February 2.

Ecology, 2019. Sediment Cleanup User's Manual (SCUM). Publ. no. 12-09-057. Second revision draft. May.

Table 4E-1. Chemicals of Potential Concern in Surface Sediment at the Gas Works Park Site

Detected Analyte	Sediment Max. Detect (mg/kg)	Natural Background (mg/kg)	Maximum > Natural Background	Chemical of Potential Concern
Metals				
Aluminum	121,000	nv	--	YES
Antimony	19	nv	--	YES
Arsenic	2,400	11	YES	YES
Barium	470	nv	--	YES
Beryllium	0.46	nv	--	YES
Cadmium	4	0.8	YES	YES
Calcium	8,000	nv	--	YES
Chromium	250	62	YES	YES
Cobalt	240	nv	--	YES
Copper	1,050	45	YES	YES
Iron	33,600	nv	--	YES
Lead	1,100	21	YES	YES
Magnesium	7,600	nv	--	YES
Manganese	390	nv	--	YES
Mercury	3.3	0.2	YES	YES
Methylmercury	0.0012	nv	--	YES
Nickel	630	50	YES	YES
Potassium	1,200	nv	--	YES
Selenium	2.3	nv	--	YES
Silver	9	0.24	YES	YES
Sodium	980	nv	--	YES
Thallium	0.14	nv	--	YES
Tin	6.8	nv	--	YES
Vanadium	130	nv	--	YES
Zinc	1,360	93	YES	YES
Butyltins				
Tributyltin	7	nv	--	YES
Low Molecular Weight PAHs				
Naphthalene	20,000	nv	--	YES
Acenaphthylene	1,100	nv	--	YES
Acenaphthene	4,100	nv	--	YES
Fluorene	2,100	nv	--	YES
Phenanthrene	9,900	nv	--	YES
Anthracene	2,500	nv	--	YES
2-Methylnaphthalene	5,000	nv	--	YES
Total LPAHs	40,000	nv	--	YES
High Molecular Weight PAHs				
Fluoranthene	5,600	nv	--	YES
Pyrene	5,700	nv	--	YES
Benzo(a)anthracene	2,100	nv	--	YES
Chrysene	2,400	nv	--	YES
Benzo(b)fluoranthene	2,100	nv	--	YES

Table 4E-1. Chemicals of Potential Concern in Surface Sediment at the Gas Works Park Site

Detected Analyte	Sediment Max. Detect (mg/kg)	Natural Background (mg/kg)	Maximum > Natural Background	Chemical of Potential Concern
Benzo(k)fluoranthene	1,400	nv	--	YES
Total benzofluoranthenes	3,500	nv	--	YES
Benzo(a)pyrene	2,200	nv	--	YES
Indeno(1,2,3-cd)pyrene	1,100	nv	--	YES
Dibenzo(a,h)anthracene	220	nv	--	YES
Benzo(g,h,i)perylene	1,100	nv	--	YES
cPAH TEQ	nv	nv	--	YES
Total HPAHs	24,000	nv	--	YES
Total PAHs	64,000	nv	--	YES
Phthalates				
Dimethylphthalate	0.42	nv	--	YES
Diethylphthalate	4.5	nv	--	YES
Di-n-butylphthalate	37	nv	--	YES
Butylbenzylphthalate	0.66	nv	--	YES
bis(2-Ethylhexyl)phthalate	6.5	nv	--	YES
Di-n-octyl phthalate	56	nv	--	YES
Phenols				
Phenol	12	nv	--	YES
2-Methylphenol	27	nv	--	YES
4-Methylphenol	69	nv	--	YES
2,4-Dimethylphenol	30	nv	--	YES
4-Nitrophenol	0.75	nv	--	YES
Pentachlorophenol	0.46	nv	--	YES
Semivolatile Organic Chemicals				
Benzoic acid	4	nv	--	YES
Benzyl alcohol	0.92	nv	--	YES
Carbazole	150	nv	--	YES
Dibenzofuran	830	nv	--	YES
Hexachlorobenzene	4.5	nv	--	YES
Isophorone	0.21	nv	--	YES
n-Nitrosodiphenylamine	2.4	nv	--	YES
Retene	12	nv	--	YES
Volatile Organic Chemicals				
Acetone	0.47	nv	--	YES
Benzene	3,500	nv	--	YES
sec-Butylbenzene	0.005	nv	--	YES
1,2,4-Trimethylbenzene	130	nv	--	YES
1,3,5-Trimethylbenzene	15	nv	--	YES
n-Propylbenzene	0.025	nv	--	YES
Ethylbenzene	730	nv	--	YES
Isopropylbenzene	0.071	nv	--	YES
Chloroform	0.056	nv	--	YES
1,2-Dichloroethane	0.0074	nv	--	YES

Table 4E-1. Chemicals of Potential Concern in Surface Sediment at the Gas Works Park Site

Detected Analyte	Sediment Max. Detect (mg/kg)	Natural Background (mg/kg)	Maximum > Natural Background	Chemical of Potential Concern
1,1,1-Trichloroethane	0.0072	nv	--	YES
Methylene chloride	0.02	nv	--	YES
2-Butanone	0.37	nv	--	YES
2-Hexanone	0.067	nv	--	YES
4-Methyl-2-pentanone (MIBK)	0.0078	nv	--	YES
Styrene	0.0058	nv	--	YES
Toluene	180	nv	--	YES
4-Isopropyltoluene	0.045	nv	--	YES
Total xylenes	480	nv	--	YES
Pesticides/PCBs				
beta-Chlordane	0.28	nv	--	YES
Chlordane	0.12	nv	--	YES
DDD	0.089	nv	--	YES
DDE	0.035	nv	--	YES
DDT	0.13	nv	--	YES
Aroclor 1248	0.02	nv	--	YES
Aroclor 1254	0.4	nv	--	YES
Aroclor 1260	0.3	nv	--	YES
Total PCBs	0.7	nv	--	YES
Source				
AECOM et al. (2012) Table 3-2	AECOM et al. (2012) Table 3-2 RI Report Table 5-4	SCUM Table 10-1	--	--

Abbreviations

cPAH - carcinogenic PAH
HPAHs - high molecular weight PAHs
LPAHs - low molecular weight PAHs
nv - no value available
TEQ - toxicity equivalent

Table 4E-2. Preliminary Direct Contact Chemicals of Concern at the Gas Works Park Site

Chemical of Potential Concern	Exceeds Direct Contact SLs		Preliminary Contact COPC	Comment
	MTCA Method B	EPA RSLs		
Metals				
Aluminum	no	YES	YES	
Antimony	no	no	no	
Arsenic	YES	YES	YES	
Barium	no	no	no	
Beryllium	no	no	no	
Cadmium	no	no	no	
Calcium	no	no	no	
Chromium	no	no	no	
Cobalt	no	YES	YES	
Copper	no	no	no	
Iron	no	no	no	
Lead	no	YES	YES	
Magnesium	no	no	no	
Manganese	no	no	no	
Mercury	no	no	no	
Methylmercury	no	no	no	
Nickel	no	no	no	
Potassium	no	no	no	
Selenium	no	no	no	
Silver	no	no	no	
Sodium	no	no	no	
Thallium	no	no	no	
Tin	no	no	no	
Vanadium	no	no	no	
Zinc	no	no	no	
Butyltins				
Tributyltin	no	no	no	
Low Molecular Weight PAHs				
Naphthalene	YES	YES	YES	
Acenaphthylene	no	no	no	
Acenaphthene	no	YES	YES	
Fluorene	no	no	no	
Phenanthrene	no	no	no	
Anthracene	no	no	no	
2-Methylnaphthalene	YES	YES	YES	
Total LPAHs	no	no	no	
High Molecular Weight PAHs				
Fluoranthene	YES	YES	YES	
Pyrene	YES	YES	YES	
Benzo(a)anthracene	YES	YES	no	Addressed as cPAH TEQ
Chrysene	YES	YES	no	Addressed as cPAH TEQ
Benzo(b)fluoranthene	YES	YES	no	Addressed as cPAH TEQ

