SECTION

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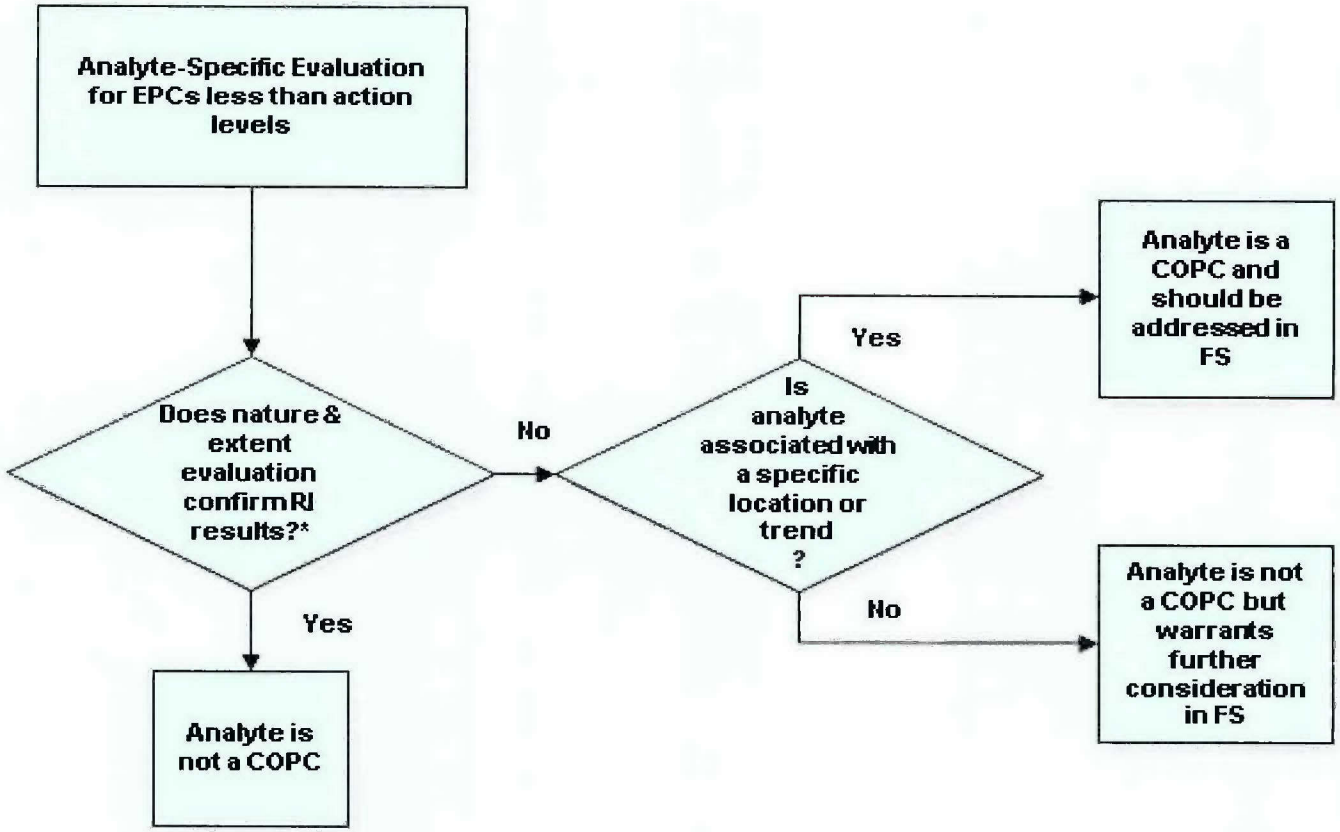
Table 6-24. Comparison of Exposure Point Concentration to Action Levels for the Near-River Exposure Area

Analyte Name	Analyte Class	Total Samples	Total Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	90th Percentile	Action Level	Action Level Basis	EPC > Action Level?	Level of Exceedance
Aluminum	METAL	24	11	46%	µg/L	10	10	7.1	72	43	50	40 CFR 141 – Secondary Federal MCL	No	0.86
Arsenic	METAL	24	21	88%	µg/L	0.80	0.80	0.82	3.1	2.3	0.018	Clean Water Act -- Human Health Water + Organism	Yes	127
Chromium	METAL	24	24	100%	µg/L	--	--	8.1	69	53	65	Clean Water Act -- Freshwater CCC	No	0.81
Hexavalent Chromium	METAL	24	24	100%	µg/L	--	--	2.6	57	50	10	40 CFR 131 -- Freshwater CCC	Yes	5.0
Iron	METAL	24	13	54%	µg/L	18	38	21	347	173	300	40 CFR 141 – Secondary Federal MCL	No	0.58
Thallium	METAL	24	1	4.2%	µg/L	0.050	0.10	1.0	1.0	0.10	0.24	Clean Water Act -- Human Health Water + Organism	No	0.42
Strontium-90	RAD	24	14	58%	pCi/L	-6.10E+00	-7.80E-01	3.1	49	38	8.0	40 CFR 141 – Primary Federal MCL	Yes	4.8
Tritium	RAD	24	24	100%	pCi/L	--	--	690	69,000	33,200	20,000	40 CFR 141 –Primary Federal MCL	Yes	1.7
Chloroform	VOC	24	19	79%	µg/L	0.10	0.10	0.11	3.0	2.4	1.4	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes	1.7
Trichloroethene	VOC	24	16	67%	µg/L	0.21	0.25	0.23	2.2	1.9	0.49	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes	3.8

Table 6-25. Comparison of Exposure Point Concentration to Action Levels for the Upland Exposure Area

Analyte Name	Analyte Class	Total Samples	Total Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	90th Percentile	Action Level	Action Level Basis	EPC > Action Level?	Level of Exceedance
Aluminum	METAL	30	12	40%	µg/L	5.0	10	9.8	41	23	50	40 CFR 141 – Secondary Federal MCL	No	0.46
Arsenic	METAL	30	30	100%	µg/L	--	--	1.5	3.9	3.5	0.018	Clean Water Act -- Human Health Water + Organism	Yes	193
Chromium	METAL	30	30	100%	µg/L	--	--	4.5	39	28	65	Clean Water Act -- Freshwater CCC	No	0.43
Hexavalent Chromium	METAL	29	24	83%	µg/L	2.0	2.0	2.4	37	23	10	40 CFR 131 -- Freshwater CCC	Yes	2.3
Iron	METAL	30	11	37%	µg/L	18	38	18	188	93	300	40 CFR 141 – Secondary Federal MCL	No	0.31
Strontium-90	RAD	30	2	6.7%	pCi/L	-8.40E+00	1.8	6.7	8.6	1.2	8.0	40 CFR 141 – Primary Federal MCL	No	0.15
Tritium	RAD	30	23	77%	pCi/L	-1.20E+02	100	190	24,000	11,000	20,000	40 CFR 141 – Primary Federal MCL	No	0.55
Chloroform	VOC	30	23	77%	µg/L	0.10	0.10	0.11	1.6	1.1	1.4	WAC 173-340-720(4)(b)(iii)(A) and (B)	No	0.79
Trichloroethene	VOC	30	24	80%	µg/L	0.21	0.25	0.29	3.3	2.4	0.49	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes	4.9



* RI results = results from three rounds of spatial and temporal sampling from monitoring well network defined in DOE/RL-2009-44.

Figure 6-9. Analyte Specific Evaluation Process for EPCs Less than Action Levels

Iron was detected in groundwater samples collected for the RI and the EPC is less than the action level. Detections of iron above the secondary MCL were reported in groundwater samples from the larger population of wells sampled over the past five years, as described previously in Section 4.3.1 and Section 6.3.2.3.1. The action level for iron is based on the secondary MCL, which is not federally enforceable but intended as a guideline for states. Additionally, iron concentrations in filtered and unfiltered water samples are less than the background level of 760 μg/L. Based on the results of this assessment, iron is not a COPC and will not be carried forward into the risk characterization section.

Thallium was detected in groundwater samples collected for the RI and the EPC is less than the action level. Thallium data from the larger population of monitoring wells sampled over the past 5 years, as described previously in Section 4.3.1 and Section 6.3.2.3.1, were not available. Thallium was detected in one groundwater sample collected for the RI at concentration above the action level but below the EQL identified in the 100-BC SAP (DOE/RL-2009-44). In addition, the EPC is less than the EQL of 2 μg/L. It should also be noted that concentrations of thallium in filtered groundwater samples are less than the 90th percentile Hanford Site background level of 1.7 μg/L. Based on the results of this assessment, thallium is not a COPC and will not be carried forward into the risk characterization section or into the FS.

