APPENDIX B

Groundwater

Appendix B Table of Contents

Appendix B Groundwater

B.1 GROUNDWATER POTABILITY

The potential for groundwater to be used as a drinking water source must be examined before removal action levels (RvALs) based on alternative groundwater exposure pathways appropriate for Terminal-117 (T-117) can be developed. For the purpose of this evaluation, groundwater at T-117 includes the groundwater associated with theT-117 Upland Study Area, the portions Dallas Avenue S, S Donovan Street, and 17th Avenue S adjacent to the T-117 Upland Study Area, and the Basin Oil recontamination assessment area (Map B-1). Throughout this appendix, this groundwater is referred to as the "groundwater in the vicinity of the T-117 Upland Study Area." Sufficient data do not exist to evaluate potability for groundwater beneath the remainder of the T-117 early action area (EAA).

Federal and state regulations require that groundwater be remediated such that groundwater contaminant concentrations are sufficiently low to be protective of the highest beneficial use, which is generally considered to be potable water (i.e., drinking water). Where groundwater is determined to be non-potable, an alternative highest beneficial use (i.e., surface water) must be evaluated. In both cases, contaminant concentrations must also be sufficiently low to be protective of other pathways and receptors (e.g., air, construction workers).

This appendix presents an evaluation of the potability of groundwater in the vicinity of T-117 in accordance with the criteria in the Model Toxics Control Act (MTCA) (WAC 173-340-720(2)). MTCA regulations are considered because of the Environmental Protection Agency's (EPA's) policy of "deferring to a State's determination of current and future groundwater uses" (EPA 2009).

MTCA Potability Evaluation

WAC 173-340-720(2) sets forth the procedure for a groundwater potability determination in Washington State. The portions of the MTCA regulations pertaining to potability are quoted below, followed by a discussion of how the groundwater in the vicinity of T-117 relates to the potability requirements. The total dissolved solids concentration provided below in subsection *(ii)* is an example. High natural background levels of other organic or inorganic constituents also meet this requirement.

MTCA Regulations Pertaining to Potability

> *WAC-173-340-720(2) Potable ground water defined. Ground water shall be classified as potable to protect drinking water beneficial uses unless the following can be demonstrated:*
>
> *(a) The ground water does not serve as a current source of drinking water;"*

(b) The ground water is not a potential future source of drinking water for any of the following reasons:

(i) The ground water is present in insufficient quantity to yield greater than 0.5 gallon per minute on a sustainable basis to a well constructed in compliance with chapter 173-160 WAC and in accordance with normal domestic water well construction practices for the area in which the site is located;

(ii) The ground water contains natural background concentrations of organic or inorganic constituents that make use of the water as a drinking water source not practicable. Ground water containing total dissolved solids at concentrations greater than 10,000 mg/L shall normally be considered to have fulfilled this requirement; or

(iii) The ground water is situated at a great depth or location that makes recovery of water for drinking water purposes technically impossible; and"

(c) The department determines it is unlikely that hazardous substances will be transported from the contaminated ground water to ground water that is a current or potential future source of drinking water, as defined in (a) and (b) of this subsection, at concentrations which exceed ground water quality criteria published in chapter WAC 173-340-200. In making a determination under this provision, the department shall consider site-specific factors including:

(i) The extent of affected ground water;

(ii) The distance to existing water supply wells;

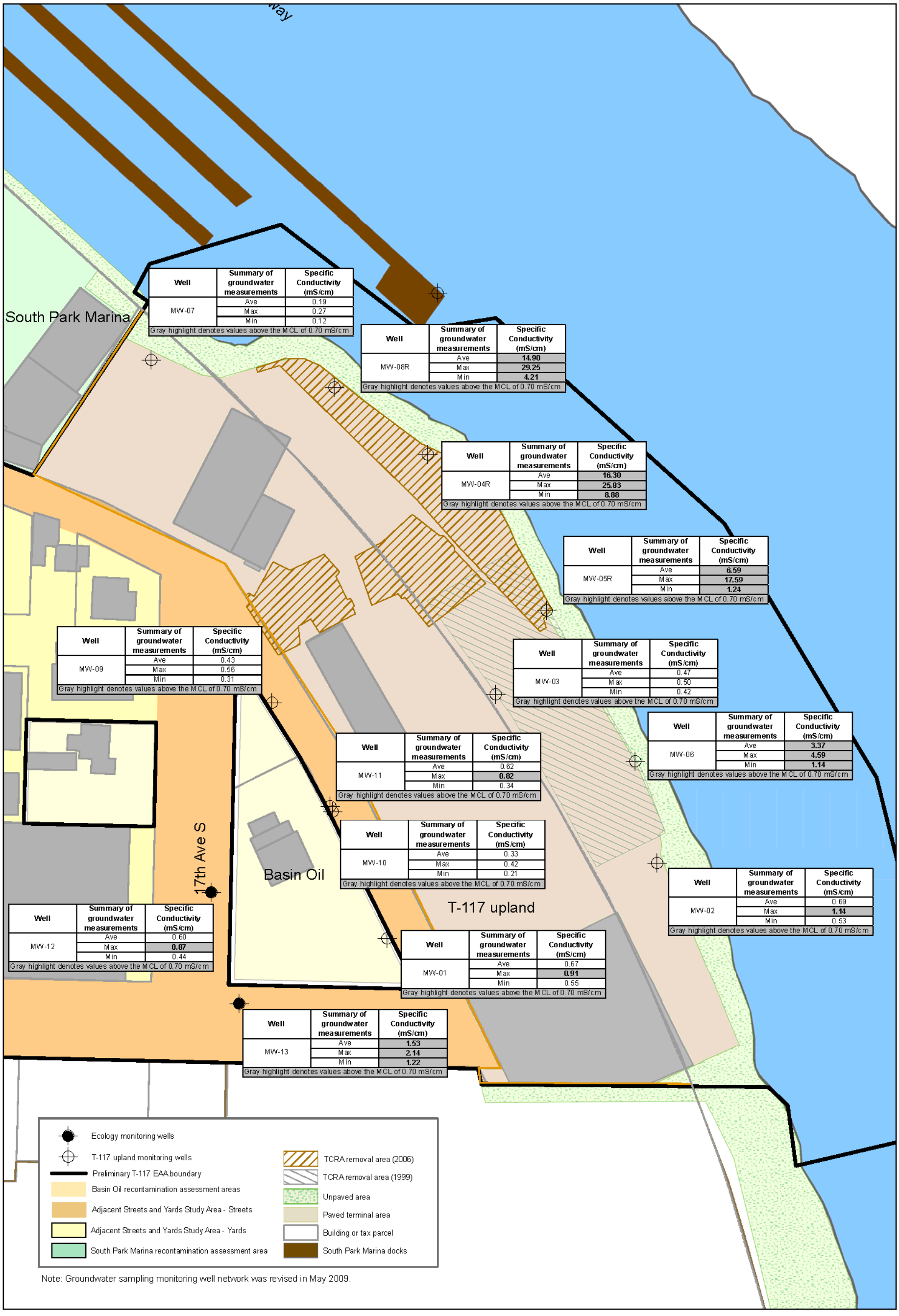
(iii) The likelihood of interconnection between the contaminated ground water and ground water that is a current or potential future source of drinking water due to well construction practices in the area of the state where the site is located;

(iv) The physical and chemical characteristics of the hazardous substance;

(v) The hydrogeologic characteristics of the site;

(vi) The presence of discontinuities in the affected geologic stratum; and

(vii) The degree of confidence in any predictive modeling performed.



Well	Summary of groundwater measurements	Specific Conductivity (mS/cm)
MW-07	Ave	0.19
	Max	0.27
	Min	0.12

Gray highlight denotes values above the MCL of 0.70 mS/cm

Well	Summary of groundwater measurements	Specific Conductivity (mS/cm)
MW-08R	Ave	**14.90**
	Max	**29.25**
	Min	**4.21**

Gray highlight denotes values above the MCL of 0.70 mS/cm

Well	Summary of groundwater measurements	Specific Conductivity (mS/cm)
MW-04R	Ave	**16.30**
	Max	**25.83**
	Min	**8.88**

Gray highlight denotes values above the MCL of 0.70 mS/cm

Well	Summary of groundwater measurements	Specific Conductivity (mS/cm)
MW-05R	Ave	**6.59**
	Max	**17.59**
	Min	**1.24**

Gray highlight denotes values above the MCL of 0.70 mS/cm

Well	Summary of groundwater measurements	Specific Conductivity (mS/cm)
MW-09	Ave	0.43
	Max	0.56
	Min	0.31

Gray highlight denotes values above the MCL of 0.70 mS/cm

Well	Summary of groundwater measurements	Specific Conductivity (mS/cm)
MW-03	Ave	0.47
	Max	0.50
	Min	0.42

Gray highlight denotes values above the MCL of 0.70 mS/cm

Well	Summary of groundwater measurements	Specific Conductivity (mS/cm)
MW-11	Ave	0.62
	Max	**0.82**
	Min	0.34

Gray highlight denotes values above the MCL of 0.70 mS/cm

Well	Summary of groundwater measurements	Specific Conductivity (mS/cm)
MW-06	Ave	**3.37**
	Max	**4.59**
	Min	**1.14**

Gray highlight denotes values above the MCL of 0.70 mS/cm

Well	Summary of groundwater measurements	Specific Conductivity (mS/cm)
MW-10	Ave	0.33
	Max	0.42
	Min	0.21

Gray highlight denotes values above the MCL of 0.70 mS/cm

Well	Summary of groundwater measurements	Specific Conductivity (mS/cm)
MW-02	Ave	0.69
	Max	**1.14**
	Min	0.53

Gray highlight denotes values above the MCL of 0.70 mS/cm

Well	Summary of groundwater measurements	Specific Conductivity (mS/cm)
MW-12	Ave	0.60
	Max	**0.87**
	Min	0.44

Gray highlight denotes values above the MCL of 0.70 mS/cm

Well	Summary of groundwater measurements	Specific Conductivity (mS/cm)
MW-01	Ave	0.67
	Max	**0.91**
	Min	0.55

Gray highlight denotes values above the MCL of 0.70 mS/cm

Well	Summary of groundwater measurements	Specific Conductivity (mS/cm)
MW-13	Ave	**1.53**
	Max	**2.14**
	Min	**1.22**

Gray highlight denotes values above the MCL of 0.70 mS/cm

Map B-1. Specific conductivity measurements

Discussion of Groundwater in the Vicinity of the T-117 Upland Study Area

In accordance with WAC 173-340-720(2)(a), groundwater in the vicinity of the T-117 Upland Study Area is not a current source of drinking water. The nearest potable well is a Class A (i.e., municipal) well, 293 ft deep, located approximately 2.6 miles south of the site in the City of SeaTac (King County 2009). The closest reservoir is approximately 1.5 miles upgradient to the west in West Seattle.