Table 4E-2. Preliminary Direct Contact Chemicals of Concern at the Gas Works Park Site

Chemical of Potential Concern	Exceeds Direct Contact SLs		Preliminary Contact COPC	Comment
	MTCA Method B	EPA RSLs		
Benzo(k)fluoranthene	YES	YES	no	Addressed as cPAH TEQ
Total benzofluoranthenes	no	no	no	
Benzo(a)pyrene	YES	YES	no	Addressed as cPAH TEQ
Indeno(1,2,3-cd)pyrene	YES	YES	no	Addressed as cPAH TEQ
Dibenzo(a,h)anthracene	YES	YES	no	Addressed as cPAH TEQ
Benzo(g,h,i)perylene	no	no	no	
cPAH TEQ	--	--	YES	
Total HPAHs	no	no	no	
Total PAHs	no	no	no	
Phthalates				
Dimethylphthalate	no	no	no	
Diethylphthalate	no	no	no	
Di-n-butylphthalate	no	no	no	
Butylbenzylphthalate	no	no	no	
bis(2-Ethylhexyl)phthalate	no	no	no	
Di-n-octyl phthalate	no	no	no	
Phenols				
Phenol	no	no	no	
2-Methylphenol	no	no	no	
4-Methylphenol	no	no	no	
2,4-Dimethylphenol	no	no	no	
4-Nitrophenol	no	no	no	
Pentachlorophenol	no	no	no	
Semivolatile Organic Chemicals				
Benzoic acid	no	no	no	
Benzyl alcohol	no	no	no	
Carbazole	YES	no	YES	
Dibenzofuran	YES	no	YES	
Hexachlorobenzene	YES	YES	YES	
Isophorone	no	no	no	
n-Nitrosodiphenylamine	no	no	no	
Retene	no	no	no	
Volatile Organic Chemicals				
Acetone	no	no	no	
Benzene	YES	YES	YES	
sec-Butylbenzene	no	no	no	
1,2,4-Trimethylbenzene	no	YES	YES	
1,3,5-Trimethylbenzene	no	no	no	
n-Propylbenzene	no	no	no	
Ethylbenzene	no	YES	YES	
Isopropylbenzene	no	no	no	
Chloroform	no	YES	YES	
1,2-Dichloroethane	no	no	no	

Table 4E-2. Preliminary Direct Contact Chemicals of Concern at the Gas Works Park Site

Chemical of Potential Concern	Exceeds Direct Contact SLs		Preliminary Contact COPC	Comment
	MTCA Method B	EPA RSLs		
1,1,1-Trichloroethane	no	no	no	
Methylene chloride	no	no	no	
2-Butanone	no	no	no	
2-Hexanone	no	no	no	
4-Methyl-2-pentanone (MIBK)	no	no	no	
Styrene	no	no	no	
Toluene	no	no	no	
4-Isopropyltoluene	no	no	no	
Total xylenes	no	no	no	
Pesticides/PCBs				
beta-Chlordane	no	no	no	
Chlordane	no	no	no	
DDD	no	no	no	
DDE	no	no	no	
DDT	no	no	no	
Aroclor 1248	no	no	no	
Aroclor 1254	no	YES	YES	
Aroclor 1260	no	YES	YES	
Total PCBs	YES	YES	YES	
Source				
AECOM et al. (2012) Table 3-2	AECOM et al. (2012) Table 3-4		--	

Abbreviations

COC - chemical of concern
cPAH - carcinogenic PAH
RSL - regional screening level
SL - screening level
TEQ - toxicity equivalent

Table 4E-3. Screening Preliminary Direct Contact Chemicals of Concern with Low Detection Frequency

Chemical	Maximum Detect	Method B Cancer	Method B Noncancer	EPA RSL CR=1E-6	EPA RSL HQ=1	Preliminary Contact COPC
Thallium	0.14	nv	5.6	nv	nv	no
Di-n-octyl phthalate	56	nv	1600	nv	nv	no
2-Methylphenol	27	nv	4000	nv	3060	no
Pentachlorophenol	0.46	8.33	2400	2.97	1380	no
Benzyl alcohol	0.92	nv	24000	nv	6110	no
Hexachlorobenzene	4.5	0.625	64	0.303	48.9	YES
n-Nitrosodiphenylamine	2.4	204	nv	99.1	nv	no
1,2-Dichloroethane	0.0074	11	1600	0.432	1390	no
Methylene chloride	0.02	133	4800	10.7	1660	no
Styrene	0.0058	33.3	16000	nv	6280	no
Chlordane	0.12	2.86	40	1.62	35.2	no
DDE	0.035	2.94	nv	1.43	nv	no
DDT	0.13	2.94	40	1.72	36.1	no
Source	AECOM et al. (2012) Table 3-2	AECOM et al. (2012) Table 3-3				--

All concentrations in mg/kg.

Abbreviations

COPC - chemical of potential concern
CR - cancer risk
HQ - hazard quotient
nv - no value available
RSL - Regional Screening Level

Table 4E-4. Sediment Cleanup Levels for Direct Contact per SCSD

Summary

Chemical	Sediment Cleanup Objective (SCO)			Cleanup Screening Level (CSL)		
	Beach Play Adult	Beach Play Child	Netfishing Adult	Beach Play Adult	Beach Play Child	Netfishing Adult
Arsenic	4.38E+00	3.02E+00	1.72E+01	4.38E+01	3.02E+01	1.72E+02
Tributyltin	6.76E+02	9.87E+01	3.35E+03	6.76E+02	9.87E+01	3.35E+03
Total DDTs	1.93E+01	1.33E+01	7.58E+01	1.93E+02	1.33E+02	7.58E+02

Equations Based on SCUM

1) Ingestion intake factor for cancer: IIFc = (ACR x BW x ATc x UCF) / (FI x IR x AB x EF x ED)
2) Ingestion intake factor for noncancer: IIFn = (HQ x BW x ATn x UCF) / (FI x IR x AB x EF x ED)
3) Dermal intake factor for cancer: DIFc = (ACR x BW x ATc x UCF) / (FI x SA x AF x ABS x EF x ED)
4) Dermal intake factor for noncancer: DIFn = (HQ x BW x ATn x UCF) / (FI x SA x AF x ABS x EF x ED)
5) Dermal CPF: CPFd = CPFo / GI
6) Dermal RfD: RfDd = RfDo x GI
7) Ingestion cleanup level for cancer: CULi - cancer = IIFc / (CPFo x AB)
8) Ingestion cleanup level for noncancer: CULi - noncancer = IIFn x RfDo x AB
9) Dermal cleanup level for cancer: CULd - cancer = DIFc / (CPFd x ABS)
10) Dermal cleanup level for noncancer: CULd - noncancer = DIFn x RfDd x ABS
11) Cancer cleanup level: Cancer CUL = 1 / [(1/CULi - cancer) + (1/CULd - cancer)]
12) Noncancer cleanup level: Noncancer CUL = 1 / [1/CULi - noncancer) + (1/CULd - noncancer)]