Upland Exposure Area. Six of the nine analytes (aluminum, chloroform, chromium, iron, tritium, and strontium-90) have been detected at least once in groundwater and have 90th percentile values less than their respective action levels (Table 6-25).

Four of the six analytes (chloroform, chromium, strontium-90, and tritium) were identified as historical COPCs in the 100-BC Work Plan (DOE/RL-2008-46-ADD3). A discussion of all analytes reported with an EPC less than the action level is provided below.

Aluminum was detected in groundwater samples collected for the RI and the EPC is less than the action level. Aluminum data from the larger population of monitoring wells sampled over the past fiveyears, as described previously in Section 4.3.1 and Section 6.3.2.3.1, were not available. The action level for aluminum is based on the secondary MCL which is not federally enforceable, but intended as a guideline for states. As such, aluminum concentrations in groundwater are compared to the AWQC of 87 μg/L. All aluminum results (detected concentrations and MDLs) are less than the AWQC of 87 μg/L. Based on these results, aluminum is not a COPC and will not be carried forward into the risk characterization section.

Chloroform was detected in groundwater samples collected for the RI and the EPC is less than the action level. Chloroform data from the larger population of monitoring wells sampled over the past five years, as described previously in Section 4.3.1 and Section 6.3.2.3.1, were not available. The action level for chloroform is 1.4 μg/L based on the "Groundwater Cleanup Standards" (WAC 173-340-720) groundwater cleanup level; however, it defaults to the EQL of 5 μg/L reported in the 100-BC Area SAP (DOE/RL-2009-44) when the analytical method cannot achieve the action level. All chloroform results (detected concentrations and MDLs) were less than the EQL of 5 μg/L. Based on these results, chloroform is not a COPC and will not be carried forward into the risk characterization section.

Chromium was detected in groundwater samples collected for the RI and the EPC is less than the action level. Detections of chromium were less than the AWQC in the samples collected for the RI and the larger population of monitoring wells sampled over the past five years, as described previously in Section 4.3.1 and Section 6.3.2.3.1. Based on the results of this evaluation, chromium is not identified as a COPC and will not be carried forward into the risk characterization section.

Iron was detected in groundwater samples collected for the RI and the EPC is less than the action level. Detections of iron were less than the secondary MCL in groundwater samples from the larger population of wells sampled over the past five years, as described previously in Section 4.3.1 and Section 6.3.2.3.1. The action level for iron is based on the secondary MCL which is not federally enforceable, but intended as a guideline for states. Additionally, iron concentrations in filtered water samples are less than the background level of 760 µg/L. Based on these results, iron is not a COPC and will not be carried forward into the risk characterization section or into the FS.

Strontium-90 was detected in groundwater samples collected for the RI and the EPC is less than the action level. Detections of strontium-90 above the DWS were reported in groundwater samples collected for the RI and in the larger population of wells sampled over the past fiveyears, as described previously in Section 4.3.1 and Section 6.3.2.3.1. Strontium-90 concentrations range between 1.8 and 19 pCi/L when measured at 199-B4-4 and between 4.4 and 21 pCi/L when measured at 199-B4-1 over the past fiveyears, with concentrations at both wells trending downward. Strontium-90 is identified as a COPC because it is associated with trends at 199-B4-4 and 199-B4-1, and will be carried forward into the risk characterization section.

Tritium was detected in groundwater samples collected for the RI and the EPC is less than the action level. Detections of tritium above the DWS were reported in groundwater samples collected for the RI and in the larger population of wells sampled over the past fiveyears, as described previously in Section 4.3.1 and Section 6.3.2.3.1. Tritium concentrations measured at 199-B4-1, 199-B8-6, 199-B-8-7, and 199-B8-8 range between 4,600 and 59,000 pCi/L over the past fiveyears. Tritium is identified as a COPC because it is associated with a trend at 199-B4-1, 199-B8-6, 199-B-8-7, and 199-B8-8, and will be carried forward into the risk characterization section.

6.3.2.3.10 Identify COPCs with 90th Percentile Values Greater than Action Levels in Each Exposure Area.

The 90th percentile values are compared to the lowest available chemical-specific ARARs for protection of human health and aquatic receptors (that is, action levels). A comparison of EPCs to action levels for the Near-River exposure area and Upland exposure area are provided in Table 6-24 and Table 6-25, respectively. A flow-chart depicting this comparison is provided in Figure 6-10.

Near-River Exposure Area. Six of the 10 analytes (arsenic, chloroform, Cr(VI), strontium-90, trichloroethene, and tritium) have been detected at least once in groundwater and have 90th percentile values greater than their respective action levels (Table 6-24). All six analytes (arsenic, Cr(VI), strontium-90, tritium, chloroform, and trichloroethene) were identified as historical COPCs in the 100-BC Work Plan (DOE/RL-2008-46-ADD3). A discussion of all analytes reported with an EPC greater than the action level is provided below.

Arsenic is detected in groundwater samples collected for the RI and the EPC is above the action level. Arsenic data from the larger population of monitoring wells sampled over the past fiveyears, as described previously in Section 4.3.1 and Section 6.3.2.3.1, were not available. Arsenic concentrations in all filtered and unfiltered samples are less than the 90th percentile Hanford Site background value of 7.85 µg/L. Based on these results, arsenic is a not a COPC and will not be carried forward into the risk characterization section.

Chloroform was detected in groundwater samples collected for the RI and the EPC is greater than the action level. Chloroform data from the larger population of monitoring wells sampled over the past five years, as described previously in Section 4.3.1 and Section 6.3.2.3.1, were not available. The action level for chloroform is 1.4 µg/L based on the "Groundwater Cleanup Standards" (WAC 173-340-720) groundwater cleanup level; however, it defaults to the EQL of 5 µg/L reported in the 100-BC Area SAP

(DOE/RL-2009-44) when the analytical method cannot achieve the action level. All chloroform results (detected concentrations and MDLs) were less than the EQL of 5 µg/L. Based on these results, chloroform is not a COPC and will not be carried forward into the risk characterization section.

Cr(VI) was detected in groundwater samples collected for the RI and the EPC is greater than the AWQC of 10 µg/L. Detections of Cr(VI) were also measured in the larger population of wells sampled over the past 5 years, as described previously in Section 4.3.1 and Section 6.3.2.3.1. Cr(VI) is identified as a COPC and will be carried forward into the risk characterization section.

Strontium-90 was detected in groundwater samples collected for the RI and the EPC is greater than the DWS of 8 pCi/L. Detections of strontium-90 were also measured in the larger population of wells sampled over the past fiveyears, as described previously in Section 4.3.1 and Section 6.3.2.3.1. Strontium-90 is identified as a COPC and will be carried forward into the risk characterization section.

Tritium was detected in groundwater samples collected for the RI and the EPC is greater than the DWS of 20,000 pCi/L. Detections of tritium were also measured in the larger population of wells sampled over the past fiveyears, as described previously in Section 4.3.1 and Section 6.3.2.3.1. Tritium is identified as a COPC and will be carried forward into the risk characterization section.

Trichloroethene was detected in groundwater samples collected for the RI and the EPC is greater than the action level of 0.49 µg/L. Trichloroethene data from the larger population of monitoring wells sampled over the past five years, as described previously in Section 4.3.1 and Section 6.3.2.3.1, were not available. The action level for trichloroethene is 0.49 µg/L based on the "Groundwater Cleanup Standards" (WAC 173-340-720) groundwater cleanup level; however, it defaults to the EQL of 1 µg/L reported in the 100-BC SAP (DOE/RL-2009-44) when the analytical method cannot achieve the action level. The EPC is also greater than the EQL of 1 µg/L. Trichloroethene concentrations greater than the EQL (ranging between 0.9 µg/L and 2.2 µg/L) were reported at two wells, 199-B3-46 and 199-B5-5. Trichloroethene is identified as a COPC because it is associated with a trend at wells 199-B3-46 and 199-B5-5, and will be carried forward into the risk characterization section.

Upland Exposure Area. Three of the nine analytes (arsenic, Cr(VI), and trichloroethene) have been detected at least once in groundwater and have 90th percentile values greater than their respective action levels (Table 6-25).