According to WAC 173-340-720(2)(b), the groundwater in the vicinity of the T-117 Upland Study Area is not a potential future source of drinking water because it contains natural background concentrations of inorganic constituents that make use of the water as a drinking water source not practicable. The appropriate criteria for this determination are the primary and the secondary maximum contaminant levels (MCLs) listed in WAC 246-290-31(3)(a): "the secondary MCLs are incorporated into the Washington State Department of Health's regulations for public water supplies. Inasmuch as the state's standards remain an applicable state law, they are still considered applicable standards under MTCA" (Ecology 2001). Compliance with MCLs is based on an annual running (i.e., based on latest four quarters) average (WAC 246-290-310(3)(b)).

Much of the groundwater in the vicinity of the T-117 Upland Study Area exceeds the Washington State drinking water criterion for specific conductivity (secondary MCL: 0.7 mS/cm (WAC 246-290-310(3)(a))). According to field data collected during the previous eight groundwater monitoring events (ENSR|AECOM 2008a, b, c; AECOM 2009a, b, c, d), 5 of 13 wells in the vicinity of the T-117 Upland Study Area, including 4 shoreline wells and 1 well upgradient of the T-117 Upland Study Area, exceeded the criterion for average specific conductivity (see Map B-1). Nine of thirteen wells exceeded the secondary MCL for at least one sampling event, including four wells upgradient of the T-117 Upland Study Area. Although isolated areas of groundwater in the center of the T-117 Upland Study Area do not exceed the secondary MCL, the high specific conductivity upgradient and downgradient indicates that the area is significantly affected by high specific conductivity and could not be used as a source of drinking water in the future.

Relative to WAC 173-340-720(2)(c), groundwater in the vicinity of the T-117 Upland Study Area will not migrate into groundwater that is a current or potential source of drinking water. Groundwater in this area flows directly into the non-potable Lower Duwamish Waterway (LDW). Map 2-5 of the EE/CA shows that the average groundwater gradient onsite is strongly toward the adjacent LDW. Surface water in the vicinity of the shoreline is a varying mixture of salt and fresh water and is, therefore, not suitable for use as drinking water. In addition, domestic water use is not a designated use of the LDW under WAC 173-201A-602. Based on regional studies of the lower Duwamish Valley, the shallow groundwater in the vicinity of the T-117 Upland Study Area will not adversely affect the potential for deeper groundwater (typically greater than 100 ft in the depth) to be used as a source of drinking water for

several reasons: 1) groundwater becomes more saline with depth in this area, and therefore the deeper groundwater is non-potable; and 2) the deeper groundwater flows upward, minimizing the possibility of contamination from the shallow aquifer (Floyd|Snider 2008; Herman and Wineman 1997).

As indicated above, the shallow groundwater at T-117 is not potable. The non-potable classification is further supported by the extremely low likelihood that a domestic supply well would be placed in the vicinity of the T-117 Upland Study Area. This determination was made under MTCA (WAC-173-340-720(2)(d)) as follows:

> *WAC-173-340-720(2) (continued)*
>
> *(d) Even if ground water is classified as a potential future source of drinking water under (b) of this subsection, the department recognizes that there may be sites where there is an extremely low probability that the ground water will be used for that purpose because of the site's proximity to surface water that is not suitable as a domestic water supply. An example of this situation would be shallow ground waters in close proximity to marine waters such as on Harbor Island in Seattle. At such sites, the department may allow ground water to be classified as non-potable for the purposes of this section if each of the following conditions can be demonstrated. These determinations must be for reasons other than that the ground water or surface water has been contaminated by a release of a hazardous substance at the site.*
>
> > *(i) The conditions specified in (a) and (c) of this subsection are met;"*
> >
> > *(ii) There are known or projected points of entry of the ground water into the surface water;*
> >
> > *(iii) The surface water is not classified as a suitable domestic water supply source under chapter173-201A WAC; and*
> >
> > *(iv) The ground water is sufficiently hydraulically connected to the surface water that the ground water is not practicable to use as a drinking water source.*

Furthermore, relative to WAC 173-340-720(2)(d)(ii)-(iii) and as stated above, groundwater in the vicinity of the T-117 Upland Study Area flows into the adjacent LDW, which is designated by WAC 173-201A-602 as not appropriate for domestic use.

Finally, regarding WAC 173-340-720(2)(d)(iv) and based on the tidal study (ENSR|AECOM 2008a), groundwater is sufficiently connected hydrologically to surface water to make groundwater use impractical in the vicinity of the T-117 Upland Study Area. Tidal influence was measured in all shoreline wells and in MW-3, which is located approximately 100 ft from the LDW (see Map 2-5 of the EE/CA). In addition, the use of a pumping well at this location could create a drawdown at significant distances, though much less than the 1,000 ft noted in (Herman and Wineman 1997). Under these conditions, the infiltration of surface water from the adjacent LDW would occur across the entire vicinity of the T-117 Upland Study Area.

Infiltration of water of poor quality into the vicinity of the T-117 Upland Study Area is not only expected from the LDW but also from upgradient areas (i.e., east and south of the T-117 EAA). A bedrock outcropping is present immediately south of the T-117 EAA on the adjacent Boeing Company property. The weathered surface of this bedrock provides a potential preferential hydraulic connection between the shallow and deeper aquifers. This hydraulic connection is evident in the potentiometric surface map and in the specific conductivity data for groundwater (Map 2-5). The potentiometric surface map shows an anomalously high hydraulic head in MW-13, which is also reflected in MW-1 and MW-12. MW-13 has the highest specific conductivity among the non-tidally influenced wells and is located closest to local high bedrock elevations to the south of the T-117 EAA. A spatial decrease in specific conductivity is evident in MW-1, MW-11, and MW-12.It should be noted that the groundwater elevations for MW-12 and MW-13 are projected on the potentiometric surface map using gauging data collected at a different time than the tidal study. The method used for projecting the groundwater elevations is included on Map 2-5

Deeper groundwater in the lower Duwamish Valley is considered brackish, and an upward hydraulic gradient exists. The freshwater/ saltwater interface was identified in the south valley area at the Boeing plant near the King County International Airport between 50 and 100 ft below grade (Weston 1996, as cited in Herman and Wineman 1997). Hydraulic heads at depths greater than 100 ft beneath the valley indicate upward gradients (Floyd|Snider 2008; Herman and Wineman 1997). These regional data, together with the site-specific groundwater flow patterns and conductivity, suggest that non-potable deep groundwater is influencing shallow groundwater quality and that this influence would increase with the addition of shallow groundwater pumping wells.

In summary, the limited areas in the vicinity of the T-117 EAA that could have potable water based on conductivity measurements are in close proximity to and are hydrologically connected with both non-potable groundwater and surface water sources.

In addition to the MTCA non-potability determination, local codes prohibit the construction of drinking water wells in the vicinity of the T-117 Upland Study Area:

- Based on the King County Board of Health regulations and King County Code sections cited below, a drinking water well would be prohibited at the site.
- KCBOH Code § 12.32.010.D requires that lots created by subdivision, short subdivision, rezone or lot line adjustment created after 1972 which are less than 5 acres must be connected to a public water supply.
- KCBOH Code § 12.32.010.A requires that property owners undertaking "new development" must connect to available public water supply. "Development" is defined broadly to include "land utilization" and according to King County staff would itself include any proposal to install a groundwater extraction well, which effectively prohibits installation of such a well.

- King County Code § 13.24.140:For properties outside the City of Seattle, the King County Water and Sewer Comprehensive Plan contained in Title 13 of the King County Code applies. The Plan requires all new development within the Urban Growth Area to be served by the appropriate existing Group A water supplier, unless service cannot be timely and reasonably provided. Since all the properties near T-117 are already connected to public water, any new development at or near T-117 must hook up to public water.
- KCBOH Code § 12.24.010A states that drinking water supply must come from the "highest quality source feasible." The highest quality source available at the T-117 EAA is the SPU water supply from the Cedar River Watershed.
- KCBOH Code § 12.24.010(C) specifies the minimum setbacks for drinking water wells, which are 100 feet from surface water, roads, utilities, and buildings. The T-117 Upland Study Area is a narrow piece of land (approximately 200 feet wide) situated between Dallas Avenue S and the LDW.

These King County Board of Health code sections reaffirm state regulations found at WAC-246-290-130(1) and 246-290-135(2)(b).

Based on the above analysis, ingestion is not a potential exposure pathway for groundwater. Under WAC 173-340-720(6)(c), other potential exposure pathways must be addressed during development of cleanup levels (CULS) (or more specifically, the development of RvALs for the T-117 NTCRA). The following sections develop screening and RvALs for groundwater with surface water as the highest beneficial use.

B.2 GROUNDWATER SCREENING LEVELS

The procedure for developing MTCA Method B CULs (WAC 173-340-730(3)) was used to develop groundwater screening levels (SLs) for this EE/CA. Figure B-1 shows this process. The groundwater SLs are intended to protect surface water beneficial uses. The following applicable or reasonable and appropriate requirements (ARARs) were considered:

- Water quality standards published in WAC 173-201A
- Ambient water quality criteria published under Section 304 of the federal Clean Water Act, excluding those human health criteria based on consumption of both water and organisms because surface water in the LDW at T-117 is not classified as suitable for domestic water supply according to WAC 173-201A
- National Toxics Rule (40 CFR 131), excluding those human health criteria based on consumption of both water and organisms because surface water in the LDW at T-117 is not classified as suitable for domestic water supply according to WAC 173-201A

Criteria are available for both marine and freshwater environments. Portions of the LDW could be considered marine or fresh, depending on salinity. State regulations (WAC 173-201A-260(3)(e)) indicate that freshwater criteria are applied only when the vertically averaged daily maximum salinity values are less than 1 part per thousand (ppt) more than 95% of the time. By this measure, the LDW would be considered marine: data available from the Lower Duwamish Waterway Group hydrodynamic model and from King County surface water quality monitoring indicate that salinity exceeds 1 ppt more than 90% of the time in the vicinity of T-117. However, based on previous EPA directives at the nearby Boeing Plant 2 site (Environmental Partners 2006), EPA directed that the lowest criteria, whether marine or fresh, be selected as SLs for groundwater.