Table 4E-4. Sediment Cleanup Levels for Direct Contact per SCSD

Exposure Parameters from SCSD

Parameter	Abbrev.	Beach Play Adult	Beach Play Child	Net Fisher Adult	Units	Source
Target cancer risk - SCO	CRs	1E-06	1E-06	1E-06	unitless	SCUM Table 9-1a
Target cancer risk - CSL	CRc	1E-05	1E-05	1E-05	unitless	SCUM Table 9-1a
Target hazard quotient	HQ	1	1	1	unitless	SCUM Table 9-1a
Body weight	BW	70	15	81.8	kg	SCSD Tables 4-5 and 4-9
Averaging time - cancer	ATc	25,550	25,550	25,550	days	SCSD Tables 4-5 and 4-9
Averaging time - noncancer	ATn	10,950	2,190	16,060	days	SCSD Tables 4-5 and 4-9
Unit conversion factor	UCF	1E+06	1E+06	1E+06	mg/kg	--
Fractional intake from site	FI	1.00	1.00	0.25	unitless	SCSD Tables 4-5 and 4-9
Sediment ingestion rate	IR	100	200	50	mg/day	SCSD Tables 4-5 and 4-9
Dermal surface area	SA	5,700	2,800	5,700	cm2	SCSD Tables 4-6 and 4-10
Sediment-to-skin adherence	AF	0.07	0.2	0.07	mg/cm2-day	SCSD Tables 4-6 and 4-10
Exposure frequency	EF	81	65	119	day/yr	SCSD Tables 4-5 and 4-9
Exposure duration	ED	30	6	44	yr	SCSD Tables 4-5 and 4-9
Ingestion intake factor - cancer, SCO	IIFc SCO	7.36E+00	4.91E+00	3.19E+01	kg BW-day/ kg sed	Equation 1
Ingestion intake factor - cancer, CSL	IIFc CSL	7.36E+01	4.91E+01	3.19E+02	kg BW-day/ kg sed	Equation 1
Ingestion intake factor - noncancer	IIFn	3.15E+06	4.21E+05	2.01E+07	kg BW-day/ kg sed	Equation 2
Dermal intake factor - cancer, SCO	DIFc SCO	1.84E+00	1.75E+00	4.00E+00	kg BW-day/ kg sed	Equation 3
Dermal intake factor - cancer, CSL	DIFc CSL	1.84E+01	1.75E+01	4.00E+01	kg BW-day/ kg sed	Equation 3
Dermal intake factor - noncancer	DIFn	7.91E+05	1.50E+05	2.52E+06	kg BW-day/ kg sed	Equation 4

Table 4E-4. Sediment Cleanup Levels for Direct Contact per SCSD

Sediment Contact Cleanup Levels for Adult Beach Play Scenario

Chemical	Toxicity Data							Cancer Cleanup Level for SCO		
	CPFo (risk per mg/kg-day)	RfDo (mg/kg-day)	GI (unitless)	CPFd (risk per mg/kg-day)	RfDd (mg/kg-day)	AB (unitless)	ABS (unitless)	Ingestion CUL (mg/kg)	Dermal CUL (mg/kg)	Cancer CUL (mg/kg)
Arsenic	1.5E+00	3.0E-04	1.0	1.5E+00	3.0E-04	1.0	0.030	4.91E+00	4.10E+01	4.38E+00
Tributyltin	na	3.0E-04	1.0	--	3.0E-04	1.0	0.100	--	--	--
Total DDTs	3.4E-01	5.0E-04	1.0	3.4E-01	5.0E-04	1.0	0.030	2.16E+01	1.81E+02	1.93E+01
Source	SCSD Table 4-12	SCSD Table 4-12	MTCA Eq. 740 4	Equation 5	Equation 6	1.0 0.6 for D/F	SCSD Table 4-11	Equation 7	Equation 9	Equation 11

Sediment Contact Cleanup Levels for Child Beach Play Scenario

Chemical	Toxicity Data							Cancer Cleanup Level for SCO		
	CPFo (risk per mg/kg-day)	RfDo (mg/kg-day)	GI (unitless)	CPFd (risk per mg/kg-day)	RfDd (mg/kg-day)	AB (unitless)	ABS (unitless)	Ingestion CUL (mg/kg)	Dermal CUL (mg/kg)	Cancer CUL (mg/kg)
Arsenic	1.5E+00	3.0E-04	1.0	1.5E+00	3.0E-04	1.0	0.030	3.28E+00	3.90E+01	3.02E+00
Tributyltin	na	3.0E-04	1.0	--	3.0E-04	1.0	0.100	--	--	--
Total DDTs	3.4E-01	5.0E-04	1.0	3.4E-01	5.0E-04	1.0	0.030	1.45E+01	1.72E+02	1.33E+01
Source	SCSD Table 4-12	SCSD Table 4-12	MTCA Eq. 740 4	Equation 5	Equation 6	1.0 0.6 for D/F	SCSD Table 4-11	Equation 7	Equation 9	Equation 11

Sediment Contact Cleanup Levels for Adult Netfishing Scenario

Chemical	Toxicity Data							Cancer Cleanup Level for SCO		
	CPFo (risk per mg/kg-day)	RfDo (mg/kg-day)	GI (unitless)	CPFd (risk per mg/kg-day)	RfDd (mg/kg-day)	AB (unitless)	ABS (unitless)	Ingestion CUL (mg/kg)	Dermal CUL (mg/kg)	Cancer CUL (mg/kg)
Arsenic	1.5E+00	3.0E-04	1.0	1.5E+00	3.0E-04	1.0	0.030	2.13E+01	8.89E+01	1.72E+01
Tributyltin	na	3.0E-04	1.0	--	3.0E-04	1.0	0.100	--	--	--
Total DDTs	3.4E-01	5.0E-04	1.0	3.4E-01	5.0E-04	1.0	0.030	9.39E+01	3.92E+02	7.58E+01
Source	SCSD Table 4-12	SCSD Table 4-12	MTCA Eq. 740 4	Equation 5	Equation 6	1.0 0.6 for D/F	SCSD Table 4-11	Equation 7	Equation 9	Equation 11

Table 4E-4. Sediment Clean

Sediment Contact Cleanup Lev

Chemical	Cancer Cleanup Level for CSL			Noncancer Cleanup Level			Beach Play - Adult	
	Ingestion CUL (mg/kg)	Dermal CUL (mg/kg)	Cancer CUL (mg/kg)	Ingestion CUL (mg/kg)	Dermal CUL (mg/kg)	Noncancer CUL (mg/kg)	SCO (mg/kg)	CSL (mg/kg)
Arsenic	4.91E+01	4.10E+02	4.38E+01	9.46E+02	7.91E+03	8.45E+02	4.38E+00	4.38E+01
Tributyltin	--	--	--	9.46E+02	2.37E+03	6.76E+02	6.76E+02	6.76E+02
Total DDTs	2.16E+02	1.81E+03	1.93E+02	1.58E+03	1.32E+04	1.41E+03	1.93E+01	1.93E+02
Source	Equation 7	Equation 9	Equation 11	Equation 8	Equation 10	Equation 12	Minimum of cancer and noncancer	Minimum of cancer and noncancer

Sediment Contact Cleanup Lev

Chemical	Cancer Cleanup Level for CSL			Noncancer Cleanup Level			Beach Play - Child	
	Ingestion CUL (mg/kg)	Dermal CUL (mg/kg)	Cancer CUL (mg/kg)	Ingestion CUL (mg/kg)	Dermal CUL (mg/kg)	Noncancer CUL (mg/kg)	SCO (mg/kg)	CSL (mg/kg)
Arsenic	3.28E+01	3.90E+02	3.02E+01	1.26E+02	1.50E+03	1.17E+02	3.02E+00	3.02E+01
Tributyltin	--	--	--	1.26E+02	4.51E+02	9.87E+01	9.87E+01	9.87E+01
Total DDTs	1.45E+02	1.72E+03	1.33E+02	2.11E+02	2.51E+03	1.94E+02	1.33E+01	1.33E+02
Source	Equation 7	Equation 9	Equation 11	Equation 8	Equation 10	Equation 12	Min of cancer & noncancer	Min of cancer & noncancer