All three analytes (arsenic, Cr(VI), and trichloroethene) were identified as historical COPCs in the 100-BC Work Plan (DOE/RL-2008-46-ADD3). The conclusions of the nature and extent evaluation for analytes identified as historical COPCs support the findings of this risk evaluation[10]. A discussion of all analytes reported with an EPC less than the action level is provided below.

Arsenic is detected in groundwater samples collected for the RI and the EPC is above the action level. Arsenic data from the larger population of monitoring wells sampled over the past fiveyears, as described previously in Section 4.3.1 and Section 6.3.2.3.1, were not available. With the exception of one arsenic detection, arsenic concentrations in all filtered and unfiltered samples are less than the 90th percentile Hanford Site background value of 7.85 µg/L. Arsenic was detected one filtered groundwater sample from 199-B3-50 (July 2010) at a concentration of 18 µg/L; however, the corresponding unfiltered sample reported an arsenic concentration of 3.1 µg/L. Arsenic concentrations from the previous and subsequent sampling rounds were less than the arsenic background value. Additionally, the arsenic result was flagged with a "Y" review qualifier indicating that the result is suspect; however, there is insufficient evidence to

[10] Arsenic and trichloroethene are represented only by RI data (no other data were available over last five years). Cr(VI) is represented by RI data and have historical data collected from the last five years.

show the result is valid or invalid. Based on these results, arsenic is a not a COPC and will not be carried forward into the risk characterization section.

Cr(VI) was detected in groundwater samples collected for the RI and the EPC is greater than the AWQC of 10 μg/L. Detections of Cr(VI) were also measured in the larger population of wells sampled over the past fiveyears, as described previously in Section 4.3.1 and Section 6.3.2.3.1. Cr(VI) is identified as a COPC and will be carried forward into the risk characterization section.

Trichloroethene was detected in groundwater samples collected for the RI and the EPC is greater than the action level of 0.49 μg/L. Trichloroethene data from the larger population of monitoring wells sampled over the past fiveyears, as described previously in Section 4.3.1 and Section 6.3.2.3.1, were not available. The action level for trichloroethene is 0.49 μg/L based on the "Groundwater Cleanup Standards" (WAC 173-340-720) groundwater cleanup level; however it defaults to the EQL of 1 μg/L reported in the 100-BC SAP (DOE/RL-2009-44) when the analytical method cannot achieve the action level. Trichloroethene concentrations greater than the EQL were reported at five wells including 199-B3-50, 199-B4-4, 199-B5-6, 199-B9-3, and 699-65-72, with concentrations ranging between 0.72 μg/L and 3.3 μg/L. Trichloroethene is identified as a COPC because it is associated with a trend at wells 199-B3-50, 199-B4-4, 199-B5-6, 199-B9-3, and 699-65-72, and will be carried forward into the risk characterization section.

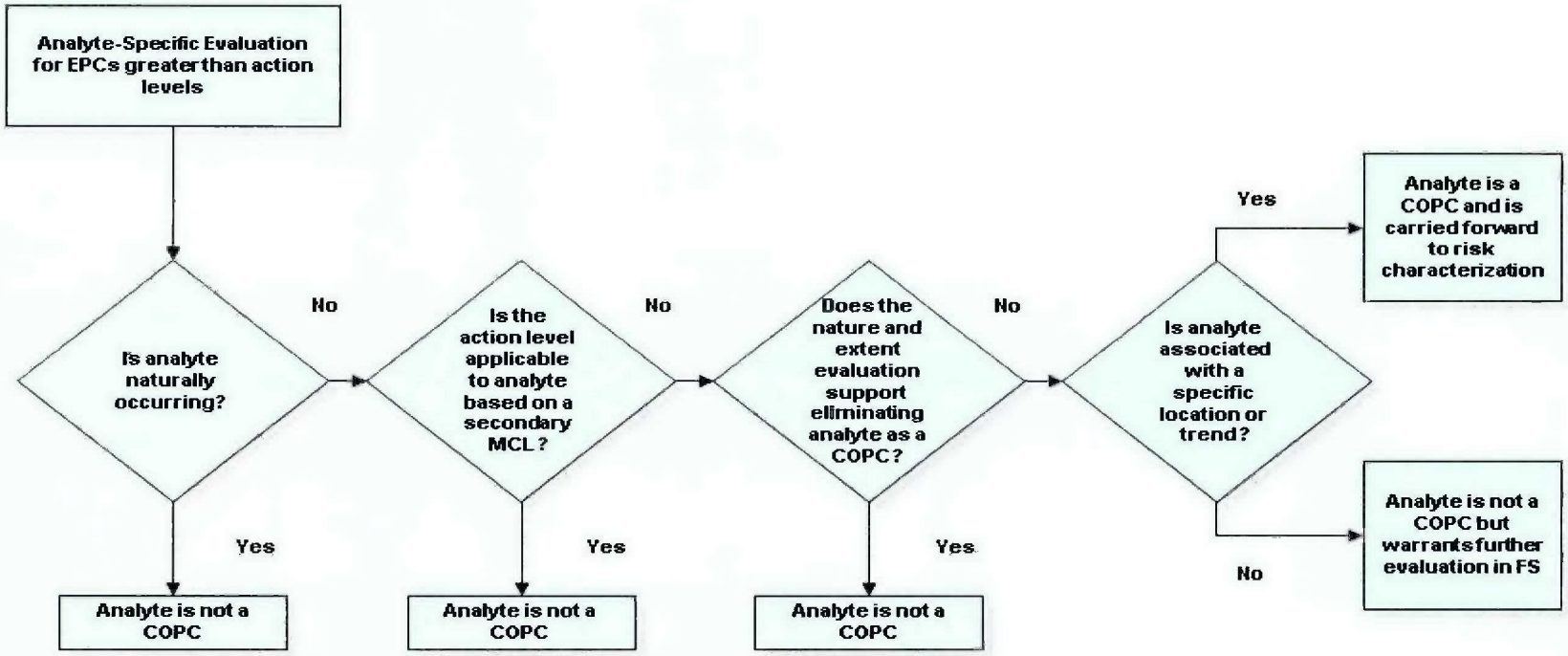


Figure 6-10. COPC Identification Analyte Specific Evaluation Process for EPCs Greater than Action Levels

6.3.2.4 Summary of COPCs

Table 6-26 presents a summary of the COPCs identified for the 100-BC-5 Groundwater OU. This list of COPCs represents the analytes most likely to contribute to overall risk within each 100-BC-5 Groundwater OU exposure area.

Table 6-26. Summary of Groundwater COPCs Identified for the 100-BC-5 Groundwater OU

Near-River Exposure Area		
Metals	**VOCs**	**Radionuclides**
Cobalt**	Trichloroethene	Strontium-90
Hexavalent Chromium		Tritium
Upland Exposure Area		
Metals	**VOCs**	**Radionuclides**
Cobalt**	Trichloroethene	Strontium-90*
Hexavalent Chromium		Tritium*

* 90th percentile value did not exceed an action level but retained as COPC due to localized contamination.

** EPC did not exceed action level, but infrequent detections above action level result in uncertain status and warrants further evaluation in the FS.

With the exception of strontium-90 and tritium in the Upland exposure area, all COPCs were identified because the 90th percentile concentration exceeds the action level. As described in Section 6.3.2.3, strontium-90 and tritium are identified as COPCs because they are associated with a long-term trend. The COPC identification process identified one analyte for the 100-BC-5 Groundwater OU that is considered a COPC and warrants further evaluation in the FS. The occurrence of cobalt in groundwater is uncertain because this analytes historically has been detected in groundwater at concentrations above the action level; however, its presence was not associated with a specific location or a trend and the analytical methods used were not of sufficient accuracy for risk characterization purposes. In addition, the EPC for this analytes is less than its respective action level. Therefore, cobalt is considered a COPC and warrants further evaluation in the FS; however, it will not move forward into the risk characterization section.

6.3.3 Exposure Assessment

The exposure assessment component of the risk assessment typically identifies the populations that may be exposed, the routes by which these receptors may become exposed, and the magnitude, frequency, and duration of potential exposures.