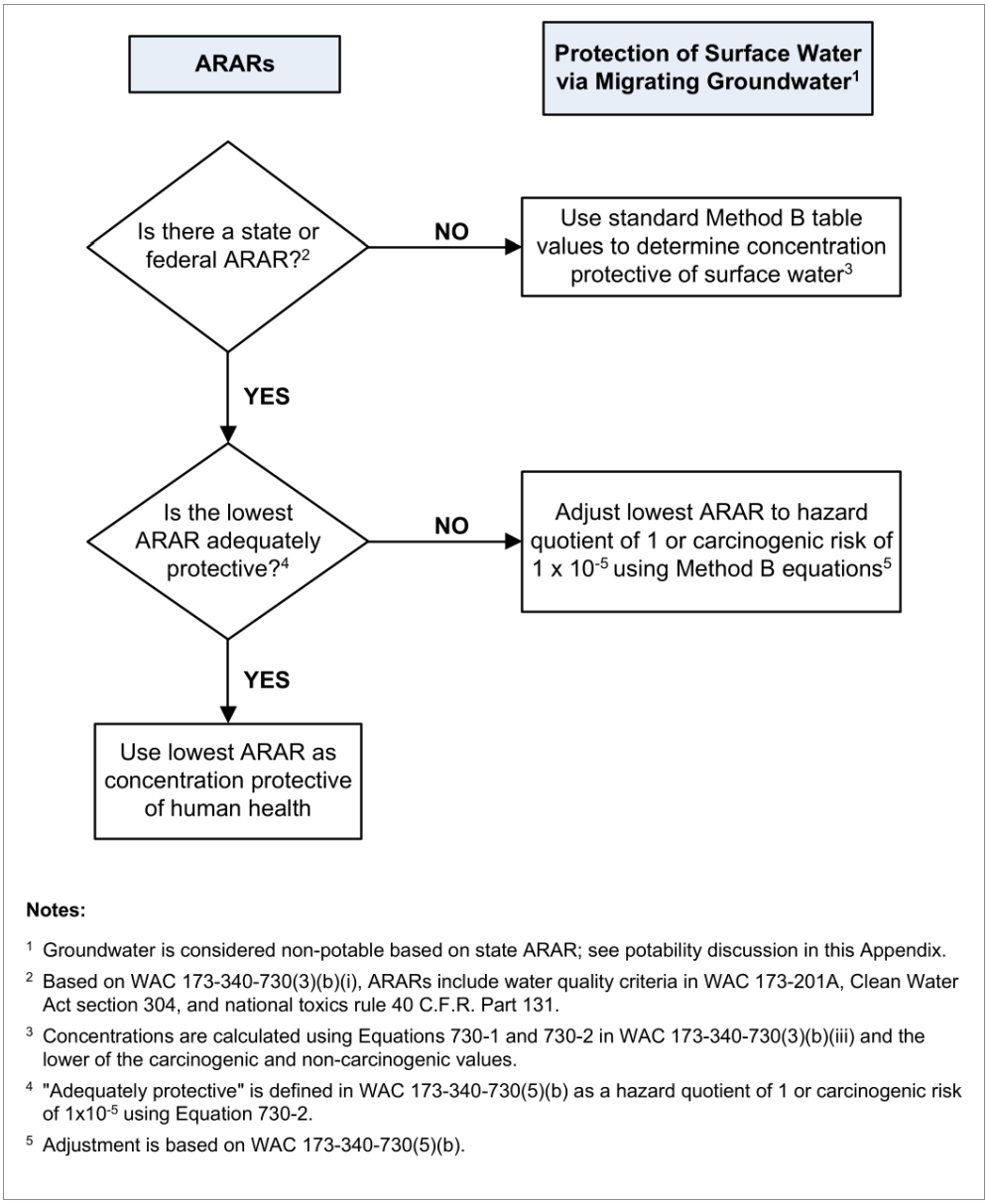


Figure B-1. Development of groundwater screening levels

Table B-1 summarizes the groundwater SLs used in this EE/CA. With six exceptions, an ARAR sufficiently protective of surface water beneficial uses (specifically, human consumption of organisms) was available. The total petroleum hydrocarbons SL was the MTCA Method A CUL of 0.5 mg/L for diesel and heavy oils based on WAC 173-340-730(3)(iii)(C). No relevant criteria were available for 1-methylnaphthalene, phenanthrene, xylene, acetone, and cis-1,2-dichlorethene.

Table B-1. Groundwater screening levels

All Detected Chemicals	Concentration (µg/L)											
	Aquatic Life Criteria[a]								Human Health Criteria for Consumption of Organisms[f]	Surface Water Criteria		SL Used for EE/CA
	Washington State WQC				National AWQC					MTCA Method B		
	Freshwater		Marine		Freshwater		Marine					
	Chronic[b]	Acute[c]	Chronic[b]	Acute[c]	CCC[d]	CMC[e]	CCC[d]	CMC[e]		Carcinogen	Non-Carcinogen	
Metals and Trace Elements												
Arsenic	190	360	36	69	150	340	36	69	0.14[g, h]	0.098	18	0.14
Cadmium	*1.0*	*3.7*	9.3	42	*0.25*	*2.0*	8.8	40	nc	nc	20	0.25
Chromium (hexavalent)	10	15	50	1,100	11	16	50	1,100	nc	nc	486	10
Chromium (trivalent)	*180*	*550*	nc	nc	*74*	*570*	nc	nc	nc	nc	243,056	10[k]
Copper	*11*	*17*	3.1	4.8	*9*	*13*	3.1	4.8	nc	nc	2,665	3.1
Nickel	*160*	*1,400*	8.2	74	*52*	*470*	8.2	74	4,600	nc	1,103	8.2
Silver	nc	*3.4*	nc	1.9	nc	*3.2*	nc	1.9	nc	nc	25,926	1.9
Zinc	100	*110*	81	90	120	*120*	81	90	26,000	nc	16,548	81
TPH												
Total TPH	nc	nc	nc	Nc	nc	nc	nc	nc	nc	nc	nc	500[j]
PCBs												
Total PCBs	0.014	2	0.03	10	0.014	nc	0.03	nc	0.000064[g]	0.00011	nc	0.000064
PAHs												
1-Methylnaphthalene	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc
Acenaphthene	nc	nc	nc	nc	nc	nc	nc	nc	990	nc	643	990[l]
Anthracene	nc	nc	nc	nc	nc	nc	nc	nc	40,000	nc	25,926	40,000[l]
Benzo(a)anthracene	nc	nc	nc	nc	nc	nc	nc	nc	0.018[g]	0.030	nc	0.018
Benzo(a)pyrene	nc	nc	nc	nc	nc	nc	nc	nc	0.018[g]	0.030	nc	0.018
Benzo(b)fluoranthene	nc	nc	nc	nc	nc	nc	nc	nc	0.018[g]	0.030	nc	0.018
Benzo(k)fluoranthene	nc	nc	nc	nc	nc	nc	nc	nc	0.018[g]	0.030	nc	0.018
Chrysene	nc	nc	nc	nc	nc	nc	nc	nc	0.018[g]	0.030	nc	0.018

All Detected Chemicals	Concentration (µg/L)											
	Aquatic Life Criteria[a]								Human Health Criteria for Consumption of Organisms[f]	Surface Water Criteria		SL Used for EE/CA
	Washington State WQC				National AWQC					MTCA Method B		
	Freshwater		Marine		Freshwater		Marine					
	Chronic[b]	Acute[c]	Chronic[b]	Acute[c]	CCC[d]	CMC[e]	CCC[d]	CMC[e]		Carcinogen	Non-Carcinogen	
Dibenzo(a,h)anthracene	nc	nc	nc	nc	nc	nc	nc	nc	0.018[g]	0.030	nc	0.018
Fluoranthene	nc	nc	nc	nc	nc	nc	nc	nc	140	nc	90	140[i]
Fluorene	nc	nc	nc	nc	nc	nc	nc	nc	5,300	nc	3,457	5,300[i]
Indeno(1,2,3-cd)pyrene	nc	nc	nc	nc	nc	nc	nc	nc	0.018[g]	0.030	nc	0.018
Naphthalene	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	4,938	4,938
Phenanthrene	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc
Pyrene	nc	nc	nc	nc	nc	nc	nc	nc	4,000	nc	2,593	4,000[l]
cPAH TEQ	nc	nc	nc	nc	nc	nc	nc	nc	0.018[g]	0.030	nc	0.018
BTEX												
Xylene	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc
Phthalates												
BEHP	nc	nc	nc	nc	nc	nc	nc	nc	2.2[g]	3.6	399	2.2
SVOCs												
Phenol	nc	nc	nc	nc	nc	nc	nc	nc	1,700,000	nc	1,111,111	1,700,000[l]
VOCs												
1,1,1-Trichloroethane	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	416,667	416,667
Acetone	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc
Chlorobenzene	nc	nc	nc	nc	nc	nc	nc	nc	1,600	nc	5,034	1,600
cis-1,2-Dichloroethene	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc
Tetrachloroethene	nc	nc	nc	nc	nc	nc	nc	nc	3.3[g]	0.39	836	3.3[l]
Trichloroethene	nc	nc	nc	nc	nc	nc	nc	nc	30[g]	6.7	71	30[l]
Dioxin/Furans												
2,3,7,8-TCDD TEQ	nc	nc	nc	nc	nc	nc	nc	nc	5.0×10^{-9} [g]	nc	nc	5.0×10^{-9} [g]

[a] Aquatic life criteria are based on dissolved concentrations for metals (except mercury) and total concentrations for mercury and organic compounds.

[b] Chronic criteria are 4-day average concentrations not to be exceeded more than once every 3 years on the average, with the exception of pesticide and PCB concentrations, which are 24-hr average concentrations not to be exceeded at any time.

[c] Acute criteria are 1-hr average concentrations not to be exceeded more than once every 3 years on average, with the exception of silver and pesticide concentrations, which are instantaneous concentrations not to be exceeded at any time, or the PCB concentration, which is a 24-hr average not to be exceeded at any time.

[d] The CCC is defined as an estimate of the highest concentration of a chemical in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect.

[e] The CMC is defined as an estimate of the highest concentration of a chemical in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect.

[f] Washington State and national water quality criteria for the protection of human health are the same. Human health criteria are based on dissolved concentrations for all chemicals for marine water for ingestion of organisms only (not water).

[g] Criteria are based on 10^{-6} excess cancer risk for carcinogenic chemicals.

[h] WQC represents the inorganic fraction of arsenic.

[i] The criteria for pentachlorophenol are pH-dependent; a pH of 7 was assumed.

[j] Criteria for MTCA Method A for groundwater

[k] Hexavalent chromium criterion used since chromium speciation was not performed

[l] SL selected based on MTCA Method B CUL development process is higher than MTCA Method B default value.

AWQC – ambient water quality criteria
BEHP – bis(2-ethylhexyl) phthalate
BTEX – benzene, toluene, ethylbenzene, and xylene
CCC – criteria continuous concentration
CMC – criteria maximum concentration
cPAH – carcinogenic polycyclic aromatic hydrocarbon
CUL – cleanup level
EE/CA – engineering evaluation/cost analysis
MTCA – Model Toxics Control Act
na – not applicable
nc – no criteria
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SL – screening level
SVOC – semivolatile organic compound
TEQ – toxic equivalent
TCDD – tetrachlorodibenzo-*p*-dioxin
TPH – total petroleum hydrocarbons
VOC – volatile organic compound
WQC – water quality criteria

Italics identify values calculated using a hardness value of 100 mg/L. In most cases, the Washington State WQC and national AWQC are the same. In cases where they are different, the lower of the two values is used.

Gray-shaded values were identified as SLs.

Screening was conducted on all chemicals detected in groundwater samples obtained from monitoring wells[1] since 2003[2] using the procedures outlined in Section 3.3 of the EE/CA. The contaminants of potential concern (COPCs) were determined to be arsenic, copper, silver, total polychlorinated biphenyls (PCBs), bis(2-ethylhexyl) phthalate (BEHP), carcinogenic polycyclic aromatic hydrocarbons (cPAHs), and TPH (Table B-2).