Sediment Contact Cleanup Lev

Chemical	Cancer Cleanup Level for CSL			Noncancer Cleanup Level			Netfishing - Adult	
	Ingestion CUL (mg/kg)	Dermal CUL (mg/kg)	Cancer CUL (mg/kg)	Ingestion CUL (mg/kg)	Dermal CUL (mg/kg)	Noncancer CUL (mg/kg)	SCO (mg/kg)	CSL (mg/kg)
Arsenic	2.13E+02	8.89E+02	1.72E+02	6.02E+03	2.52E+04	4.86E+03	1.72E+01	1.72E+02
Tributyltin	--	--	--	6.02E+03	7.55E+03	3.35E+03	3.35E+03	3.35E+03
Total DDTs	9.39E+02	3.92E+03	7.58E+02	1.00E+04	4.19E+04	8.10E+03	7.58E+01	7.58E+02
Source	Equation 7	Equation 9	Equation 11	Equation 8	Equation 10	Equation 12	Min of cancer & noncancer	Min of cancer & noncancer

Abbreviations

AB - gastrointestinal absorption fraction
ABS - dermal absorption fraction
CLARC - Cleanup Levels and Risk Calculation database
CPFd - dermal carcinogenic potency factor
CPFo - oral carcinogenic potency factor
CSL - cleanup screening level
CUL - cleanup level
GI - gastrointestinal absorption conversion factor (relative bioavailability)
RfDd - dermal reference dose
RfDo - oral reference dose
SCO - sediment cleanup objective
SCUM - Sediment Cleanup User's Manual
TEQ - toxicity equivalence

Table 4E-5. Comparison of Direct Contact Cleanup Levels between SCSD and SCUM

Chemical	SCO per SCUM Beach Play Child	SCO per SCUM Netfishing Adult	SCO per SCSD Beach Play Child	SCO per SCSD Netfishing Adult	SCSD/SCUM Beach Play Child	SCSD/SCUM Netfishing Adult
Arsenic	4.80E+00	3.00E+00	3.02E+00	1.72E+01	0.6	6
Tributyltin	1.60E+02	1.20E+03	9.87E+01	3.35E+03	0.6	3
DDT	2.10E+01	1.30E+01	1.33E+01	7.58E+01	0.6	6
Source	SCUM Table 9-3		Table 4E-4		--	

All concentrations in mg/kg.

Abbreviations

SCSD - supplemental cleanup standards document (AECOM et al., 2012)

SCO - sediment cleanup objective

SCUM - Sediment Cleanup User's Manual (Ecology, 2019)

Table 4E-6. Sediment Direct Contact Chemicals of Concern in Surface Sediment at the Gas Works Park Site

Preliminary Contact Chemical of Concern	Risk/Hazard for RME Beach Play Scenario				Risk/Hazard for RME Netfishing Scenario		Contact COC	Comments
	Child		Adult					
	Cancer	Noncancer	Cancer	Noncancer	Cancer	Noncancer		
Metals								
Aluminum	np	no	np	nc	np	no	no	Table 4E-7
Arsenic	YES	no	YES	no	YES	YES	YES	
Cobalt	np	no	np	no	np	no	no	
Lead	np	no	np	nc	np	no	no	Table 4E-7
Low Molecular Weight PAHs								
Naphthalene	np	no	np	no	np	no	no	
Acenaphthene	np	no	np	no	np	no	no	
2-Methylnaphthalene	np	no	np	no	np	no	no	
High Molecular Weight PAHs								
Fluoranthene	np	no	np	no	np	no	no	
Pyrene	np	no	np	no	np	no	no	
cPAH TEQ	--	--	--	--	--	--	YES	
Semivolatile Organic Chemicals								
Carbazole	no	nc	no	nc	no	nc	no	
Dibenzofuran	np	no	np	no	np	no	no	
Hexachlorobenzene	YES	no	nc	nc	YES	no	YES	Tables 4E-3 and 4E-7
Volatile Organic Chemicals								
Benzene	no	no	no	no	no	no	no	
1,2,4-Trimethylbenzene	np	no	np	no	np	no	no	
Ethylbenzene	no	no	no	no	no	no	no	
Chloroform	no	no	nc	nc	no	no	no	Table 4E-7

Table 4E-6. Sediment Direct Contact Chemicals of Concern in Surface Sediment at the Gas Works Park Site

Preliminary Contact Chemical of Concern	Risk/Hazard for RME Beach Play Scenario				Risk/Hazard for RME Netfishing Scenario		Contact COC	Comments
	Child		Adult					
	Cancer	Noncancer	Cancer	Noncancer	Cancer	Noncancer		
Pesticides/PCBs								
Aroclor 1254	no	no	no	no	no	no	no	
Aroclor 1260	no	nc	no	nc	no	nc	no	
Total PCBs	no	no	no	no	no	no	no	
Source								
AECOM et al. (2012) Table 3-2	AECOM et al. (2012) Table 4-13	AECOM et al. (2012) Table 4-14	AECOM et al. (2012) Table 4-13	AECOM et al. (2012) Table 4-14	AECOM et al. (2012) Table 4-17	AECOM et al. (2012) Table 4-18	--	--
Criterion	Risk > 2E-6	HQ > 2	Risk > 1E-6	HQ > 1	Risk > 2E-7	HQ > 0.3	--	--

Abbreviations

COC - chemical of concern
cPAH - carcinogenic PAH
DMMP - Dredged Materials Management Program (ACOE at al., 2016)
nc - not calculated in risk assessment
np - not applicable because not carcinogenic
PBT - persistent, bioaccumulative toxin (173-333-310 WAC)
RME - reasonable maximum exposure
RSL - regional screening level
SL - screening level
TEQ - toxicity equivalent

Table 4E-7. Sediment Cleanup Levels for Direct Contact

Summary

Chemical	Sediment Cleanup Objective		Cleanup Screening Level	
	Beach Play	Netfishing	Beach Play	Netfishing
Aluminum	6.23E+05	4.43E+06	6.23E+05	4.43E+06
Hexachlorobenzene	3.93E+00	2.55E+00	3.93E+01	2.55E+01
Chloroform	2.51E+02	1.48E+02	2.51E+03	1.48E+03

Equations Based on SCUM

1) Ingestion intake factor for cancer: IIFc = (ACR x BW x ATc x UCF) / (IR x AB x EF x ED)
2) Ingestion intake factor for noncancer: IIFn = (HQ x BW x ATn x UCF) / (IR x AB x EF x ED)
3) Dermal intake factor for cancer: DIFc = (ACR x BW x ATc x UCF) / (SA x AF x ABS x EF x ED)
4) Dermal intake factor for noncancer: DIFn = (HQ x BW x ATn x UCF) / (SA x AF x ABS x EF x ED)
5) Dermal CPF: CPFd = CPFo / GI
6) Dermal RfD: RfDd = RfDo x GI
7) Ingestion cleanup level for cancer: CULi - cancer = IIFc / (CPFo x AB)
8) Ingestion cleanup level for noncancer: CULi - noncancer = IIFn x RfDo x AB
9) Dermal cleanup level for cancer: CULd - cancer = DIFc / (CPFd x ABS)
10) Dermal cleanup level for noncancer: CULd - noncancer = DIFn x RfDd x ABS
11) Cancer cleanup level: Cancer CUL = 1 / [(1/CULi - cancer) + (1/CULd - cancer)]
12) Noncancer cleanup level: Noncancer CUL = 1 / [1/CULi - noncancer) + (1/CULd - noncancer)]