6.3.3.1 Contaminant Sources

The primary sources of contamination in 100-BC Source OU are the two water-cooled nuclear reactors (105-B and 105-C) and the structures (e.g., fuel storage basins) and processes (e.g., the sodium dichromate process) associated with reactor operations. A complete discussion of primary and secondary sources is provided in Section 4.2.1 and Section 5.2.

6.3.3.2 Release Mechanisms and Environmental Transport Media

The primary COPC release mechanisms and transport pathways at 100-BC are discussed in Sections 5.3 and 5.4, and include the following:

- Direct contact with groundwater containing COPCs
- Volatilization of COPCs in groundwater from showering or household activities
- Discharge of groundwater to the Columbia River through upwelling and seeps

6.3.3.3 100-BC-5 Groundwater OU Exposure Areas

The 100-BC-5 Groundwater OU is generally distinguished by the presence of hexavalent chromium, strontium-90, and tritium plumes with concentrations above federal MCLs or aquatic standards. A wedge-shaped plume of strontium-90 extends from central 100-BC north toward the Columbia River. Strontium-90 trends in wells near some of the former contaminant sources including the 116-B-11 retention basin, 116-B-1 Trench, and the 116-C-1 Trench. The unconfined aquifer beneath the 100-B C Source OU contains localized areas of tritium that are above the federal MCL. Tritium was present in effluent discharged to former cribs near the B Reactor (116-B-5 Crib) and near the Columbia River. The former 118-B-1 Burial Ground in the southwestern area of 100-BC is an additional source of tritium. Sources of hexavalent chromium are located primarily in the eastern portion of 100-BC. The sources included cribs near the reactor buildings, trenches, and retention basins near the Columbia River (116-B-1, 116-B-11, 116-C-1, and 116-C-5), and pipelines from the reactor buildings to these near river facilities. The 100-BC-5 Groundwater OU represents all of the plume sources in 100-BC.

The 100-BC-5 Groundwater OU is evaluated as two exposure areas. The Near-River exposure area represents the portion of the Cr(VI) plume that is located within 500 m (1,640 ft) of the Columbia River shoreline. The Upland exposure area represents the portion of the Cr(VI) plume that is located greater than 500 m (1,640 ft) from the Columbia River shoreline. The primary objectives for evaluating each exposure area are to provide information necessary to determine the need for remedial action and to use the information to select the best remedy. These objectives are achieved by performing the following steps:

- EPCs for each COPC are compared to contaminant-specific ARARs for the purpose of understanding the potential for exposure to groundwater contaminants and the associated health risks.
- Specific locations are identified within the exposure area for the purpose of evaluating remedial alternatives in the FS.

The basis for the exposure area and the known or suspected sources were described above. The location of each well within the 100-BC-5 Groundwater OU network is shown on Figure 6-5. Table 6-18 lists the monitoring wells included in each exposure area.

6.3.3.4 Potentially Complete Human and Aquatic Exposure Pathways and Receptors

This section describes the potentially complete exposure pathways and receptors that are specifically addressed in the federal and state chemical-specific ARARs evaluated in this groundwater risk assessment.

6.3.3.4.1 Chemical-Specific ARARs for Protection of Human Health

All the chemical-specific ARARs for use as a drinking water source consider ingestion as a complete and significant pathway for exposure. Washington State regulations assume that inhalation of vapors for VOCs is also a complete and significant exposure pathway. Washington State regulations do not include the dermal contact exposure route in the equations for calculation of groundwater cleanup levels, whereas

federal regulations consider dermal contact exposure a complete but insignificant groundwater contaminant exposure pathway. Elimination of the dermal contact exposure route from chemical-specific ARARs may result in an overestimation of the cleanup level; uncertainties associated with exclusion of this exposure route are addressed in Section 6.3.9.4.

For groundwater with the potential to impact surface water, federal water quality standards assume that exposure to humans occurs through ingestion of water and consumption of fish tissue, and Washington State regulations assume that exposure occurs through consumption of fish tissue. These federal standards are developed for protection of human health where groundwater discharges to surface water that is used as a drinking water source and used for fishing. Washington State regulations as defined in MTCA, "Surface Water Cleanup Standards" (WAC 173-340-730(3)(b)) developed surface water standards that assume that exposure occurs through consumption of fish tissue.

6.3.3.4.2 Chemical-Specific ARARs for Protection of Aquatic Receptors

The objectives and methodology for deriving the numerical AWQC are described in *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses* (PB85-227049). The AWQC are intended to provide a reasonable level of protection of all except a small fraction (0.05) of the taxa, unless a commercially or recreationally important species is very sensitive. Protection of the following aquatic organisms and their uses are defined in *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses* (PB85-227049) as prevention of unacceptable long-term and short-term effects:

- Commercially, recreationally, and other important species
- Fish and benthic invertebrate assemblages in rivers and streams
- Fish, benthic invertebrate, and zooplankton assemblages in lakes, reservoirs, estuaries, and oceans

Numeric values are expressed as two numbers, the criteria maximum concentration (CMC) and criteria continuous concentration (CCC), which provide an appropriate degree of protection of aquatic organisms and their uses from acute and chronic toxicity to animals, toxicity to plants, and bioaccumulation by aquatic organisms. The CMC is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. EPA derives acute criteria from 48- to 96-hour tests of lethality or immobilization. The CCC is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect. EPA derives chronic criteria from longer-term (often greater than 28 days) tests that measure survival, growth, reproduction or, in some cases, bioconcentration. The CMC and the CCC are two of the six parts of the aquatic life criterion. The other four parts are the acute averaging period, chronic averaging period, acute frequency of allowed exceedance, and chronic frequency of allowed exceedance. The lower of the CMC or the CCC is the numeric water quality criteria used as the chemical-specific ARAR for protection of freshwater species.

6.3.4 Toxicity Assessment

The toxicity assessment component evaluates the relationship between the magnitude of exposure to an analyte and the likelihood of adverse health effects to potentially exposed populations. Similar to the exposure assessment, the comparison to chemical-specific ARARs takes into consideration the likelihood of an adverse health effect to occur to the potentially exposed population. The risk-based concentrations, such as the MTCA, "Groundwater Cleanup Standards" (WAC 173-340-720), are developed using toxicological information published at EPA's IRIS database and EPA's hierarchy of toxicity values, as

described in Section 6.2.4. The assignment of chemical-specific ARARs to COPCs is described in Section 6.3.2.2.

6.3.4.1 State and Federal Maximum Contaminant Levels for Nonradionuclides

The MCLG is the maximum level of a contaminant in drinking water at which no known or anticipated adverse health effects occur, allowing for an adequate margin of safety. MCLGs are nonenforceable health goals. EPA establishes the MCL, an enforceable standard, based on the MCLG. The MCL is the maximum permissible level of a contaminant in water that is delivered to any user of a public water system. Prior to the *Safe Drinking Water Act of 1974* (SDWA) amendments in 1996, the MCL was set as close to the MCLG as was feasible. The 1996 Amendments to the SDWA allow consideration of costs and benefits in establishing an MCL. Primary MCLs are legally enforceable standards and protect public health by limiting the levels of contaminants in drinking water. Secondary MCLs are nonenforceable guidelines regulating those contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. The secondary MCLs are recommended standards but are not federally enforceable.

The *Six Year Review Chemical Contaminants Health Effects Technical Support Document (*EPA 822-R-03-008) describes how MCLGs are derived. MCLGs are developed using an oral reference dose (RfD) for contaminants that exhibit a threshold toxic effect. The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious noncancer effects during a lifetime. EPA generally assumes that the relative source contribution from drinking water is 20 percent of the RfD, unless other exposure data for the chemical are available. This allows 80 percent of the total exposure to come from sources other than drinking water, such as exposure from food, inhalation, or dermal contact.

6.3.4.2 Maximum Contaminant Levels for Radionuclides in Drinking Water

Current MCLs for radionuclides are set at 4 mrem/yr for the sum of the doses from beta particle and photon emitters, 15 pCi/L for gross alpha emitter activity (including radium-226, but excluding uranium and radon), and 5 pCi/L combined for radium-226 and radium-228. A mass-based concentration MCL of 30 μg/L has been established for uranium. The current MCLs for beta emitters specify that MCLs are to be calculated based upon an annual dose equivalent of 4 mrem to the total body or any internal organ. It is further specified that the calculation be performed based on a 2 L (0.5 gal)/day drinking water intake using the 168-hour data listed in *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air or Water for Occupational Exposure (*NBS Handbook 69).