Table B-2. Groundwater COPCs and COCs

COPC	Designated as a COC?	Rationale for COC Selection
Arsenic	yes	one or more recent SL exceedance in groundwater
Copper	no	concentrations are not significantly different than background concentrations
Silver	yes	one or more recent SL exceedance in groundwater
PCBs	yes	one or more recent SL exceedance in groundwater
TPH	yes	one or more recent SL exceedance in groundwater
cPAH	yes	one or more recent SL exceedance in groundwater
BEHP	yes	one or more recent SL exceedance in groundwater

BEHP – bis(2-ethylhexyl) phthalate
COC – contaminant of concern
COPC – contaminant of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SL – screening level
TPH – total petroleum hydrocarbons

Under WAC 173-340-730(5)(c), copper was not retained as groundwater contaminants of concern (COCs) because concentrations in the vicinity of the T-117 Upland Study Area are not significantly different than the site specific background populations. Copper concentrations in upgradient wells (wells MW-01, and MW-09 through MW-13) were compared to concentrations in T-117 Upland Study Area wells (wells MW-02 through MW-08R). Copper concentrations between these two data sets are not significantly different and therefore, concentrations at the T-117 Upland Study Area wells are considered background values (see Attachment B-1).

The site-specific background groundwater dissolved copper concentration is 5 ug/L based on the 90th percentile. This concentration is lower, but consistent, with the background concentration (8 ug/L, as established by EPA) calculated for the Boeing Plant 2 site (Environmental Partners 2006).

[1] MW-01, MW-02, MW-03, MW-04R, MW-05R, MW-06, MW-07, MW-08R, MW-09, MW-10, and MW-11

[2] Data were collected infrequently prior to 2003 from monitoring wells that were not representative of site-wide activities. In addition, monitoring conducted prior to 2003 overlapped source removal activities, making the data less reliable for screening purposes.

These SLs are re-examined in Section B.4 as part of the groundwater RvAL development to ensure the concentrations are also protective of the groundwater recontamination of sediment pathway.

With the exception of dioxins and furans, the groundwater chemistry dataset used for screening was relatively large, both temporally and spatially. Monitoring wells are located throughout the site and are sampled on a routine quarterly schedule. Groundwater sampling events used for this evaluation are summarized in Table B-3.

Table B-3. Monitoring well sampling events

Monitoring Well	Sampling Event
MW-02	May 2003, January 2004, June 2005, August 2006, March 2008, June 2008, September 2008, December 2008, March 2009, May 2009, and August 2009
MW-03	May 2003, March 2008, June 2008, September 2008, December 2008, March 2009, and May 2009
MW-04R	March 2008, June 2008, September 2008, December 2008, March 2009, May 2009, and August 2009
MW-05R	March 2008, June 2008, September 2008, December 2008, March 2009, May 2009, and August 2009
MW-06	January 2004, June 2005, March 2008, June 2008, September 2008, December 2008, March 2009, and May 2009
MW-07	June 2005, August 2006, March 2008, June 2008, September 2008, December 2008, March 2009, May 2009, and August 2009
MW-08R	March 2008, June 2008, September 2008, December 2008, March 2009, May 2009, and August 2009

Dioxins and furans were sampled during the fourth quarter 2008 groundwater sampling event from site wells selected to represent the overall site conditions (MW-05R, MW-08R, and MW-10). Only a single congener (1,2,3,4,6,7,8,9-octachloro dibenzo-*p*-dioxin) was detected and in only one well (MW-10). The dioxin and furan concentrations from this well were below the applicable SL. Further analysis of dioxins and furans will be performed as part of the routine groundwater monitoring program to verify these results.

B.3 GROUNDWATER REMOVAL ACTION LEVELS

The Groundwater RvALs were calculated or developed using:

- MTCA Method B (Equations 720-1 and 720-2, WAC 173-340-720)
- ARARs
- Surface water protection using MTCA Equation 730-2 with a site-specific fish consumption rate of 57 g/day and a fish diet fraction of 1 for the Duwamish corridor and Elliott Bay based on the King County Asian Pacific Islander seafood consumption survey
- CULs from MTCA based on background concentrations

- CULs based on site-specific background concentrations

Because groundwater in the vicinity of the T-117 Upland Study Area is not potable, as described in the first part of this appendix, MTCA cancer risks for groundwater ingestion were not calculated. The total cancer risk was calculated (Table B-4) based on surface water protection using MTCA Equation 730-2 as modified. The total cancer risk for groundwater protective of surface water was less than 1×10^{-6}, below the acceptable total risk range threshold of 10^{-5}. The hazard quotient (HQ), calculated using MTCA Equation 730-1, was 0.01, well below the acceptable total HQ of 1. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) risks were not calculated for groundwater, inasmuch as it is not suitable for domestic use.

Table B-4 is developed using the MTCA framework for evaluating potential cleanup levels that protects human health and environmental receptors. RvALs for the T-117 NTCRA are premised upon these CULs. Table B-4 also identifies the state and federal laws that are applicable. Under MTCA, cleanup standards consist of the following:

- The concentration of a hazardous substance that protects human health and the environment (cleanup level)
- The location on the site where the cleanup level must be attained (point of compliance)
- Other regulatory requirements that apply to a cleanup action because of the type of action and/or the location of the site

Each of these is included in Table B-4. As presented below, in Table B-4, the groundwater COCs for the T-117 Upland Study Area includes arsenic, silver, PCBs, TPH, cPAH TEQ, and BEHP. The derivation of the RvALs for each COC is discussed below.

Arsenic

Arsenic background values were determined based on the MTCA Method A table value. A site specific background value was not calculated because of the small sample set and elevated reporting limits. Reporting limits, for select sampling events, are significantly greater than the MTCA Method A table value. The arsenic RvAL is 5 µg/L.

Silver, TPH, and BEHP

Silver and BEHP RvALs are based on the protection of surface water. RvALs were derived from published standards defined in the clean water act. The silver RvAL is 1.9 µg/L and the BEHP RvAL is 1.7 µg/L. The TPH RvAL is based on the MTCA Method A table value since no surface water quality criterion is available. The TPH RvAL is 500 ug/L.

Total PCBs and cPAH TEQ

Total PCBs and cPAH TEQ RvALs are based on the practical qualitative limit, which represents the practical level that analytical laboratories can sample and report results at. The RvAL for total PCBs are 0.01 µg/L and the RvAL for cPAH TEQ is 0.15 µg/L.

Table B-4. T-117 Upland Study Area groundwater removal action levels

MTCA Regulation (WAC 173-340)	Basis	TPH (Heavy Oil Range)[a]	Total cPAH TEQ	BEHP	Total PCBs	Silver	Arsenic	Total Risk
Surface Water								
730(3)(b)(i)(A)	WAC 173-201A, marine (µg/L)[b]	nc	nc	nc	0.03	1.9	36	
730(3)(b)(i)(B)	Sec. 304, CWA, marine, chronic (µg/L)[c]	nc	nc	nc	0.03	1.9	36	
730(3)(b)(i)(B)	Sec. 304, CWA, organism only (µg/L)[c]	nc	0.018	2.2	0.000064	nc	0.14	
730(3)(b)(i)(C)	40CFR131, NTR, marine, chronic (µg/L)[d]	nc	nc	nc	0.03	1.9	36	
	40CFR131, NTR, organism only (µg/L)[d]	nc	0.031	5.9	0.00017	nc	0.14	
730(3)(b)(ii)	environmental effects (µg/L)	nc	nc	nc	nc	nc	nc	
	appropriate ARAR (µg/L)	nc	0.0180	2.2	0.000064	1.9	5	
	CPF (kg-day/mg)	na	7.3	0.014	2	na	1.5	
	oral RfD (mg/kg day)	na	na	0.02	na	0.005	0.0003	
	BCF	na	30	130	31,000	0.5	44	
	cancer risk	na	1×10^{-6}	1×10^{-6}	1×10^{-6}	na	1×10^{-4}	1×10^{-4}
	hazard quotient	na	na	0.012	na	2×10^{-4}	0.597	0.609
730(3)(b)(iii)(A)	human health, fish consumption, non-carcinogen (µg/L)	nc	nc	399	nc	25,926	17.7	
730(3)(b)(iii)(B)	human health, fish consumption, carcinogen (µg/L)	nc	0.014	1.7	0.00005	nc	0.047	
730(3)(b)(iii)(C)	human health, fish consumption, petroleum mixture (µg/L)	500	na	na	na	na	na	
	preliminary CUL (µg/L)	500	0.014	1.7	0.00005	1.9	0.047	
	cancer risk	na	1×10^{-6}	1×10^{-6}	1×10^{-6}	na	1×10^{-6}	4×10^{-6}

MTCA Regulation (WAC 173-340)	Basis	TPH (Heavy Oil Range)[a]	Total cPAH TEQ	BEHP	Total PCBs	Silver	Arsenic	Total Risk
	hazard quotient	na	na	0.009	na	0.0002	0.006	0.015
700(6)(d)	PQLs (µg/L)[e]	250/500	0.15	1.0	0.01	0.02	0.02	
	background (µg/L)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated	
730	CUL (µg/L)	500	0.15	1.7	0.01	1.9	0.05	
Groundwater								
720(4)(b)(i)	MCL, SDWA (µg/L)	nc	nc	6.0	0.5	nc	10	
	MCLG for non-carcinogens, SDWA (µg/L)	nc	nc	nc	nc	100	10	
	MCL, WSDOH (µg/L)	nc	nc	nc	nc	nc	nc	
720(4)(b)(ii)	protect surface water (from above) (µg/L)	500	0.014	1.7	0.00005	1.9	0.05	
	preliminary CUL (µg/L)	500	0.014	1.7	0.00005	1.9	0.05	
	cancer risk	na	1×10^{-6}	1×10^{-6}	1×10^{-6}	na	1×10^{-6}	4×10^{-6}
	hazard quotient	na	na	0.009	na	0.0002	0.006	0.015
700(6)(d)	PQLs (µg/L)[e]	250/500[f]	0.15	1.0	0.01	0.02	0.5	
	background (µg/L)[g]	na	na	na	na	na	5	
720	CUL (µg/L)[h]	500	0.15	1.7	0.01	1.9	5	
720(8)(e)	shoreline compliance level	12,500	0.15	42.5	0.01	47.5	5	

Note: Equation 730-2 in MTCA was modified to include the site-specific Asian Pacific Islander fish consumption rate of 57 g/day and fish diet fraction of 1 for the Duwamish corridor and Elliott Bay. The EPA consumption rate for the LDW of 97 g/day is not appropriate for the computation of MTCA surface water CULs.

[a] NWTPH-Dx (diesel- plus lube oil-ranges).

[b] Table 240(3) WAC 173-201A.

[c] National recommended water quality criteria (EPA 2002).

[d] 40CFR131.35, revised July 1, 2003.

[e] PQL assumes a single Aroclor (1260) for PCBs and incorporates the TEF calculation for cPAH.

[f] 250 µg/L is the diesel-range PQL; 500 µg/L is the lube oil-range PQL.

[g] Background groundwater concentration for arsenic is based on MTCA Method A.

[h] CULs are MTCA-defined CULs. These serve as a basis for the RvALs throughout the EE/CA. Human health surface water quality criteria based on bioaccumulation have been conservatively assumed to apply to groundwater discharges even though the applicability of these criteria is uncertain.