Table 4E-7. Sediment Cleanup Levels for Direct Contact
SCUM Exposure Parameters

Parameter	Abbrev.	Beach Play Child	Subsistence Clam Digger Adult	Subsistence Net Fisher Adult	Units	Source
Target cancer risk - SCO	CRs	1E-06	1E-06	1E-06	unitless	SCUM Table 9-1a
Target cancer risk - CSL	CRc	1E-05	1E-05	1E-05	unitless	SCUM Table 9-1a
Target hazard quotient	HQ	1	1	1	unitless	SCUM Table 9-1a
Body weight	BW	15	75	75	kg	SCUM Tables 9-1a and E-4
Averaging time - cancer	ATc	25,550	25,550	25,550	days	SCUM Tables 9-1a and E-4
Averaging time - noncancer	ATn	2,190	25,550	25,550	days	SCUM Tables 9-1a and E-4
Unit conversion factor	UCF	1E+06	1E+06	1E+06	mg/kg	--
Sediment ingestion rate	IR	200	100	50	mg/day	SCUM Tables 9-1a and E-4
Dermal surface area	SA	2,378	3,212	3,212	cm2	SCUM Tables 9-1a and E-4
Sediment-to-skin adherence	AF	0.2	0.6	0.02	mg/cm2-day	SCUM Tables 9-1a and E-4
Exposure frequency	EF	41	120	119	day/yr	SCUM Table 9-1a
Exposure duration	ED	6	70	70	yr	SCUM Tables 9-1a and E-4
Ingestion intake factor - cancer, SCO	IIFc SCO	7.79E+00	2.28E+00	4.60E+00	kg BW-day/ kg sed	Equation 1
Ingestion intake factor - cancer, CSL	IIFc CSL	7.79E+01	2.28E+01	4.60E+01	kg BW-day/ kg sed	Equation 1
Ingestion intake factor - noncancer	IIFn	6.68E+05	2.28E+06	4.60E+06	kg BW-day/ kg sed	Equation 2
Dermal intake factor - cancer, SCO	DIFc SCO	3.28E+00	1.18E-01	3.58E+00	kg BW-day/ kg sed	Equation 3
Dermal intake factor - cancer, CSL	DIFc CSL	3.28E+01	1.18E+00	3.58E+01	kg BW-day/ kg sed	Equation 3
Dermal intake factor - noncancer	DIFn	2.81E+05	1.18E+05	3.58E+06	kg BW-day/ kg sed	Equation 4

Table 4E-7. Sediment Cleanup Levels for Direct Contact

Cleanup Levels for Sediment Contact for Beach Play Scenario

Chemical	Toxicity Data							Cancer Cleanup Level for SCO		
	CPFo (risk per mg/kg-day)	RfDo (mg/kg-day)	GI (unitless)	CPFd (risk per mg/kg-day)	RfDd (mg/kg-day)	AB (unitless)	ABS (unitless)	Ingestion CUL (mg/kg)	Dermal CUL (mg/kg)	Cancer CUL (mg/kg)
Aluminum	nv	1.0E+00	1.0	--	1.0E+00	1.0	0.030	--	--	--
Hexachlorobenzene	1.6E+00	8.0E-04	1.0	1.6E+00	8.0E-04	1.0	0.100	4.87E+00	2.05E+01	3.93E+00
Chloroform	3.1E-02	1.0E-02	1.0	3.1E-02	1.0E-02	1.0	0.001	2.51E+02	1.06E+05	2.51E+02
Source	CLARC	CLARC	MTCA Eq. 740 4	Equation 5	Equation 6	1.0 0.6 for D/F	MTCA Eq. 740 4	Equation 7	Equation 9	Equation 11

Cleanup Levels for Sediment Contact for Netfishing Scenario

Chemical	Toxicity Data							Cancer Cleanup Level for SCO		
	CPFo (risk per mg/kg-day)	RfDo (mg/kg-day)	GI (unitless)	CPFd (risk per mg/kg-day)	RfDd (mg/kg-day)	AB (unitless)	ABS (unitless)	Ingestion CUL (mg/kg)	Dermal CUL (mg/kg)	Cancer CUL (mg/kg)
Aluminum	nv	1.0E+00	1.0	--	1.0E+00	1.0	0.030	--	--	--
Hexachlorobenzene	1.6E+00	8.0E-04	1.0	1.6E+00	8.0E-04	1.0	0.100	2.88E+00	2.24E+01	2.55E+00
Chloroform	3.1E-02	1.0E-02	1.0	3.1E-02	1.0E-02	1.0	0.001	1.48E+02	1.16E+05	1.48E+02
Source	CLARC	CLARC	MTCA Eq. 740 4	Equation 5	Equation 6	1.0 0.6 for D/F	MTCA Eq. 740 4	Equation 7	Equation 9	Equation 11

Table 4E-7. Sediment Clean

Cleanup Levels for Sediment Co

Chemical	Cancer Cleanup Level for CSL			Noncancer Cleanup Level			Beach Play Scenario	
	Ingestion CUL (mg/kg)	Dermal CUL (mg/kg)	Cancer CUL (mg/kg)	Ingestion CUL (mg/kg)	Dermal CUL (mg/kg)	Noncancer CUL (mg/kg)	SCO (mg/kg)	CSL (mg/kg)
Aluminum	--	--	--	6.68E+05	9.36E+06	6.23E+05	6.23E+05	6.23E+05
Hexachlorobenzene	4.87E+01	2.05E+02	3.93E+01	5.34E+02	2.25E+03	4.32E+02	3.93E+00	3.93E+01
Chloroform	2.51E+03	1.06E+06	2.51E+03	6.68E+03	2.81E+06	6.66E+03	2.51E+02	2.51E+03
Source	Equation 7	Equation 9	Equation 11	Equation 8	Equation 10	Equation 12	Minimum of cancer and noncancer	Minimum of cancer and noncancer

Cleanup Levels for Sediment Co

Chemical	Cancer Cleanup Level for CSL			Noncancer Cleanup Level			Net Fishing Scenario	
	Ingestion CUL (mg/kg)	Dermal CUL (mg/kg)	Cancer CUL (mg/kg)	Ingestion CUL (mg/kg)	Dermal CUL (mg/kg)	Noncancer CUL (mg/kg)	SCO (mg/kg)	CSL (mg/kg)
Aluminum	--	--	--	4.60E+06	1.19E+08	4.43E+06	4.43E+06	4.43E+06
Hexachlorobenzene	2.88E+01	2.24E+02	2.55E+01	3.68E+03	2.86E+04	3.26E+03	2.55E+00	2.55E+01
Chloroform	1.48E+03	1.16E+06	1.48E+03	4.60E+04	3.58E+07	4.59E+04	1.48E+02	1.48E+03
Source	Equation 7	Equation 9	Equation 11	Equation 8	Equation 10	Equation 12	Minimum of cancer and noncancer	Minimum of cancer and noncancer

Abbreviations

AB - gastrointestinal absorption fraction
ABS - dermal absorption fraction
CLARC - Cleanup Levels and Risk Calculation database
CPFd - dermal carcinogenic potency factor
CPFo - oral carcinogenic potency factor
CSL - cleanup screening level
CUL - cleanup level
GI - gastrointestinal absorption conversion factor (relative bioavailability)
nv - no value available
RfDd - dermal reference dose
RfDo - oral reference dose
SCO - sediment cleanup objective
SCUM - Sediment Cleanup User's Manual
TEQ - toxicity equivalence

Table 4E-8. Screening Preliminary Direct Contact Chemicals of Concern Not Included in Risk Assessment

Preliminary Contact Chemical of Concern	Maximum Detect (mg/kg)	SCO Beach Play Child (mg/kg)	SCO Netfishing Adult (mg/kg)	COC for Direct Contact
Aluminum	1.21E+05	6.23E+05	4.43E+06	no
Lead	1.10E+03	2.23E+03	1.23E+03	no
Hexachlorobenzene	4.50E+00	3.93E+00	2.55E+00	YES
Chloroform	5.60E-02	2.51E+02	1.48E+02	no
Source	AECOM et al. (2012) Table 3-2	Table 4E-7 SCO for lead explained in text		--