6.3.4.3 Washington State Regulations

Toxicological parameter values are obtained from the CLARC (Ecology, 2009) compendium of technical information related to the calculation of cleanup levels under MTCA regulation (WAC 173-340). The sources for the oral cancer potency values and RfDs are provided in the CLARC database (Ecology, 2009). The sources for identifying reference doses and carcinogenic potency factors are defined in MTCA and "Human Health Risk Assessment Procedures" (WAC 173-340-708(7) and WAC 173-340-708(8)).

6.3.4.4 Toxicity Values

The sources of toxicity values for human health are the same as those described in Section 6.2.4.2 of this report.

As discussed in Section 6.3.3.4.2, the lower of the CMC or the CCC is the numeric water quality criteria used as the chemical-specific ARAR for protection of freshwater species. *Technical Support*

*Document for Water Quality-based Toxics Control (*EPA/505/2-90-001) explains that development of national numerical water quality criteria for the protection of aquatic organisms is a complex process that uses information from many areas of aquatic toxicology After a decision is made that a national criterion is needed for a particular material, all available information concerning toxicity to and bioaccumulation by aquatic organisms is collected and reviewed for acceptability. If enough acceptable data for 48- to 96-hour toxicity tests on aquatic animals are available, the data are used to derive the chronic or long-term exposure criteria. The chronic criteria can also be calculated directly if sufficient data are available. If justified, one or both of the criteria may be related to another water quality characteristic (e.g. pH, temperature, or hardness). Separate criteria are developed for fresh water and salt water.

6.3.5 Risk Characterization

Risk characterization is the final step of the HHRA process. In this step, the toxicity values are combined with the estimated chemical intakes for the receptor populations in order to quantitatively estimate both carcinogenic risk and risks from noncarcinogens. The risk characterization step is completed through the comparison of the EPC to the chemical-specific ARAR using the equations presented in Section 6.3.5.1. As described earlier in this section, the comparison to chemical-specific ARARs determines whether existing groundwater concentrations are protective of HHE. It is also used to determine if current groundwater concentrations have the potential to exceed an HI greater than 1 or the upper end of the NCP (40 CFR 300) risk range for cumulative carcinogenic site risk to an individual based on the RME for both current and future land use.

6.3.5.1 Protectiveness Evaluation

Protectiveness of human health is determined by the comparison of 90th percentile groundwater concentrations to existing federal or state MCLs. Similarly, protectiveness of human and aquatic receptors is determined by the comparison of 90th percentile groundwater concentrations to water quality criteria established under Section 304 or 303 of the *Clean Water Act of 1977* and Washington State water quality standards.

This risk characterization step is included to address the presence of multiple exposure pathways or the potential for exposure to multiple contaminants. The presence of either one of these conditions may render ARARs not adequately protective. This step is also included to address the requirements of MTCA, "Human Health Risk Assessment Procedures" (WAC 173-340-708(5)(a) and WAC 173-340-708(6)(b)). These regulations require that cleanup levels be adjusted downward to take into account exposure to multiple hazardous substances or multiple pathways of exposure. This adjustment needs to be made only if without this adjustment, the HI would exceed 1 or the total ELCR would exceed 1 in 100,000 (1×10^{-5}).

To determine the potential to exceed an HI greater than 1 or the upper end of the NCP (40 CFR 300) risk range for cumulative carcinogenic site risk to an individual based on the RME for both current and future land use, the following standards are used:

- "Groundwater Cleanup Standards", (WAC 173-340-720)
- "Surface Water Cleanup Standards" (WAC 173-340-730)
- *National Recommended Water Quality Criteria* (EPA, 2009a)

For the purposes of this risk assessment, the potential for unacceptable human health risk is identified using the following risk thresholds:

- ELCR values are compared to the "target range" of 10^{-6} to 10^{-4} that is generally used by EPA. The MTCA (WAC 173-340) states that cancer risks resulting from multiple hazardous substances

should not exceed 1×10^{-5} for unrestricted land use. ELCR values within or exceeding the target range require a risk management decision that includes evaluating site-specific characteristics and exposure scenario factors to assess whether remedial action is warranted.

- An HI (the sum of the ratios of the chemical intake to the RfDs for all COPCs) greater than 1 indicates that some potential exists for adverse noncancer health effects associated with exposure to the COPCs.

Although this groundwater risk assessment produces numerical estimates of risk, it should be recognized that these numbers may not predict actual health outcomes because they are based largely on hypothetical assumptions. Their purpose is to provide a frame of reference for risk management decision making. Interpretation of the risk estimates provided should consider the nature and weight of evidence supporting these estimates, as well as the magnitude of uncertainty surrounding them.

Protectiveness of humans from exposure to beta/photon emitters is determined by an annual dose equivalent to the body or any internal organ and determined by comparison to an activity concentration in drinking water for alpha emitters; therefore, a risk assessment is not conducted for COPCs that are radionuclides.

6.3.5.1.1 Cancer Risk Estimation Method

The potential for cancer effects is evaluated by estimating the ELCRs. This risk is the incremental increase in the probability of developing cancer during one's lifetime in addition to the background probability of developing cancer (that is, if no exposure to site chemicals occurs). To estimate the cancer risks from exposure to an individual carcinogen from all exposure routes considered, the following equation is used:

$$Risk_I = \frac{EPC_{water}}{CUL_{carcinogen}} \times TR$$

where:

$Risk_I$	=	ELCR for individual chemical
EPC_{water}	=	90th percentile concentration in groundwater (µg/L)
$CUL_{carcinogen}$	=	groundwater cleanup level based on 10^{-6} carcinogenic effect (µg/L)
TR	=	target ELCR for individual hazardous substance for unrestricted land use (10^{-6})

To estimate the cancer risks from exposure to multiple carcinogens from all exposure routes considered, the following equation is used:

$$Risk_T = \sum_i \frac{EPC_{water}}{CUL_{carcinogen}} \times TR$$

where:

$Risk_T$	=	total ELCR for all chemicals
EPC_{water}	=	90th percentile concentration in groundwater (µg/L)
$CUL_{carcinogen}$	=	groundwater cleanup level based on 10^{-6} carcinogenic effect (µg/L)

TR = target ELCR for individual hazardous substance for unrestricted land use (10^{-6})

i = the sum of the ratios for the ith chemical

6.3.5.1.2 Noncancer Risk Estimation Method

For noncancer effects, the likelihood that a receptor will develop an adverse effect is estimated by comparing the predicted level of exposure for a particular chemical with the highest level of exposure that is considered protective (i.e., its RfD). The ratio of the chronic daily intake divided by RfD is termed the HQ.

When the HQ for a chemical exceeds 1 (i.e., exposure exceeds RfD), a concern exists for potential noncancer health effects. To estimate the HQ from all exposure routes considered for an individual hazardous substance, the following equation is used:

$$HQ = \frac{EPC_{water}}{CUL_{noncarcinogen}}$$

where:

HQ = HQ for individual chemical

EPC_{water} = 90th percentile concentration in groundwater (µg/L)

$CUL_{noncarcinogen}$ = groundwater cleanup level based on HQ = 1 noncarcinogenic effects (µg/L)

To estimate the HI from all exposure routes considered for multiple hazardous substances, the following equation is used:

$$HI_T = \sum_i \frac{EPC_{water}}{CUL_{noncarcinogen}}$$

where:

HI_T = total HI for all chemicals

EPC_{water} = 90th percentile concentration in groundwater (µg/L)

$CUL_{noncarcinogen}$ = groundwater cleanup level based on HQ=1 noncarcinogenic effects (µg/L)

i = the sum of the ratios for the ith chemical

6.3.5.1.3 Estimating the Sum of Fractions and 4 mrem/yr Dose Equivalent

An annual cumulative dose equivalent of 4 mrem to the total body or any internal organ from beta and photon emitters is considered protective of human health. The sum of fractions (SOF) is used to determine whether the contribution of each radioisotope is greater than the cumulative annual dose equivalent of 4 mrem. The following equation is used to determine if the 4 mrem standard is exceeded when a mixture of radioisotopes is present:

$$Sum\ of\ Fractions = \left(\frac{A\left(\frac{pCi}{L}\right)}{MCL_A\left(\frac{pCi}{L}\right)} + \frac{B\left(\frac{pCi}{L}\right)}{MCL_B\left(\frac{pCi}{L}\right)} + \bullet\bullet\bullet \right)$$

where:

A = the EPC activity concentration of specific beta/photon emitting nuclide A

B = the EPC activity concentration of specific beta/photon emitting nuclide B

MCL_A = the derived single-nuclide beta/photon emitting MCL-equivalent activity concentration for nuclide A

MCL_B = the derived single-nuclide beta/photon emitting MCL-equivalent activity concentration for nuclide B

The 4 mrem standard is not exceeded if the SOF is less than 1. Each fraction is converted to a dose equivalent of 4 mrem/year by multiplying the fraction by 4.