ARAR – applicable or relevant and appropriate requirement
BCF – bioconcentration factor
BEHP – bis(2-ethylhexyl) phthalate
CFR – Code of Federal Regulations
cPAH – carcinogenic polycyclic aromatic hydrocarbon
CPF – carcinogenic potency factor
CUL – cleanup level
CWA – Clean Water Act
EE/CA – engineering evaluation/cost analysis
EPA – US Environmental Protection Agency
LDW – Lower Duwamish Waterway
MCL – maximum contaminant level
MCLG – maximum contaminant level goal
MTCA – Model Toxics Control Act
na – not applicable
nc – no criteria
NTR – National Toxics Rule
NWTPH-Dx – Northwest total petroleum hydrocarbons – diesel and lube oil
PCB – polychlorinated biphenyl
PQL – practical quantitation limit
RfD – reference dose
RvAL – removal action levels
SDWA – Safe Drinking Water Act
TEF – toxic equivalency factor
TPH – total petroleum hydrocarbons
WAC – Washington Administrative Code
WSDOH – Washington State Department of Health

SLs based on surface water protection for cPAH (0.018 µg/L) and PCBs (6.4×10^{-5} µg/L) were below their respective practical quantitation limits (PQLs) (0.15 µg/L for cPAH and 0.01 µg/L for PCBs). Under WAC 173-340-730(5)(c), groundwater CULs (Table B-4) were adjusted to match the PQLs. The RvAL based on surface water protection (0.047 ug/L) for arsenic was below background (5 ug/L), the CUL for arsenic was adjusted to the background level[3].

The final RvALs for the T-117 Upland Study Area are based on the above-described CULs and are as follows:

- PCBs: 0.01 µg/L, adjusted to the PQL
- TPH: 500 µg/L
- cPAHs: 0.15 µg/L, adjusted to the PQL
- BEHP: 1.7 µg/L
- Silver: 1.9 µg/L
- Arsenic: 5 ug/L, adjusted to background

The point of compliance for these RvALs is the point of exposure or the location where groundwater discharges to surface water (see Figure 4-1 in Section 4 of the EE/CA). MTCA allows for consideration of natural attenuation between upland monitoring wells and the point of exposure (WAC 173-340-720(8)(e)). A shoreline well compliance level can be derived by multiplying the RvAL by the estimated attenuation factor associated with groundwater migration between the shoreline and the point of discharge to surface water. Compliance with the RvAL can be evaluated by comparing shoreline monitoring well data to the derived shoreline compliance level.

As groundwater discharges to surface water in a tidal environment, surface water (river water) infiltrates into the ground at high tide and mixes with groundwater. Typical attenuation factors for unconfined aquifers discharging to tidally-influenced surface waters are discussed in Section 2 of the EE/CA. These attenuation factors should not be confused with dilution factors based on mixing zones, which are not permitted under either MTCA or CERCLA.

Attenuation factors are greater where the following conditions are found:

- The surface water at high tide has more surface area through which to infiltrate (a more gentle beach slope, greater tidal range).
- There is more hydraulic head driven by a greater tidal range.

[3] The Arsenic RvAL is based on background values. Arsenic background values were determined based on the MTCA Method A table value. A site specific background value was not calculated because of the small sample set and elevated reporting limits. Reporting limits, for select sampling events, are significantly greater than the MTCA Method A table value.

- The hydraulic conductivity of the shoreline soil is greater and allows more infiltration.
- There is less net groundwater discharge because of lower hydraulic gradient toward the river or thinner saturated thickness.

Average attenuation factors based on empirical data from 13 tidally influenced sites (only one of which is local) ranged from 1.3 to 135 (Table B-5); the tidal range for the 12 non-local sites was significantly less than that in the vicinity of the T-117 EAA. This value was also at the lower end of the range for similar sites with much smaller tidal ranges and considered to be conservative. The attenuation factor of 50 derived for the local site along the LDW was based on a modeling study (CALIBRE 2008). Relevant T-117 EAA physical site information is provided in Table B-5 for comparison.

Shoreline groundwater compliance levels were developed by multiplying the preliminary RvALs in Table B-4 with an attenuation factor of 25. The shoreline compliance levels are shown in the last row of Table B-4. These concentrations are equal to the RvAL for cPAHs and PCBs where the RvAL was based on an adjustment to the PQL. To assess compliance with the groundwater RvALs, shoreline groundwater well data can be compared to the compliance levels to assess compliance with the RvAL at the point of discharge. Since these attenuation factors are sensitive to site-specific hydrogeologic conditions and monitoring well positions relative to the shoreline, these attenuation factors will be reassessed during remedial design and after the removal action is complete.

Table B-5. Literature survey of attenuation factors for groundwater-surface water interaction

Site Location	Attenuation Factor				Beach Slope	Tidal Range (m)	Avg. Hydraulic Conductivity (m/d)	Hydraulic Gradient	Sat. Thickness (m)	Confined?	Soil Description	Source
	Min	Max	Avg.	Notes on Attenuation Factor Estimate								
Abe River Outlet, Suruga, Japan			11	Based on seepage meters. Value considered a low estimate: "freshwater % estimated to be at most 9%."	flat, alluvial fan	0.8	8.8 (2.0 to 15.5)	na	na	No	silt, sand, and gravel	Taniguchi et al.(2005a)
Boeing, Lower Duwamish Waterway, Seattle, WA			50	Based on modeling.	na	~4	120	0.0011	17 – 21	No	unconsolidated silty to clean, fine to medium sand with discontinuous interbeds of silt	CALIBRE (2008)
Chesapeake Bay, VA			10	Average based on Rn tracer study.	na	0.9	na – 70% porosity in estuary surface sediment	na	na	No	porous silty loams and sand	Hussain et al. (1999)
Cockburn Sound, Western Australia	5	15	10	Based on temperature tracer studies and seepage meters.	na	0.8	na	na	30	No	Sand	Taniguchi et al. (2003)
Columbia Aquifer, Cherrystone Inlet of Chesapeake Bay, VA			7.3	Based on elevation gradients, conductivity measurements, and salinity. Average during July 1994.	7%	0.85	1.68 (0.34 to 4.61)	0.0014 to 0.0089	8.5	No	fine sandy loam	Robinson, Gallagher, and Reay (1998)
Columbia Aquifer, Cherrystone Inlet of Chesapeake Bay, VA			15.1	Modeling, with comparison to empirical data. Also cited in Urish and McKenna (2004).	shallow, low slope	0.85	2.48 (0.34 to 4.61)	0.005	8.5	No	Pleistocene sediments, silty sands to gravely sands	Robinson and Gallagher (1999)
Indian River Lagoon/Banana River Lagoon, FL	60	133	83	Based on Ra, Rn tracers and seepage meters.	na	0.1	porosity: 0.37 to 0.48	na	0.5 (thickness of permeable surface layer)	No	permeable sands, shell hash, and some fine-grained sediment	Cable et al. (2004)
Manila Bay, Philippines			135	Based on Rn tracers, seepage meters and modeling.	5 to 15% slopes in the upland	1	3.7 (2.2 to 5.1)	0.017	21 – 34	No	sand- to gravel-sized volcaniclastic sediments	Taniguchi et al. (2005b)
Model demonstrated with data from South Atlantic Bight (NC, GA, FL)			25	Based on modeling – including wave action and tidal action.	20%	1.5	0.001	na	30	No	beach sand	Li et al. (1999)
Nauset Marsh Embayment, Cape Cod, MA (Nauset Bay and Town Cove)	1.1	Max (100% salt water)	2.8 – 6.7	Min and max represent the range during the tidal cycle based on salinity measurements. Average represents the range of average attenuation factors over the entire study area.	12%	1.34	64 (7 to 125)	na	na	No	unconsolidated glacial sediments, silty to coarse sands	Urish and McKenna (2004)
Waquoit Bay, Cape Cod, MA	1.1	1.4	1.3	The freshwater estimate was derived using Darcy's law, the saltwater component was derived using Ra tracer, and the total flow was derived using Rn tracer.	mostly steep, bluffs	1.1	52 (32 to 150)	0.001 to 0.006	5.5	No	glaciolacustrine clay, silt and very-fine sands	Mulligan and Charette (2006)
Waquoit Bay, Cape Cod, MA	2.10	Max (100% salt water)	4	Submarine groundwater of the uppermost permeable unit, 7.6 m off-shore. Max and min represent ranges, DF based on salinity.	27%	0.5	91 (10 to 317)	0.001	11	No	outwash gravel, sand, and silt, with occurrences of lacustrine silts and clays	Cambareri and Eichner (1998)
West Neck Bay, NY	18	73	37	Average based on 2 estimates using salinity measurements and 2 estimates using ^{222}Rn tracer.	na	0.6	na	na	27	No	unconsolidated fine-to-medium coarse sands	Dulaiova et al. (2006)
T-117, Lower Duwamish Waterway, WA					10 to 30%	4.2	(0.09 to 900)	0.01	3.7	No	unconsolidated silty to clean, fine to medium sand with discontinuous interbeds of silt	

na – not available in the cited literature Ra – radium Rn – radon

B.4 EMPIRICAL DEMONSTRATION THAT GROUNDWATER IS NOT A SOURCE OF SEDIMENT RECONTAMINATION

Groundwater in the vicinity of the T-117 Upland Study Area was also evaluated relative to the potential for sediment recontamination. Using the screening process and COC selection process described in this appendix, the COCs for groundwater were determined to be PCBs, TPH, cPAHs, BEHP, arsenic, and silver. The SL for each is based on the protection of surface water beneficial uses. SLs were also reviewed to confirm they do not exceed PQLs or natural background levels.

In this section, RvALs and shoreline compliance levels for groundwater developed in Section B.3 are evaluated to verify that they are below concentrations that could cause sediment recontamination to levels that exceed sediment quality standards [SQS] per WAC 173-340-720(8)(d)(i)(E). This evaluation is based on an empirical assessment of sediment grab and core samples.

In 2003 site data was collected from seeps, adjacent sediment cores, and surface grab samples to empirically demonstrate the potential for sediment recontamination. Methods and sample locations are detailed in the December 2003 T-117 Quality Assurance Project Plan (Windward et al. 2003). To provide empirical data, sediment cores were analyzed for the full suite of SMS chemicals to (Map 2-9). The cores were advanced within the nearshore intertidal mudflat area and intercepted the soil column where the bulk of groundwater enters the LDW. Below is a summary of the data collected in 2003:

- Surface sediment grab samples (39-G, 25-G, and 33-G) (Map 2-8) collected from the three seep locations that had been sampled in 2003 (surface water samples SW-1, SW-2, and SW-3 (Map 2-8)
- Nearshore sediment core samples that were analyzed at multiple intervals

The surface sediment grab samples were collected from three locations that were co-located with three seep water samples (SW-1, SW-2, and SW-3, as shown on (Map 2-8)). These sediment samples (39-G, 25-G, and 33-G, as shown on (Map 2-8)) were analyzed for the full Washington State Sediment Management Standards (SMS) suite, to determine if contaminants detected in groundwater or seep water had the potential to contaminate sediment at these locations to concentrations above the SQS. The results shown in Table B-6 demonstrate that under current conditions these seeps have not caused contamination of sediment.

Several observations can be made regarding the data presented on Map 2-9 and in Table B-6:

- PCB concentrations in the sediment cores decreased from the surface to subsurface, suggesting that the primary mechanism for sediment contamination was erosion or spills and leaks from the T-117 Upland Study Area.