Abbreviations

COC - chemical of concern

SCO - sediment cleanup objective

Table 4E-9. Potentially Bioaccumulative Chemicals

Chemical of Potential Concern	PBT List	DMMP List 1 or 2	Bioaccumulative COPC	Comment
Metals				
Aluminum				
Antimony				
Arsenic		X	X	
Barium				
Beryllium				
Cadmium	X		X	
Calcium				
Chromium		X	X	Only hexavalent is bioaccumulative
Cobalt				
Copper				
Iron				
Lead	X	X	X	
Magnesium				
Manganese				
Mercury		X	X	
Methylmercury	X		X	
Nickel				
Potassium				
Selenium		X	X	
Silver				
Sodium				
Thallium				
Tin				
Vanadium				
Zinc				
Butyltins				
Tributyltin		X	X	
Low Molecular Weight PAHs				
Naphthalene				
Acenaphthylene				
Acenaphthene				
Fluorene				
Phenanthrene				
Anthracene				
2-Methylnaphthalene				
Total LPAHs				
High Molecular Weight PAHs				
Fluoranthene	X	X	X	
Pyrene		X	X	
Benzo(a)anthracene	X			Addressed as cPAH TEQ
Chrysene	X			Addressed as cPAH TEQ
Benzo(b)fluoranthene	X			Addressed as cPAH TEQ
Benzo(k)fluoranthene	X			Addressed as cPAH TEQ
Total benzofluoranthenes	X			Addressed as cPAH TEQ
Benzo(a)pyrene	X			Addressed as cPAH TEQ
Indeno(1,2,3-cd)pyrene	X			Addressed as cPAH TEQ

Table 4E-9. Potentially Bioaccumulative Chemicals

Chemical of Potential Concern	PBT List	DMMP List 1 or 2	Bioaccumulative COPC	Comment
Dibenzo(a,h)anthracene	X			Addressed as cPAH TEQ
Benzo(g,h,i)perylene	X		X	
cPAH TEQ			X	
Total HPAHs				
Total PAHs				
Phthalates				
Dimethylphthalate				
Diethylphthalate				
Di-n-butylphthalate				
Butylbenzylphthalate				
bis(2-Ethylhexyl)phthalate				
Di-n-octyl phthalate				
Phenols				
Phenol				
2-Methylphenol				
4-Methylphenol				
2,4-Dimethylphenol				
4-Nitrophenol				
Pentachlorophenol		X	X	
Semivolatile Organic Chemicals				
Benzoic acid				
Benzyl alcohol				
Carbazole				
Dibenzofuran				
Hexachlorobenzene	X	X	X	
Isophorone				
n-Nitrosodiphenylamine				
Retene				
Volatile Organic Chemicals				
Acetone				
Benzene				
sec-Butylbenzene				
1,2,4-Trimethylbenzene				
1,3,5-Trimethylbenzene				
n-Propylbenzene				
Ethylbenzene				
Isopropylbenzene				
Chloroform				
1,2-Dichloroethane				
1,1,1-Trichloroethane				
Methylene chloride				
2-Butanone				
2-Hexanone				
4-Methyl-2-pentanone (MIBK)				
Styrene				
Toluene				
4-Isopropyltoluene				

Table 4E-9. Potentially Bioaccumulative Chemicals

Chemical of Potential Concern	PBT List	DMMP List 1 or 2	Bioaccumulative COPC	Comment
Total xylenes				
Pesticides/PCBs				
beta-Chlordane		X		Addressed as chlordane
Chlordane	X	X	X	
DDD				
DDE				
DDT	X	X	X	
Aroclor 1248				
Aroclor 1254				
Aroclor 1260				
Total PCBs	X	X	X	
Source				
Table 1	173-333-310 WAC	ACOE et al. (2016)	--	--

Abbreviations

cPAH - carcinogenic PAH
DMMP - Dredged Materials Management Program (ACOE at al., 2016)
HPAHs - high molecular weight PAHs
LPAHs - low molecular weight PAHs
PBT - persistent, bioaccumulative toxin (173-333-310 WAC)
TEQ - toxicity equivalent

Table 4E-10. Bioaccumulative Chemicals of Concern in Surface Sediment at the Gas Works Park Site

Potentially Bioaccumulative COPC	Crayfish Tissue > Fish Consump. SL	Noncancer Concern ERA	Cancer Concern HHRA	Noncancer Concern HHRA	Bioaccumulative Chemical of Concern
Inorganics and Tributyltin					
Arsenic	YES	YES	YES	YES	YES
Cadmium	no	--	--	--	no
Chromium	YES	no	YES	no	YES
Lead	YES	no	np	na	no
Mercury	YES	no	np	no	no
Methylmercury	na	na	na	na	YES
Selenium	no	--	--	--	no
Tributyltin	no	--	--	--	no
PAHs					
Fluoranthene	no	--	--	--	no
Pyrene	no	--	--	--	no
Benzo(g,h,i)perylene	nc	no	np	no	no
cPAH TEQ	YES	YES	YES	no	YES
Semivolatile Organic Chemicals					
Hexachlorobenzene	na	na	na	na	YES
Pentachlorophenol	YES	no	YES	no	YES
Pesticides and PCBs					
Chlordane	YES	no	YES	no	YES
DDT	YES	no	no	no	no
Total PCBs	YES	no	YES	YES	YES
Source					
Table 2	AECOM et al. (2012) Table 3-6a	AECOM et al. (2012) Table 4-27	AECOM et al. (2012) Table 4-15	AECOM et al. (2012) Table 4-16	--
Criterion	--	LOAEL HQ > 1 Salmon NOAEL HQ > 1	Tribal RME Adult risk > 9E-7 Child risk > 2E-7	Tribal RME Adult HQ >0.9 Child HQ > 2	--

Abbreviations

-- - not evaluated; chemical was screened out earlier in process
cPAH - carcinogenic PAH
ERA - ecological risk assessment
HHRA - human health risk assesment
HQ - hazard quotient for noncancer health effects
LOAEL - lowest observed adverse effect level
na - not analyzed
nc - not calculated because required comparison value not available
NOAEL - no observed adverse effect level
np - not applicable because not carcinogenic
SCSD - supplemental cleanup standards document (AECOM et al., 2012)
SCUM - Sediment Cleanup User's Manual (Ecology, 2019)
TEQ - toxicity equivalent

Table 4E-11. Calculation of Risk-Based Concentrations for Fish Tissue per SCSD

Equations Based on SCUM

1) IF-c = (ACR x BW x AT-c x UCF) / (FCR x FDF x EF x ED)
2) IF-n = (HQ x BW x AT-n x UCF) / (FCR x FDF x EF x ED)
3) RBC-cancer = IF-c / CPF
4) RBC-noncancer = IF-n x RfD
5) Final RBC = 1 / [1/(Minimum Adult RBC) + 1/(Minimum Child RBC)]

RME Tribal Exposure Assumptions from SCSD

Parameter	Abbrev	Adult	Child	Units	Source
Acceptable cancer risk	ACR	1.00E-06	1.00E-06	unitless	SCUM Table 9-4
Noncancer hazard quotient	HQ	1	1	unitless	SCUM Table 9-4
Body weight	BW	81.8	15	kg	SCSD Table 4-8
Averaging time-cancer	AT-c	25,550	25,550	days	SCSD Table 4-8
Averaging time-noncancer	AT-n	25,550	2,190	days	SCSD Table 4-8
Unit conversion factor	UCF	1,000	1,000	g/kg	--
Crayfish+fish ingestion rate	FCR-c	97.5	39	g/day	SCSD Table 4-8
Fractional intake	FDF	1	1	unitless	SCSD Table 4-8
Exposure frequency	EF	365	365	days/year	SCSD Table 4-8
Exposure duration	ED	70	6	years	SCSD Table 4-8
Intake factor-cancer	IF-c	8.39E-04	4.49E-03	kg BW-day/ kg fish	Equation 1
Intake factor-noncancer	IF-n	8.39E+02	3.85E+02	kg BW-day/ kg fish	Equation 2