6.3.6 Risk Characterization Results Using Chemical-Specific ARARs by Exposure Area

A comprehensive set of chemical-specific ARARs that are considered protective of HHE were used to identify COPCs that warrant further evaluation in the FS. The lowest of the available chemical-specific ARARs was selected for comparison if more than one chemical-specific ARAR exists for a certain analyte. The analytes listed in Tables 6-27, 6-28, 6-29, and 6-30 for the Near-River exposure area and Tables 6-31, 6-32, 6-33, and 6-34 for the Upland exposure area are considered COPCs because (1) the 90th percentile groundwater concentration is greater than the lowest available chemical-specific ARAR, or (2) the analyte is measured at concentrations above the lowest chemical-specific ARAR in a localized area.

6.3.6.1 Near-River Exposure Area

Groundwater in the Near-River exposure area is evaluated as a potential drinking water source and nearshore groundwater has the potential to discharge to the Columbia River. Table 6-27 provides a summary of the COPCs, the 90th percentile groundwater concentration, federal and state MCLs, and the MTCA "Groundwater Cleanup Standards" (WAC 173-340-720) groundwater cleanup standards for carcinogenic and noncarcinogenic effects. Table 6-28 provides a summary of the COPCs, the 90th percentile groundwater concentration, and federal and state surface water quality standards. These standards (listed in Tables 6-27 and 6-28) represent the chemical-specific ARARs that were exceeded by at least one COPC.

Table 6-27. Summary of Current Conditions 90th Percentile Groundwater Concentrations, Federal and State MCLs, and WAC 173-340-720 Groundwater Cleanup Levels for the Near-River Exposure Area (Human Health Action Levels)

					WAC 173-340-720 Cleanup Levels		
COPCs	**Units**	**90th Percentile Value**	**Federal MCL**	**State MCL**	**Non-carcinogens**	**Carcinogens at 10^{-6} Risk Level**	**Carcinogens at 10^{-5} Risk Level**
Strontium-90	pCi/L	38	8	--	--	--	--
Tritium	pCi/L	33,200	20,000	--	--	--	--
Trichloroethene	µg/L	1.9	5	5	--	0.49	4.9
Cr(VI)	µg/L	50	--	--	48	--	--

Table 6-28. Summary of Current Conditions 90th Percentile Groundwater Concentrations, and Federal and State Water Quality Standards for the Near-River Exposure Area (Aquatic Action Levels)

			AWQC		WAC 173-201A	CFR 131 Water Quality Standards	
COPCs	**Units**	**90th Percentile Value**	**Freshwater CMC (Acute)**	**Freshwater CCC (Chronic)**	**Freshwater CCC (Chronic)**	**Freshwater CMC (Acute)**	**Freshwater CCC (Chronic)**
Strontium-90	pCi/L	38	--	--	--	--	--
Tritium	pCi/L	33,200	--	--	--	--	--
Trichloroethene	µg/L	1.9	--	--	--	--	--
Cr(VI)	µg/L	50	16	11	10	15	10

Sources:

"Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A).

"Water Quality Standards" (40 CFR 131).

6.3.6.1.1 Protectiveness Evaluation for Human Health

The protectiveness evaluation for human health is performed to help determine if a CERCLA remedial action is appropriate. *Rules of Thumb for Superfund Remedy Selection* (EPA 540-R-97-013) states that a remedial action is generally appropriate when a regulatory standard that helps define protectiveness (a federal or state MCL or nonzero MCLG for current or potential drinking water aquifers) is exceeded.

The 90th percentile groundwater concentration for strontium-90 is greater than the DWS developed for the protection of human health. Strontium-90 is identified as a COPC indicating the need to evaluate potential remedial technologies for strontium-90 in the FS. As Table 6-29 shows, potential exposure to groundwater as a drinking water source would result in a dose greater than 4 mrem/yr from strontium-90. Of the eight wells in the Near-River exposure area, five monitoring wells (199-B2-14, 199-B3-1, 199-B3-46, 199-B3-47, and 199-B5-2) were reported with concentrations of strontium-90 above 8 pCi/L. Section 4.3.2 provides a detailed discussion of the strontium-90 plume in the 100-BC-5 Groundwater OU.

Table 6-29. Summary of 90th Percentile Current Groundwater Concentrations and Associated Sum of Fractions for the Near-River Exposure Area

COPC	Units	90th Percentile Value	Federal MCL	Individual Fraction
Strontium-90	pCi/L	38	8	4.8
Tritium	pCi/L	33,200	20,000	1.7
Sum of Fractions				**6.5**
Cumulative Annual Dose (mrem)				**26**

Note: MCL; derived single-nuclide MCL-equivalent activity concentration.

The 90th percentile groundwater concentration of tritium is greater than the DWS developed for the protection of human health. Tritium is identified as a COPC, indicating the need to evaluate potential remedial technologies for tritium in the FS. As Table 6-29 shows, potential exposure to groundwater as a drinking water source would result in a dose greater than 4 mrem/yr from tritium. Of the eight wells in the Near-River exposure area, two monitoring wells (199-B3-47 and 199-B5-2) were reported with concentrations of tritium above 20,000 pCi/L. Section 4.3.2 provides a detailed discussion of the tritium plume in the 100-BC-5 Groundwater OU.

A federal and state MCL is not available for Cr(VI); therefore, the protectiveness evaluation was not performed. Cr(VI) is discussed in the protectiveness evaluation for aquatic organisms (Section 6.3.6.1.2) and the risk evaluation (Section 6.3.6.1.3).

The 90th percentile groundwater concentration for trichloroethene is less than the federal and state MCL of 5 µg/L. Trichloroethene is not identified as a COPC and a need for further review in the FS is not established based on the results of this evaluation.

6.3.6.1.2 Protectiveness Evaluation for Aquatic Receptors

The protectiveness evaluation for aquatic receptors is performed to help determine if a CERCLA remedial action is appropriate. *Rules of Thumb for Superfund Remedy Selection* (EPA 540-R-97-013) states that a remedial action is generally appropriate when a regulatory standard that helps define protectiveness (National Recommended Water Quality Criteria [EPA, 2009a]) is exceeded. As described in the exposure assessment, groundwater discharges to the Columbia River through upwelling and seeps. The point of compliance for surface water cleanup levels is defined in the MTCA, "Surface Water Cleanup Standards" (WAC 173-340-730(7)(a)) as the point or points at which hazardous substances are release to surface waters of the state. MTCA, "Surface Water Cleanup Standards" (WAC 173-340-730(7)(b)) indicates that no mixing zone shall be allowed to demonstrate compliance with surface water cleanup levels. Groundwater EPCs from each exposure area within the 100-BC-5 Groundwater OU are compared to determine if groundwater concentrations discharging to the Columbia River are in compliance with federal and state standards.

Federal and state water quality standards for the protection of freshwater organisms are not published for tritium or strontium-90; therefore, a protectiveness evaluation is not included. Strontium-90 and tritium are included in the protectiveness evaluation for human health in Section 6.3.6.1.1.

Federal and state water quality standards for the protection of freshwater organisms are not published for trichloroethene; therefore, a protectiveness evaluation is not included. Trichloroethene is included in the protectiveness evaluation for human health in Section 6.3.6.1.1 and the risk evaluation presented in Section 6.3.6.1.3.