Table B-6. Chemical concentrations in seep co-located surface sediment and intertidal subsurface sediment samples for groundwater COCs compared with SQS and CSL

Location ID	Sample ID	Sample Depth	Silver (mg/kg dw)	Benzo(a)-anthracene (mg/kg OC)	Benzo(a)-pyrene (mg/kg OC)	Total Benzo-fluoranthenes (mg/kg OC)	Chrysene (mg/kg OC)	Bis(2-ethylhexyl) Phthalate (mg/kg OC)	Total PCBs (mg/kg OC)
Seep Co-Located Surface Sediment									
25-G	T117-SE25-SG	0 – 15 cm	0.400 U	67	59	120	59	10	**<u>290</u>**
33-G	T117-SE33-SG	0 – 15 cm	0.500 U	3.0	2.7	8.0	5.3	4.0	**<u>310 J</u>**
39-G	T117-SE39-SG	0 – 15 cm	0.500 U	5.0	5.4	12	6.9	4.6	**<u>420</u>**
Intertidal Surface and Subsurface Sediment									
21-G 21-SC	T117-SE21-SG	0 – 15 cm	0.500 U	10 J	11 J	38	19	5.6 J	**<u>2,200</u>**
	T117-SE21-SC-01	0 – 1 ft	Na	Na	na	na	na	na	**<u>760</u>**
	T117-SE21-SC-12	1 – 2 ft	Na	Na	na	na	na	na	**16**
	T117-SE21-SC-24	2 – 4 ft	0.500 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U
25-SC	T117-SE25-SC-01	0 – 1 ft	Na	Na	na	na	na	na	**<u>260</u>**
	T117-SE25-SC-23	1 – 2 ft	Na	Na	na	na	na	na	**19**
	T117-SE25-SC-24	2 – 4 ft	0.400 U	5.7	3.1	7.1	7.6	0.95 U	4.6 J
31-SC	T117-SE31-SC-01	0 – 1 ft	Na	Na	na	na	na	na	**<u>2,600</u>**
	T117-SE31-SC-12	1 – 2 ft	0.500 U	1.3 U	1.3 U	1.3 U	1.3 U	1.3 U	1.7
37-G 37-SC	T117-SE37-SG	0 – 15 cm	0.400 U	**<u>440</u>**	**<u>420</u>**	**<u>890</u>**	**410**	12 J	**<u>230</u>**
	T117-SE37-SC-01	0 – 1 ft	Na	Na	na	na	na	na	**<u>3.1</u>**
	T117-SE37-SC-12	1 – 2 ft	0.400 U	0.020 U[a]	0.020 U[a]	0.020 U[a]	0.020 U[a]	0.020 U[a]	0.019 U[a]
SQS			**6.1**	**110**	**99**	**230**	**110**	**47**	**12**
CSL			**6.1**	**270**	**210**	**450**	**460**	**78**	**65**

[a] Value is presented in dry weight because TOC was less than 0.5%.

CSL – cleanup screening level
COC – contaminant of concern
dw – dry weight
ID – identification
J – estimated concentration
na – not analyzed
OC – organic carbon
SQS – sediment quality standards
U – not detected at reporting limit shown
TOC – total organic carbon

Bold indentifies SQS exceedance. **<u>Bold and underlined</u>** identifies SQS and CSL exceedance.

- Sediment COC and groundwater contaminant concentrations at depth did not exceed the SQS, suggesting that groundwater under current conditions was not recontaminating sediment.

These empirical data and lines of evidence demonstrate that groundwater is not causing sediment recontamination under current conditions. It can therefore be inferred that groundwater will not result in sediment recontamination after contaminated soils have been removed from the upland site.

Upland groundwater shoreline compliance levels based on the foregoing attenuation discussion are presented in Table B-4. Analyses of groundwater at MW-1, MW-9, MW-10, and MW-11 indicated that all measurements were below these shoreline compliance levels, except for one BEHP concentration (89 µg/L) at MW-1 during the second quarter 2009 groundwater sampling event. These wells are all located in Dallas Avenue S, beyond the extent of tidal influence, so the full attenuation factor is relevant as these well concentrations have not been attenuated by tidal effects.

B.5 GROUNDWATER BENEATH ADJACENT STREETS

Available data indicate that groundwater beneath Adjacent Streets has not been impacted as result of T-117 contaminants. This section reviews the available groundwater and soil data and uses Ecology guidelines to provide an empirical demonstration that soil concentrations measured in this area will not cause an exceedance of groundwater RvALs.

According to WAC 173-340-747(9), an empirical demonstration may be used to show that soil concentrations measured at a site will not cause an exceedance of groundwater CULs if the site meets each of the following criteria:

- Measured groundwater concentrations are at or below groundwater RvALs (as derived for the T-117 EAA from the MTCA CULs).
- The soil contamination has been present for a duration sufficient to have allowed it to reach groundwater.
- Site conditions will not change in the future so as to increase the potential for leaching.

Available information indicates that groundwater beneath the Adjacent Streets flows north-northeast and beneath the T-117 and South Park Marina sites before discharging to the LDW. Beneath the easternmost portion of Dallas Avenue S, groundwater elevations are approximately 12 ft beneath the surface. Groundwater is likely at this depth or greater with increasing distance from the LDW, in the western portions of the Adjacent Streets area. Boring data suggests groundwater in this area flows through native sands, silts and sandy silts.

Groundwater chemistry

Groundwater chemistry data is available for wells completed on Dallas Avenue S and 17th Avenue S through the 3rd quarter of 2009 and include wells MW-09 (four sampling events), MW-10 (four sampling events), MW-11 (five sampling events), MW-12 (two sampling events), and MW-13 (two sampling events). MW-01 is located on the Basin Oil Site (10 sampling events) and MW-12 and MW-13, were installed by Ecology in May 2009 to evaluate groundwater conditions at the Basin Oil site. Exceedances of SLs (see Section B.2) for these wells are summarized in Table B-7.

Table B-7. Summary of SL exceedances in Adjacent Streets Groundwater

Chemical	Date of Exceedance
Dissolved arsenic	MW-12, May 2009, 17.7 µg/L
	MW-13, May 2009, 9.4 µg/L
Diesel range hydrocarbons	MW-10, June 2008, 0.53 mg/L
bis(2-ethylhexyl)phthalate	MW-09, March 2009, 4.7 J µg/L
	MW-10, March 2009, 3 µg/L
	MW-11, September 2009, 19 J µg/L
PCB Arolors	MW-01, September 2008, 0.088 AJ µg/L

The groundwater RvAL for arsenic (based on background) is 5 ug/L. The RvALs was exceeded in May 2009 at MW-12 and MW-13 by factors of approximately 3.5 and 2, respectively. However, groundwater in wells down gradient (MW-9, MW-10, and MW-11) have not exceeded RvALs, suggesting these concentrations are due to local conditions. The diesel exceedance is 1.06 times the RvAL and was not exceeded in the subsequent sampling events. Bis(2-ethylhexyl)phthalate exceeds the RvALs by up to 9 times (MW-11), however screening levels were not exceeded in the subsequent sampling events. The PCB exceedance in MW-01, 3 times the RvAL, was also a single event that was not confirmed in subsequent sampling events. In summary, while some organic chemicals have exceeded RvALs, the exceedances occur sporadically, are below T-117 Upland Study Area concentrations, and are not consistently detected in these wells.

Three wells were installed by Ecology at the South Park Marina near the shoreline, and are located approximately 175 ft downgradient of Dallas Avenue S between 16th and 17th Avenue S (Map 2-40). These wells have had two sampling events resulting in detections above MTCA CULs of pesticides (detected in MW-3) and arsenic (detected in all 3 site wells (see section 2.3.2.2). Pesticides are not a T-117 COC. Arsenic concentrations are consistent with the other wells installed beneath Adjacent Streets (i.e. within the range of background concentrations).

Soil chemistry

Soil borings and test pit data collected from depths of two feet or more are located on Dallas Avenue S, 17th Avenue S, S Donovan Street and 16th Avenue S and include the following:

- 85 samples analyzed for PCBs
- 2 samples analyzed for dioxins and furans
- 19 samples analyzed for TPH
- 6 samples analyzed for PAHs
- 5 samples analyzed for metals
- 5 samples analyzed for VOCs

Subsurface soil and associated groundwater conditions are discussed below for chemicals detected in Adjacent Streets soil. Soil screening levels, RvALs used in this discussion are identified in Section 3.

- The deepest soils with PCB concentrations exceeding the RvAL of 1 mg/kg are located at a depth 4 ft (1.4 mg/kg at P66 and 1.2 mg/kg at P65, which is one of two field replicates, the other being 0.45 mg/kg) (Integral 2006, Table 1). With one exception, there have been no exceedances of PCB groundwater screening levels (0.03 ug/L) in the wells at and around Basin Oil. The exception is MW-01 where on September 11, 2008 PCB 1260 was detected at a concentration of 0.088 ug/L. Subsequent testing has not detected PCBs in the well above screening levels. The low solubility of PCBs is demonstrated in the Upland Study Area wells. The highest concentration measured in groundwater is 2 µg/L at MW-03 where soil concentrations up to 170 mg/Kg were measured in the borehole soils.
- The deepest soils analyzed for dioxins and furans are at 2 ft below ground surface at P100. The field split from this location had a concentration of 50 ng/kg. Groundwater does not appear to be impacted by dioxins as shown during 4th quarter 2008 sampling event. All wells sampled (MW-5R, 8R and 10) were below detection limits except for a detection of octachlorodibenzo-p-dioxin (OCDD), which was below the MCL.
- TPH was detected in surface soils above the RvAL (2,000 mg/kg) at one location, P81-2 (1,200 mg/kg TPH-D, 4,700 mg/kg TPH-0). The deeper interval (4 ft) at this location was well below the soil RvAL. Groundwater is expected to be between 9 and 10 ft bgs in this area, which is well below the impacted soil interval. P81 is located near the intersection of Dallas Avenue S and S Donovan Street, south of Basin Oil. The wells at and around Basin Oil (MW-01, MW-09 through MW-13) have had two detections of TPH-diesel (at MW-10 and MW-11) with the detection at MW-10 slightly exceeding the screening l0evel.

- The deepest soils with cPAHs exceeding the RvAL of 0.14 mg/kg are located at a depth of 6 ft at P60 (4.2 mg/kg) located near the intersection of Dallas Avenue S and 16th Avenue S. PAHs were not detected in groundwater in downgradient South Park Marina wells, except for a detection of pyrene at a concentration well below the Method B groundwater screening level. The next deepest impacted soil was found at MW-12 at 2.5 ft (0.38 mg/kg). There have been no detections of PAHs above groundwater CULs at this or any wells located on Adjacent Streets. cPAHs have not been detected above the detection limits..
- Arsenic is the only metal that exceeds the RvAL in soil. The highest concentration in Adjacent Streets is 19.2 mg/kg at P81. Groundwater concentrations at wells at and around Basin Oil exceed arsenic RvALs with a maximum concentration of 17.7 µg/L. However, as discussed above, these groundwater values are not observed in downgradient wells suggesting a local source.
- VOCs detected in soil were not detected above MTCA Method B CULs[4] in soil or in groundwater at and around Basin Oil.