Table 4E-11. Calculation of Risk-Based Concentrations for Fish Tissue per SCSD

Risk-Based Concentrations for Fish Tissue Based on SCSD

Chemical	CPF (risk per mg/kg-day)	RfD (mg/kg-day)	Adult			Child		
			RBC Cancer (mg/kg)	RBC Noncancer (mg/kg)	Minimum RBC (mg/kg)	RBC Cancer (mg/kg)	RBC Noncancer (mg/kg)	Minimum RBC (mg/kg)
Arsenic	1.50E+00	3.00E-04	5.59E-04	2.52E-01	5.59E-04	2.99E-03	1.15E-01	2.99E-03
Cadmium	nv	1.00E-03	--	8.39E-01	8.39E-01	--	3.85E-01	3.85E-01
Methylmercury	nv	1.00E-04	--	8.39E-02	8.39E-02	--	3.85E-02	3.85E-02
Tributyltin	nv	3.00E-04	--	2.52E-01	2.52E-01	--	1.15E-01	1.15E-01
Total DDTs	3.40E-01	5.00E-04	2.47E-03	4.19E-01	2.47E-03	1.32E-02	1.92E-01	1.32E-02
Source	SCSD Table 4-12		Equation 3	Equation 4	Equation 5	Equation 3	Equation 4	Equation 5

Abbreviations

CPF - carcinogenic potency factor
nv - no value available
RBC - risk-based concentration
RfD - reference dose
SCSD - supplemental cleanup standards document (AECOM et al., 2012)
SCUM - Sediment Cleanup User's Manual (Ecology, 2019)

Table 4E-12. Comparison of Risk-Based Concentrations for Fish Tissue between SCSD and SCUM

Chemical	SCUM Tulalip Adult	SCSD Adult	SCSD Child	Adult SCSD / SCUM Adjusted	Child SCSD / SCUM Adjusted
Arsenic	5.13E-04	5.59E-04	2.99E-03	1.1	6
Cadmium	7.69E-01	8.39E-01	3.85E-01	1.1	0.5
Methylmercury	7.69E-02	8.39E-02	3.85E-02	1.1	0.5
Tributyltin	2.31E-01	2.52E-01	1.15E-01	1.1	0.5
DDT	2.26E-03	2.47E-03	1.32E-02	1.1	6
Source	SCUM Appendix K with adjusted fish consumption rate	Table 4E-11		--	

All concentrations in mg/kg.

Abbreviations

SCSD - supplemental cleanup standards document (AECOM et al., 2012)

SCUM - Sediment Cleanup User's Manual (Ecology, 2019)

APPENDIX 4F
Screening Level Calculations

Table 4F-1

Groundwater Screening Level Calculations Based on Protection of Sediment

Gas Works Park Site

Seattle, Washington

Constants

Parameter	Unit	Value
Conversion Factor	mg/µg	1E-03
Dilution Factor	unitless	1
Water-filled Porosity[a]	ml/ml	0.32
Dry Sediment Bulk Density[b]	kg/L	1.8

Groundwater Screening Levels[c]

Chemicals of Potential Concern	Sediment Screening Levels (Tables 4-3 and 4-4) SCO mg/kg	Sediment Screening Levels (Tables 4-3 and 4-4) CSL mg/kg	Koc[d] L/kg	foc[e] g/g	Kd[f] L/kg	Groundwater Screening Level Protective of Sediment Sediment SCO (µg/L)	Groundwater Screening Level Protective of Sediment Sediment CSL (µg/L)
Conventionals							
Sulfide	39	61	--	0.13	--	NC	NC
PAHs							
Total PAHs	17	30	--	0.13	--	NC	NC
Total cPAH TEQ	0.021	0.21	9.69E+05	0.13	1.3E+05	1.7E-04	1.7E-03
SVOCs							
4-Methylphenol	0.26	2.0	--	0.13	--	NC	NC
Benzoic acid	2.9	3.8	6.00E-01	0.13	7.8E-02	1.1E+04	1.5E+04
Bis(2-ethylhexyl)phthalate	0.50	22	1.11E+05	0.13	1.4E+04	3.5E-02	1.5E+00
Carbazole	0.90	1.1	3.39E+03	0.13	4.4E+02	2.0E+00	2.5E+00
Dibenzofuran	0.20	0.68	--	0.13	--	NC	NC
Di-n-butyl phthalate	0.38	1.0	1.57E+03	0.13	2.0E+02	1.9E+00	4.9E+00
Di-n-octyl phthalate	0.039	1.1	8.32E+07	0.13	1.1E+07	3.6E-06	1.0E-04
Hexachlorobenzene	0.005	0.005	8.00E+04	0.13	1.0E+04	4.8E-04	4.8E-04
Pentachlorophenol	0.02	0.02	5.92E+02	0.13	7.7E+01	2.6E-01	2.6E-01
Phenol	0.12	0.21	2.88E+01	0.13	3.7E+00	3.1E+01	5.4E+01
Butyltins							
Tributyltin	0.047	0.32	--	0.13	--	NC	NC
Metals							
Arsenic	11	24	--	0.13	2.90E+01	3.8E+02	8.2E+02
Cadmium	2.1	5.4	--	0.13	6.70E+00	3.1E+02	7.9E+02
Chromium	62	62	--	0.13	1.00E+03	6.2E+01	6.2E+01
Copper	400	1,200	--	0.13	2.20E+01	1.8E+04	5.4E+04
Lead	360	1,300	--	0.13	1.00E+04	3.6E+01	1.3E+02
Mercury	0.66	0.8	--	0.13	5.20E+01	1.3E+01	1.5E+01
Nickel	50	110	--	0.13	6.50E+01	7.7E+02	1.7E+03
Silver	0.57	1.7	--	0.13	8.30E+00	6.7E+01	2.0E+02

Notes:

[a] Site-specific value representative of fill/outwash from ENSR|AECOM's "North Lake Union Groundwater Modeling Memorandum, Draft" (Februrary 2008).

[b] Site-specific representative of fill/outwashfrom ENSR|AECOM's "North Lake Union Groundwater Modeling Memorandum, Draft" (Februrary 2008).

[c] Groundwater SL = Sediment SL / (CF * DF * (K_d + Ow/pb)); Equation from Ecology's "Lower Duwamish Waterway, Preliminary Cleanup Level Workbook, Supplemental Information" white paper dated December 2018.

[d] Washington State Department of Ecology - Cleanup Levels and Risk Calculations (CLARC) Master Spreadsheet, January 2020.

[e] Site-specific; mean value for surface sediment within the AOI.

[f] Kd = Koc * foc; metals Kd values from CLARC Master Spreadsheet, January 2020.

NC = not calculated. No Koc available.