The 90th percentile groundwater concentration for Cr(VI) is greater than the "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A) freshwater AWQC value of 10 µg/L as shown in Table 6-27. Cr(VI) is identified as a COPC indicating the need to evaluate potential remedial technologies for Cr(VI) in the FS. Of the eight monitoring wells in the Near-River exposure area, seven monitoring wells (199-B2-14, 199-B3-1, 199-B3-46, 199-B3-47, 199-B5-1, 199-B5-2, and 199-B5-5) were reported with concentrations of Cr(VI) above 10 µg/L. The approximate distances from the Columbia River for those wells reporting concentrations greater than 10 µg/L are listed below:

- 199-B2-14 (147 m [482 ft])
- 199-B3-1 (145 m [478 ft])
- 199-B3-46 (222 m [728 ft])

- 199 B3-47 (88 m [289 ft])
- 199-B5-1 (483 m [1,585 ft])
- 199-B5-2 (495 m [1,624 ft])
- 199-B5-5 (304 m [997 ft])

Section 4.3.2 provides a detailed discussion of the Cr(VI) plume in the 100-BC-5 Groundwater OU.

6.3.6.1.3 Risk Evaluation

The risk evaluation is also performed to help determine whether a CERCLA remedial action is appropriate. *Rules of Thumb for Superfund Remedy Selection* (EPA 540-R-97-013) states that a remedial action is generally appropriate when the estimated risk calculated in a risk assessment exceeds a noncarcinogenic level for an adverse health effect or the upper end of the NCP (40 CFR 300) risk range for "cumulative carcinogenic site risk" to an individual based on the RME for both current and future land use.

The potential cumulative ELCR for the Near-River exposure area from all nonradiological carcinogenic COPCs is 3.9×10^{-6}, which is less than the WAC 173-340-708 risk threshold of 1×10^{-5} for multiple hazardous substances and less than the upper NCP threshold of 1×10^{-4}. Table 6-30 shows the only contributor to risk is trichloroethene (3.9×10^{-6}, 100 percent contribution). Trichloroethene is not identified as COPC based on the results of this evaluation. Concentrations of trichloroethene in monitoring wells from this exposure area range between 0.23 and 2.2 µg/L. However, there have been no measured concentrations above the 10^{-5} level of 4.9 µg/L.

The HI for the Near-River exposure area is 1.0, which is equal to the EPA and WAC 173-340 target HI of 1. The individual HQ for Cr(VI) is equal to one. Cr(VI) is not identified as a COPC based on the results of this evaluation.

Table 6-30. Summary of 90th Percentile Current Groundwater Concentrations and Associated Cancer Risk and Noncancer Hazard Index for the Near-River Exposure Area

			WAC 173-340-720 Cleanup Levels			
COPC	**Units**	**90th Percentile Value**	**Non-carcinogens**	**HQ**	**Carcinogens at 10^{-6} Risk Level**	**ELCR**
Trichloroethene	µg/L	1.9	--	--	0.49	3.9×10^{-6}
Total ELCR					--	**3.9×10^{-6}**
Cr(VI)	µg/L	50	48	1.0	--	--
Hazard Index				**1.0**		

6.3.6.2 Upland Exposure Area

Groundwater in the Upland exposure area is evaluated as a potential drinking water source and nearshore groundwater has the potential to discharge to the Columbia River. Table 6-31 provides a summary of the COPCs, the 90th percentile groundwater concentration, federal and state MCLs, and the MTCA "Groundwater Cleanup Standards" (WAC 173-340-720) groundwater cleanup standards for carcinogenic and noncarcinogenic effects. Table 6-32 provides a summary of the COPCs, the 90th percentile groundwater concentration, and federal and state surface water quality standards. These standards (listed

in Tables 6-31 and 6-32) represent the chemical-specific ARARs that were exceeded by at least one COPC.

Table 6-31. Summary of Current Conditions 90th Percentile Groundwater Concentrations, Federal and State MCLs, and WAC 173-340-720 Groundwater Cleanup Levels for the Upland Exposure Area (Human Health Action Levels)

					WAC 173-340-720 Cleanup Levels		
COPC	Units	90th Percentile Value	Federal MCL	State MCL	Non-carcinogens	Carcinogens at 10^{-6} Risk Level	Carcinogens at 10^{-5} Risk Level
Strontium-90	pCi/L	1.2	8	--	--	--	--
Tritium	pCi/L	11,000	20,000	--	--	--	--
Trichloroethene	µg/L	2.4	5	5	--	0.49	4.9
Cr(VI)	µg/L	23	--	--	48	--	--

Table 6-32. Summary of Current Conditions 90th Percentile Groundwater Concentrations, and Federal and State Water Quality Standards for the Upland Exposure Area (Aquatic Action Levels)

			AWQC		WAC 173-201A	CFR 131 Water Quality Standards	
COPC	Units	90th Percentile Value	Freshwater CMC (Acute)	Freshwater CCC (Chronic)	Freshwater CCC (Chronic)	Freshwater CMC (Acute)	Freshwater CCC (Chronic)
Strontium-90	pCi/L	1.2	--	--	--	--	--
Tritium	pCi/L	11,000	--	--	--	--	--
Trichloroethene	µg/L	2.4	--	--	--	--	--
Cr(VI)	µg/L	23	16	11	10	15	10

Sources:

"Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A).

"Water Quality Standards" (40 CFR 131).

6.3.6.2.1 Protectiveness Evaluation for Human Health

The protectiveness evaluation for human health is performed to help determine if a CERCLA remedial action is appropriate. *Rules of Thumb for Superfund Remedy Selection* (EPA 540-R-97-013) states that a remedial action is generally appropriate when a regulatory standard that helps define protectiveness (a federal or state MCL or nonzero MCLG for current or potential drinking water aquifers) is exceeded.

The 90th percentile groundwater concentration for strontium-90 is less than the DWS developed for the protection of human health and is a minimal contribution to overall dose (Table 6-33). Of the 10 wells in the Upland exposure area, strontium-90 has been detected in 199-B4-4 at concentrations above the federal MCL, indicating its presence is localized downgradient of the 116-B-12 Crib. Because of this, strontium-

90 is identified as a COPC, indicating the need to evaluate potential remedial technologies for strontium-90 in the FS. Section 4.3.2 provides a detailed discussion of the strontium-90 plume in the 100-BC-5 Groundwater OU.

Table 6-33. Summary of 90th Percentile Current Groundwater Concentrations and Associated Sum of Fractions for the Upland Exposure Area

COPC	Units	90th Percentile Value	Federal MCL	Individual Fraction
Strontium-90	pCi/L	1.2	8	0.15
Tritium	pCi/L	11,000	20,000	0.55
Sum of Fractions				**0.70**
Cumulative Annual Dose (mrem)				**2.8**

Note: MCL; derived single-nuclide MCL-equivalent activity concentration.

The 90th percentile groundwater concentration of tritium is less than the DWS developed for the protection of human health and is a minimal contribution to overall dose (Table 6-32). Of the 10 wells, tritium has been detected in 199-B8-6 at concentrations above the DWS, indicating its presence is localized downgradient of 118-B-1 Burial Ground. Tritium concentrations above the DWS were also measured in wells 199-B8-7 and 199-B8-8, based on results from the larger population of wells and longer sampling timeframe. Because of this, tritium is identified as a COPC, indicating the need to evaluate potential remedial technologies for strontium-90 in the FS. Section 4.3.2 provides a detailed discussion of the tritium plume in the 100-BC-5 Groundwater OU.

A federal and state MCL is not available for Cr(VI); therefore, the protectiveness evaluation was not performed. Cr(VI) is discussed in the protectiveness evaluation for aquatic organisms (Section 6.3.6.2.2) and the risk evaluation (Section 6.3.6.2.3).

The 90th percentile groundwater concentration for trichloroethene is less than the federal and state MCL of 5 µg/L. Trichloroethene is not identified as COPC and a need for further review in the FS is not established based on the results of this evaluation.

6.3.6.2.2 Protectiveness Evaluation for Aquatic Receptors

The protectiveness evaluation for aquatic receptors is performed to help determine if a CERCLA remedial action is appropriate. *Rules of Thumb for Superfund Remedy Selection* (EPA 540-R-97-013) states that a remedial action is generally appropriate when a regulatory standard that helps define protectiveness (National Recommended Water Quality Criteria) is exceeded.

Federal and state water quality standards for the protection of freshwater organisms are not published for tritium or strontium-90; therefore, a protectiveness evaluation is not included. Strontium-90 and tritium are included in the protectiveness evaluation for human health in Section 6.3.6.2.1.

Federal and state water quality standards for the protection of freshwater organisms are not published for trichloroethene; therefore, a protectiveness evaluation is not included. Trichloroethene is evaluated in the protectiveness evaluation for human health in Section 6.3.6.2.1 and the risk evaluation presented in Section 6.3.6.2.3.