PCBs and dioxins are characterized by extremely low vapor pressures, high log Kow, high organic-carbon coefficients (Koc), and extremely low water solubilities. These factors indicate a strong affinity for soil, particularly soil with high organic content. Their strong adsorption to soil, low water solubilities, and high Koc values indicate that the rate of transport from unsaturated zone soils to the water table via rain infiltration would be extremely low. Once sorbed to particulate matter or bound in the sediment organic phase, they exhibit little potential for leaching or volatilization.

Based on the Site Characterization, provided in Section 2, the soil contamination described above has likely been present at the site since the mid-1970's when used oils were used in asphalt manufacturing facility. If contaminant leaching from these soils to groundwater (above groundwater RvALs) was likely, this duration is sufficient for this process to have occurred.

These observations show that while some chemicals have been sporadically detected below or immediately downgradient of Basin Oil, the presence of a groundwater contamination beneath the Adjacent Streets Study Area due to former asphalt manufacturing facility operations is unlikely. The solubility of PCBs, dioxins and furans, PAHs, TPH-D, and TPH-O is low and empirical data suggest that where concentrations exist in surface and subsurface soils, they have not leached to groundwater in the 30-plus years that they have been present. The potential for contaminant leaching in the future will be further reduced by removal of soils with residual contamination as part of the permanent remedy for the site.

[4] RvALs were not developed for soil VOCs because they were not identified as soil COPCs, thus the comparison to MTCA Method B CULs.

B-6. REFERENCES

AECOM. 2009a. Lower Duwamish Waterway Superfund Site, Terminal 117 Early Action Area. First quarter 2009 interim groundwater monitoring data results - non-time critical removal action. Prepared for the Port of Seattle and the City of Seattle. AECOM, Seattle, WA.

AECOM. 2009b. Lower Duwamish Waterway Superfund Site, Terminal 117 Early Action Area. Fourth quarter 2008 interim groundwater monitoring data results - non-time critical removal action. Prepared for the Port of Seattle and the City of Seattle. AECOM, Seattle, WA.

AECOM. 2009c. Lower Duwamish Waterway Superfund Site, Terminal 117 Early Action Area. Second quarter 2009 interim groundwater monitoring data results - non-time critical removal action. Prepared for the Port of Seattle and the City of Seattle. AECOM Environment, Seattle, WA.

AECOM. 2009d. Lower Duwamish Waterway Superfund Site, Terminal 117 Early Action Area. Third quarter 2009 interim groundwater monitoring data results - non-time critical removal action. Prepared for the Port of Seattle and the City of Seattle. AECOM Environment, Seattle, WA.

Cable JE, Martin JB, Swarzenski PW, Lindenberg MK, Steward J. 2004. Advection within shallow pore waters of a coastal lagoon, Florida. Ground Water 42(7):1011-1020.

CALIBRE. 2008. Historical data summary report. Final. EMF site, Seattle, Washington. Prepared for The Boeing Company, Shared Services Group. CALIBRE Systems, Bellevue, WA.

Cambareri TC, Eichner EM. 1998. Watershed delineation and ground water discharge to a coastal embayment. Ground Water 36(4):676-685.

Dulaiova H, Burnett WC, Chanton JP, Moore WS, Bokuniewicz HJ, Charette MA, Sholkovitz E. 2006. Assessment of groundwater discharges into West Neck Bay, New York, via natural tracers. Cont Shelf Res 26(1971-1983).

Ecology. 2001. Concise explanatory statement for the amendments to the Model Toxics Control Act Cleanup Regulation, Chapter 173-340 WAC. No. 01-09-043. Appendix D: Calculations for Method D cleanup levels. Toxics Cleanup Program, Washington State Department of Ecology, Olympia, WA.

ENSR|AECOM. 2008a. Lower Duwamish Waterway Superfund Site, Terminal 117 Early Action Area. First quarter interim groundwater monitoring data results - non-time critical removal action. Final. Prepared for the Port of Seattle and the City of Seattle. ENSR|AECOM, Seattle, WA.

ENSR|AECOM. 2008b. Lower Duwamish Waterway Superfund Site, Terminal 117 Early Action Area. Second quarter interim groundwater monitoring data results - non-time critical removal action. Prepared for the Port of Seattle and the City of Seattle. ENSR|AECOM, Seattle, WA.

ENSR|AECOM. 2008c. Lower Duwamish Waterway Superfund Site, Terminal 117 Early Action Area. Third quarter interim groundwater monitoring data results - non-time critical removal action. Prepared for the Port of Seattle and the City of Seattle. ENSR|AECOM, Seattle, WA.

Environmental Partners. 2006. CMS phase quarterly shoreline ground water monitoring report, August 2006, Boeing Plant 2, Seattle/Tukwila, Washington. Environmental Partners, Inc., Issaquah, WA.

EPA. 2002. National recommended water quality criteria: 2002. EPA-822-R-02-047. US Environmental Protection Agency, Washington, DC.

EPA. 2009. Memorandum dated June 26, 2009 from J E Woolford and J E Reeder to Superfund National Policy Managers, Regions 1-10, regarding transmittal of the CERCLA policy directive "Summary of Key Existing EPA CERCLA policies for groundwater restoration. Office of Solid Waste and Emergency Response, US Environmental Protection Agency, Washington, D C.

Floyd|Snider. 2008. Target media cleanup levels technical memorandum, Boeing Plant 2, Seattle, Washington. Revised agency review draft. Floyd|Snider, Inc., Seattle, WA.

Herman L, Wineman M. 1997. Criteria and approach for area-wide determination of surface water protection as most beneficial use of groundwater. Hart Crowser, Inc., Seattle, WA.

Hussain N, Church TM, Kim GB. 1999. Use of ^{222}Rn and ^{226}RA to trace groundwater discharge into the Chesapeake Bay. Mar Chem 65:127-134.

King County. 2009. Groundwater data search: Water quality data, 1990-1998, Well GrpA_77050_04. Local number 23N/04E-16D [online]. Water and Land Resources Division, King County Department of Natural Resources and Parks, Seattle, WA. [Cited 11/23/09.] Available from: http://www5.kingcounty.gov/groundwater/Details.aspx?Equis_ID=GrpA_77050_04.

Li L, Barry DA, Stagnitti F, Parlange J-Y. 1999. Submarine groundwater discharge and associated chemical input to a coastal sea. Wat Res Research 35(11):3253-3259.

Mulligan AE, Charette MA. 2006. Intercomparison of submarine groundwater discharge estimates from a sandy unconfined aquifer. J Hydrol 327:411-425.

Robinson M, Gallagher D, Reay W. 1998. Field observations of tidal and seasonal variations in ground water discharge to tidal estuarine surface water. Ground Wat Monit Remed (Winter 1998):83-92.

Robinson MA, Gallagher DL. 1999. A model of ground water discharge from an unconfined coastal aquifer. Ground Water 37(1):80-87.

Taniguchi M, Turner JV, Smith AJ. 2003. Evaluations of groundwater discharge rates from subsurface temperature in Cockburn Sound, Western Australia. Biogeochemistry 66:111-124.

Taniguchi M, Ishitobi T, Saeki K. 2005a. Evaluation of time-space distributions of submarine ground water discharge. Ground Water 43(3):336-342.

Taniguchi M, Burnett WC, Dulaiova H, Siringan F, Foronda JM, Wattayakorn G, Rungsupa S, Kontar EA, McManus L. 2005b. Groundwater discharge as an important land-sea pathway in Southeast Asia. Final report for APN Project 2004-16NSY. APN Workshop, 8-10 February 2005, Sichang Island, Thailand.

Urish DW, McKenna TE. 2004. Tidal effects on ground water discharge through a sandy marine beach. Ground Water 42(7):971-982.

Windward, DOF, Onsite. 2003. Lower Duwamish Waterway Superfund site, Terminal 117 early action area. Quality assurance project plan. Prepared for the Port of Seattle. Windward Environmental LLC, Dalton, Olmsted & Fuglevand, Inc., and Onsite Enterprises, Inc., Seattle, WA.

Attachment B-1. T-117 Copper Statistical Assessment

T-117 Copper Statistical Assessment: ProUCL 4.00.04

Notes:
non-parametric Mann-Whitney test used.

1) Summary Statistics - With NDs, Untransformed

	N	Detects	NDs	% NDs	Min	Max	Mean	SD
Tot. Cu (RL)	16	10	6	37.5	0.002	0.01	0.00378	0.00248
Tot. Cu (0.5*RL)	16	10	6	37.5	0.001	0.01	0.00341	0.0028
Diss. Cu (RL)	16	8	8	50	0.002	0.009	0.00278	0.00176
Diss. Cu (0.5*RL)	16	8	8	50	0.001	0.009	0.00225	0.00205

Notes

Tot. = total
Diss. = dissolved
RL = reporting limit (RL) substituted for non-detects (NDs)
*0.5*RL = one half the RL substituted for NDs; equivalent to "HRL" in the histogram below*
Field duplicate results were averaged with their parent sample results for purposes of this analysis.

2) Goodness of Fit Statistics - With NDs, Untransformed (α = 0.05)

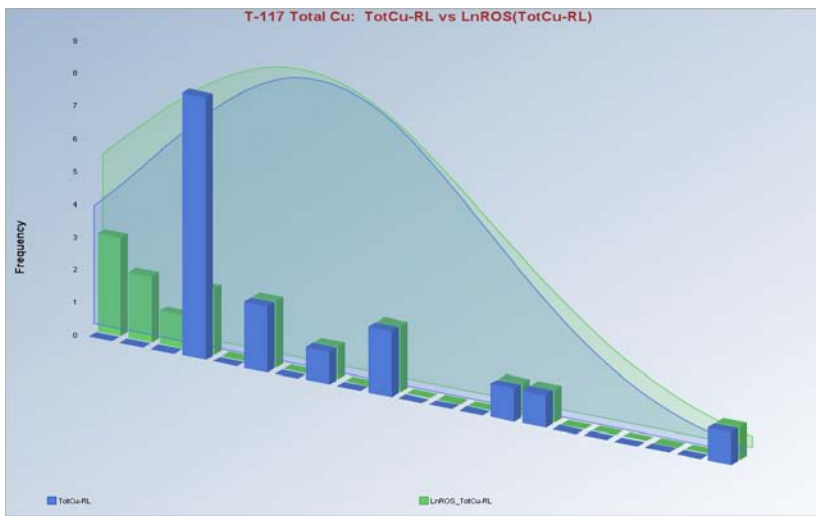
	Shapiro-Wilks (Detects only)	Lilliefors (NDs = DL*)	Normal ROS Estimate	Lognormal ROS Estimate
Tot. Cu (RL)	Normal, Lognormal	Not Normal, Not Lognormal	Normal#	Lognormal
Tot. Cu (0.5*RL)	Normal, Lognormal	Normal, Not Lognormal	Normal#	Lognormal
Diss. Cu (RL)	Not Normal, Lognormal	Not Normal, Not Lognormal	Normal#	Lognormal
Diss. Cu (0.5*RL)	Not Normal, Not Lognormal	Not Normal, Not Lognormal	Normal#	Lognormal