Table 4F-2

Sediment Screening Level Calculations Based on Direct Contact (Ingestion and Dermal Contact)

Gas Works Park Site

Seattle, Washington

Constants[a]

Parameter	Unit	Scenario			
		Beach Play Child		Tribal Net Fishing Adult	
		Cancer	Noncancer	Cancer	Noncancer
Cancer Risk (CR)/Hazard Quotient (HQ)	unitless	1E-06 (SCO) 1E-05 (CSL)	1E+00 (SCO) 1E+00 (CSL)	1E-06 (SCO) 1E-05 (CSL)	1E+00 (SCO) 1E+00 (CSL)
Body Weight (BW)	kg	15	15	75	75
Averaging Time (AT)	days	25,550	2,190	25,550	25,550
Exposure Frequency (EF)	days/year	41	41	119	119
Exposure Duration (ED)	years	6	6	70	70
Ingestion Rate (IR)	mg/day	200	200	50	50
Dermal Surface Area (SA)	cm^2	2,378	2,378	3,212	3,212
Sediment to Skin Adherence Factor (AF)	mg/cm^2-day	0.2	0.2	0.02	0.02
Conversion Factor (CF)	kg/mg	1E-06	1E-06	1E-06	1E-06

Sediment Screening Levels[b,c]

Analyte	Oral Cancer Potency Factor[d] (CPFo)	Oral Reference Dose[d,e] (RfDo)	Dermal Absorption Fraction[f] (ABS)	Gastrointestinal Absorption Factor[d] (GI)	Dermal Cancer Potency Factor[g] (CPFd)	Dermal Reference Dose[h] (RfDd)	Scenario				Minimum Value
							Beach Play Child		Tribal Net Fishing Adult		
	kg-day/mg	mg/kg-day	unitless	unitless	kg-day/mg	mg/kg-day	Cancer - mg/kg	Noncancer - mg/kg	Cancer - mg/kg	Noncancer - mg/kg	mg/kg
Sediment Cleanup Objectives											
Total cPAHs TEQ	1.0	0.0003	0.13	1	1.0	0.0003	0.90	153	0.68	1,200	0.68
Hexachlorobenzene	1.6	0.0008	0.1	1	1.6	0.0008	3.9	432	2.5	3,300	2.5
Arsenic	1.5	0.0003	0.03	1	1.5	0.0003	4.8	187	3.0	1,300	3.0
Cleanup Screening Levels											
Total cPAHs TEQ	1.0	0.0003	0.13	1	1.0	0.0003	9.0	153	6.8	1,200	6.8
Hexachlorobenzene	1.6	0.0008	0.1	1	1.6	0.0008	39	432	25	3,300	25
Arsenic	1.5	0.0003	0.03	1	1.5	0.0003	48	187	30	1,300	30

Notes:

[a] Values are from Ecology's "Sediment Cleanup User's Manual (SCUM), Guidance for Implementing the Cleanup Provisions of the Sediment Management Standards, Chapter 173-204 WAC (revised December 2019).

[b] Noncancer SL = (HQ * BW * AT)/(EF * ED * ((1/RfDo * (IR * FI * CF)) + (1/RfDd * (SA * AF * ABS * CF)))

[c] Cancer SL = (CR * BW * AT)/(EF * ED * ((CPFo * IR * FI * CF) + (CPFd * SA * AF * ABS * CF)))

[d] Washington State Department of Ecology - Cleanup Levels and Risk Calculations (CLARC) Master Spreadsheet, January 2020.

[e] The oral reference dose of 0.003 mg/kg-day for Total cPAHs TEQ only applies to benzo(a)pyrene, one of the seven cPAHs that are used to calculate Total cPAHs TEQ. The use of the benzo(a)pyrene RFD to calculate a noncancer sediment screening level for Total cPAH TEQ does not affect the selection of sediment screening levels, which are driven by cancer effects.

[f] Values are from Exhibit 3-4 in EPA's "Risk Assessment Guidance for Superfund, Volumen1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment" (July 2004).

[g] Dermal cancer potency factor = oral cancer potency factor/gastrointestinal absorption factor.

[h] Dermal reference dose = oral reference dose * gastrointestinal absorption factor.

cm^2 = square centimeters

Shading indicates basis for minimum screening level.

See text for full acronym and abbreviation list.

Table 4F-3

Sediment Cleanup Level Calculations Based on Direct Contact (Ingestion and Dermal Contact) - (cPAHs; Carcinogenic Screening Levels Only)

Gas Works Park Site

Seattle, Washington

Constants[a]

Parameter	Units	Beach Play Child and Netfishing Adult			
		0-2 years old	2-6 years old	6-16 years old	16-30 years old
		Cancer	Cancer	Cancer	Cancer
Cancer Risk (CR)	unitless	1E-06 (SCO) 1E-05 (CSL)	1E-06 (SCO) 1E-05 (CSL)	1E-06 (SCO) 1E-05 (CSL)	1E-06 (SCO) 1E-05 (CSL)
Age-Dependent Adjustment Factor (ADAF)	unitless	10	3	3	1
Body Weight (BW)	kg	10	17	44	81
Averaging Time (AT)	days	25,550	25,550	25,550	25,550
Exposure Frequency (EF)	days/year	41	41	119	119
Exposure Duration (ED)	years	2	4	10	54
Ingestion Rate (IR)	mg/day	200	200	50	50
Fractional Intake (FI)	unitless	1	1	1	1
Dermal Surface Area (SA)	cm^2	1,952	2,591	2,161	3,407
Sediment to Skin Adherence Factor (AF)	mg/cm^2-day	0.2	0.2	0.02	0.02
Conversion Factor (CF)	kg/mg	1E-06	1E-06	1E-06	1E-06

Beach Play Child - Sediment Screening Levels[b]

Analytes	Oral Cancer Potency Factor[c] (CPFo)	Dermal Absorption Fraction[d] (ABS)	Gastrointestinal Absorption Factor[c] (GI)	Dermal Cancer Potency Factor[e] (CPFd)	Beach Play Child				
					0-2 years old	2-6 years old	n/a	n/a	0-6 years old[f]
	kg-day/mg	unitless	unitless	kg-day/mg	mg/kg	mg/kg	n/a	n/a	mg/kg
Sediment Cleanup Objectives									
Benzo(a)pyrene	1	0.13	1	1	1.2	3.3	n/a	n/a	0.90
Cleanup Screening Levels									
Benzo(a)pyrene	1	0.13	1	1	12	33	n/a	n/a	9.0

Netfishing Adult - Sediment Screening Levels[b]

Analytes	Oral Cancer Potency Factor[c] (CPFo)	Dermal Absorption Fraction[d] (ABS)	Gastrointestinal Absorption Factor[c] (GI)	Dermal Cancer Potency Factor[e] (CPFd)	Netfishing Adult				
					0-2 years old	2-6 years old	6-16 years old	16-30 years old	0-30 years old[g]
	kg-day/mg	unitless	unitless	kg-day/mg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Sediment Cleanup Objectives									
Benzo(a)pyrene	1	0.13	1	1	1.2	3.3	5.7	5.5	0.68
Cleanup Screening Levels									
Benzo(a)pyrene	1	0.13	1	1	12	33	57	55	6.8

Notes:

[a] Values are from Ecology's "Sediment Cleanup User's Manual (SCUM), Guidance for Implementing the Cleanup Provisions of the Sediment Management Standards, Chapter 173-204 WAC (revised December 2019).

[b] Cancer SL = (CR * BW * AT)/(EF * ED * ((CPFo *ADAF * IR * FI * CF) + (CPFd * ADAF * SA * AF * ABS * CF)))

[c] Washington State Department of Ecology - Cleanup Levels and Risk Calculations (CLARC) Master Spreadsheet, January 2020.

[d] Values are from Exhibit 3-4 in EPA's "Risk Assessment Guidance for Superfund, Volumen1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment" (July 2004).

[e] Dermal cancer potency factor = oral cancer potency factor/gastrointestinal absorption factor.

[f] 0-6 SL = 1/((1/[0-2 SL]) + (1/[2-6 SL]))

[g] 0-30 SL = 1/((1/[0-2 SL]) + (1/[2-6 SL]) + (1/[6-16 SL]) + (1/[16-30 SL]))

cm^2 = square centimeters

See text for full acronym and abbreviation list.