Notes

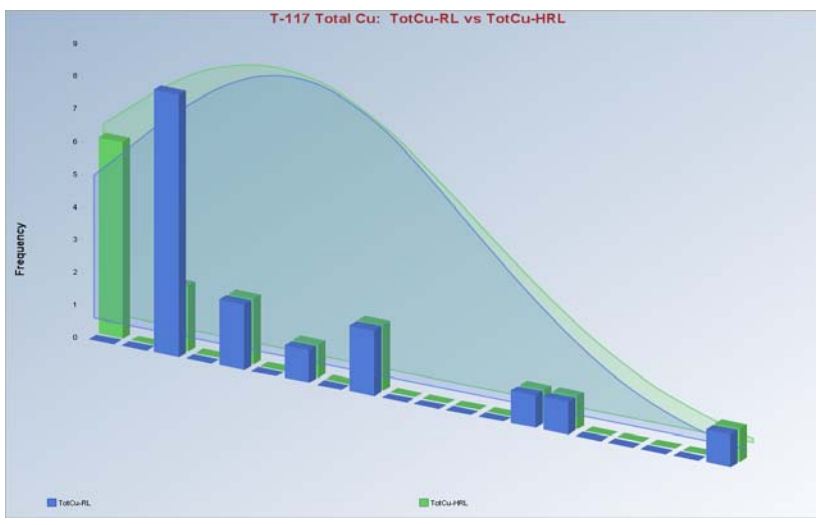
** Cu (0.5*RL) has already halved the DL, so ProUCL's "DL/2" is not shown here; in these instances, "DL" = "DL/2."*
ROS = Regression on Order Statistics; used to extrapolate ND observations.
 # Closer inspection showed Normal ROS Estimates using negative values; thus, LnROS will be used moving forward.

3) Histograms

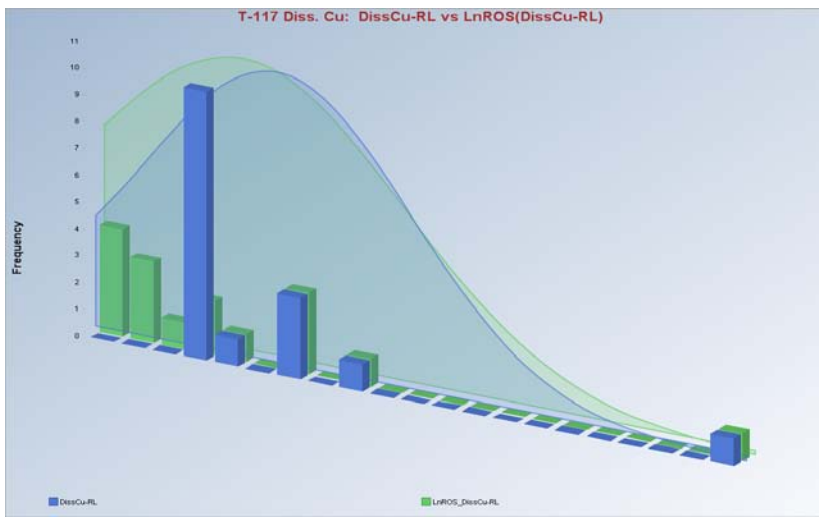
a) Tot. Cu (RL) vs LnROS



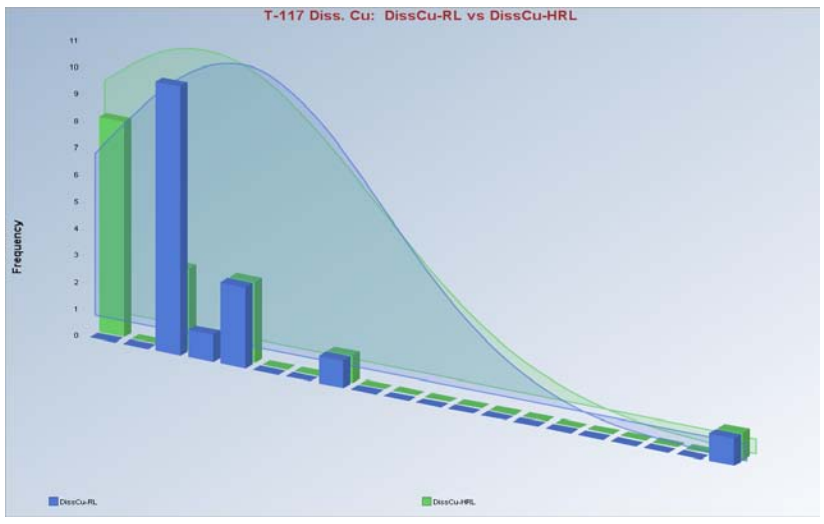
b) Tot. Cu (RL) vs Tot. Cu (0.5*RL)



a) Diss. Cu (RL) vs LnROS



b) Diss. Cu (RL) vs Diss. Cu (0.5*RL)



4) Summary Stats

units in ug/L

Analyte	N	# D	# ND	Mean	Min	Max	Distribution	R^2	Pctile Type	Pctile
Diss. Cu	16	8	8	3.56	2	9	Lognormal	0.9	90th	5.04
Tot. Cu	16	10	6	4.85	2	10	Lognormal	0.95	90th	7.97

UCL Based on Mean

	95% UCL	90% UCL
Tot. Cu (RL)	0.00489	0.00463
Tot. Cu (LnROS)	0.00506	0.00464
Diss. Cu (RL)	0.00358	0.00339
Diss. Cu (LnROS)	0.00327	0.00300

33

Notes

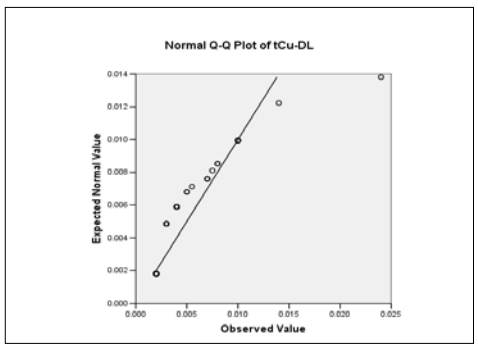
Tot. Cu (RL) recommended UCL: KM (t) UCL
Tot. Cu (LnROS) recommended UCL: Approximate Gamma UCL
Diss. Cu (RL) recommended UCL: KM (t) UCL
Diss. Cu (LnROS) recommended UCL: Approximate Gamma UCL

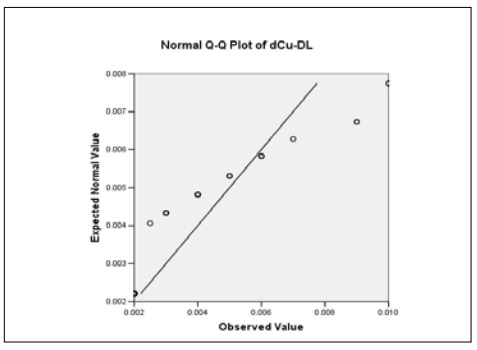
T-117 Copper Statistical Assessment

B) Upgradient vs T-117 Upland Site MW Comparison (*SPSS 13.0*)

1) 2-Sample Hypothesis Testing: Upgradient vs T117 Upland Site Wells (Site MW)

a) normality assessment (Q-Q plot)





Notes

tCu-DL = tot. Cu, full detection limit for non-detects
dCu-DL = diss. Cu, full detection limit for non-detects
Q-Q plots showed total & dissolved Cu to be non-normally distributed
Q-Q plots for half detection limit for non-detects (not shown) were also non-normal for both dCu and tCu

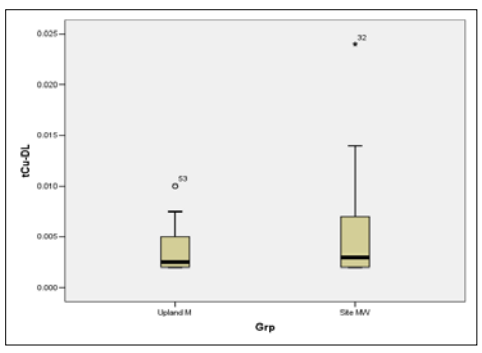
b) 2-sample testing

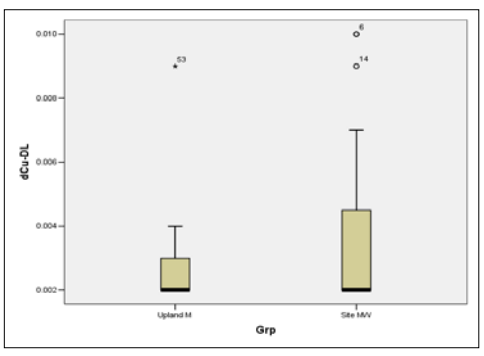
	p-value	Sig. Difference?
Tot. Cu (RL)	0.628	No
Tot. Cu (0.5*RL)	0.893	No
Diss. Cu (RL)	0.644	No
Diss. Cu (0.5*RL)	0.896	No

Notes

Non-parametric Mann-Whitney test, using SPSS 13.0
α = 0.05

c) box plots (for reference)





Notes

Box legend:
horizontal line = median
bottom = 25th percentile
top = 75th percentile
"whiskers" extending from box = min/max observed non-outlier values
circle = values 1.5 box lengths from 75th (or 25th) percentile
asterisk = values 3+ box lengths from 75th (or 25th) percentile
Boxplots confirm that the Cu distributions are not distinct (i.e., do overlap) between the upland and site MW

d) summary stats, by group (to assess between-group variability)

Parameter	Group	N	Detects	% Detects	NDs	% NDs	All Data (mg/L)				Detects Only (mg/L)			
							Min	Max	Mean	SD	Min	Max	Mean	SD
Tot. Cu (RL)	Upgradient	16	10	62.5	6	37.5	0.0020	0.0100	0.0038	0.0025	0.0020	0.0100	0.0049	0.0026
	Upland	39	20	51.3	19	48.7	0.0020	0.0240	0.0049	0.0045	0.0020	0.0240	0.0068	0.0052
Tot. Cu (0.5*RL)	Upgradient	16	10	62.5	6	37.5	0.0010	0.0100	0.0034	0.0028	0.0020	0.0100	0.0049	0.0026
	Upland	39	20	51.3	19	48.7	0.0010	0.0240	0.0042	0.0047	0.0020	0.0240	0.0068	0.0052
Diss. Cu (RL)	Upgradient	16	8	50.0	8	50.0	0.0020	0.0090	0.0028	0.0018	0.0020	0.0090	0.0036	0.0023
	Upland	39	14	35.9	25	64.1	0.0020	0.0100	0.0034	0.0023	0.0020	0.0090	0.0046	0.0022
Diss. Cu (0.5*RL)	Upgradient	16	8	50.0	8	50.0	0.0010	0.0090	0.0023	0.0020	0.0020	0.0090	0.0035	0.0023
	Upland	39	14	35.9	25	64.1	0.0010	0.0090	0.0025	0.0022	0.0020	0.0090	0.0046	0.0022

Upgradient - wells upgradient from T117 Upland Study Area Wells
Upland - T117 Upland Site Wells