The 90th percentile groundwater concentration for Cr(VI) is greater than the "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A) freshwater AWQC value of 10 µg/L. Cr(VI) is identified as a COPC, indicating the need to evaluate potential remedial technologies for Cr(VI) in the FS. Of the 10 monitoring wells in the Upland exposure area, five monitoring wells (199-B3-50, 199-B4-4, 199-B4-8, 199-B5-6, and 199-B9-3) were reported with concentrations of Cr(VI) above 10 µg/L. Cr(V) concentrations above the AWQC were also measured in wells 199-B4-1, 199-B4-7, 199-B8-7, 199-B8-8, and 199-B9-2, based on the larger population of wells and longer sampling time frame. All wells in this exposure area are a distance of 500 m (1,640 ft) or more from the Columbia River. Section 4.3.2 provides a detailed discussion of the Cr(VI) plume in the 100-BC-5 Groundwater OU.

6.3.6.2.3 Risk Evaluation

The risk evaluation is also performed to help determine whether a CERCLA remedial action is appropriate. *Rules of Thumb for Superfund Remedy Selection* (EPA 540-R-97-013) states that a remedial action is generally appropriate when the estimated risk calculated in a risk assessment exceeds a noncarcinogenic level for an adverse health effect or the upper end of the NCP (40 CFR 300) risk range for "cumulative carcinogenic site risk" to an individual based on the RME for both current and future land use.

The potential cumulative ELCR for the Upland exposure area from all nonradiological carcinogenic COPCs is 4.9×10^{-6}, which is less than the WAC 173-340-708 risk threshold of 1×10^{-5} for multiple hazardous substances and less than the upper NCP threshold of 1×10^{-4}. Table 6-34 shows the only contributor to risk is trichloroethene (4.9×10^{-6}, 100 percent contribution). Trichloroethene is not identified as COPC based on the results of this evaluation. Concentrations of trichloroethene in monitoring wells from this exposure area range between 0.29 and 3.3 µg/L; however, there have been no measured concentrations above the 1×10^{-5} level of 4.9 µg/L.

The HI for the Upland exposure area is 0.48, which is less than the EPA and WAC 173-340 target HI of 1. Cr(VI) is not identified as a COPC based on the results of this evaluation.

Table 6-34. Summary of 90th Percentile Current Groundwater Concentrations and Associated Cancer Risk and Noncancer Hazard Index for the Upland Exposure Area

			WAC 173-340-720 Cleanup Levels			
COPC	**Units**	**90th Percentile Value**	**Non-carcinogens**	**HQ**	**Carcinogens at 10^{-6} Risk Level**	**ELCR**
Trichloroethene	µg/L	2.4	--	--	0.49	4.9×10^{-6}
Total ELCR					--	**4.9×10^{-6}**
Cr(VI)	µg/L	23	48	0.48	--	--
Hazard Index				**0.48**		

6.3.7 Risk Characterization Results of the EPA Tap Water Scenario

This section summarizes the results for each of the exposure pathways associated with use of groundwater as a drinking water (tap water) source. As described in EPA guidelines (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/), the EPA tap water scenario reflects a RME scenario. The EPA tap water scenario is consistent with a residential exposure scenario as it

incorporates default residential exposure assumptions. The results of the Tap Water Risk Assessment are provided in Tap Water Risk Assessment for the 100-BC-5 Groundwater Operable Unit (Appendix G).

Potentially complete exposure routes for the EPA tap water scenario include exposure of adult and children residents to groundwater used as a drinking water source from the following:

Ingestion of drinking water

- Inhalation of volatiles when showering and other domestic purposes
- Dermal contact with skin while showering and using groundwater for other domestic purposes (such as washing dishes)

It should be noted that EPA considers external radiation to be a significant exposure route only for radionuclides in soil (EPA/540/1-89/002). External radiation from radionuclides in water is considered insignificant because of its shielding effects. EPA does not publish radionuclide cancer slope factors to quantify cancer risk from external or dermal exposure to radioactive analytes in groundwater. Radionuclide cancer risk is therefore calculated in this evaluation only for ingestion and inhalation exposure routes.

6.3.7.1 Use of Groundwater as a Potential Tap Water Source

In order to provide a comprehensive evaluation of current risks associated with the 100-BC-5 Groundwater OU, potential exposure to groundwater as a tap water source is evaluated under this scenario. Potential routes of exposure to groundwater include ingestion, dermal contact, and inhalation of volatiles during household activities. Results from this analysis are used to provide baseline conditions for all analytes with available toxicity information. Table 6-35 provides a summary of the risk estimates by exposure route for the Near-River and Upland exposure areas. Table 6-36 and Table 6-37 show the details of contribution to risk and hazard, respectively, by contaminant for the Near-River exposure area. Table 6-38 and Table 6-39 show the details of contribution to risk and hazard, respectively, by contaminant for the Upland exposure area. The results in Tables 6-36 through 6-39 provide overall summaries of the EPA tap water scenario analysis for all detected analytes identified in Section 6.3.2.4.

Table 6-35. Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source Using EPA Tap Water Equations

Exposure Route	Near-River Exposure Area		Upland Exposure Area	
	ELCR	Hazard Index	ELCR	Hazard Index
Nonradionuclide Analytes				
Ingestion	5.5×10^{-5}	1.3	8.1×10^{-5}	1.1
Dermal	7.8×10^{-7}	0.20	9.9×10^{-7}	0.10
Inhalation	5.0×10^{-7}	<0.01	4.3×10^{-7}	<0.01
Total	**5.6×10^{-5}**	**1.5**	**8.3×10^{-5}**	**1.2**
Radionuclide Analytes				
Ingestion	7.4×10^{-5}	--	1.2×10^{-5}	--
Inhalation	4.9×10^{-6}	--	1.6×10^{-6}	--

Table 6-35. Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source Using EPA Tap Water Equations

	Near-River Exposure Area		Upland Exposure Area	
Exposure Route	**ELCR**	**Hazard Index**	**ELCR**	**Hazard Index**
Total	7.9×10^{-5}	--	1.4×10^{-5}	--
Total Cumulative ELCR*	1.4×10^{-4}	--	9.7×10^{-5}	--

* Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.

-- = hazard index is not applicable

6.3.7.1.1 Near-River Exposure Area

The total ELCR is 5.6×10^{-5} for nonradiological analytes and 7.9×10^{-5} for radiological analytes (total cumulative ELCR is 1.4×10^{-4}), the total cumulative risk is greater than the EPA upper target risk threshold of 1×10^{-4} (Table 6-35).

Results in Table 6-36 show the major contributors to ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are strontium-90 (4.0×10^{-5}; 30 percent contribution), tritium (3.7×10^{-5}; 27 percent contribution), trichloroethene (3.1×10^{-6}; 2.3 percent contribution), and chloroform (1.5×10^{-6}; 1.1 percent contribution). Strontium-90, tritium, and trichloroethene are identified as COPCs in Section 6.3.2.4. Chloroform was not identified as a COPC in Section 6.3.2.4 because reported concentrations were not greater than the EQL. Contribution to ELCR is elevated for arsenic (5.1×10^{-5}; 38 percent), where measured contributions are within natural background values.

The HI is 1.5, which is slightly greater than the EPA target HI of 1. Results in Table 6-37 show that all individual analytes that contribute greater than 1 percent of the HI also reported a HQ less than 1. No COPCs were identified based on the results of this evaluation. Although the HQ for Cr(VI) is less than 1, it is identified as a COPC in Section 6.3.2.4 because concentrations are greater than the AWQC.

6.3.7.1.2 Upland Exposure Area

The total ELCR is 8.3×10^{-5} for nonradiological analytes and 1.4×10^{-5} for radiological analytes (total cumulative ELCR is 9.7×10^{-5}), which are within the EPA risk range of 1×10^{-4} to 1×10^{-6} (Table 6-35).

Results in Table 6-38 show the major contributors to ELCR (those analytes that contribute greater than 1 percent of the total cumulative ELCR) are tritium (1.2×10^{-5}; 13 percent contribution), trichloroethene (4.0×10^{-6}; 4.1 percent contribution), and strontium-90 (1.3×10^{-6}; 1.3 percent contribution). Tritium, trichloroethene, and strontium-90 are identified as COPCs in Section 6.3.2.4. Contribution to ELCR is elevated for arsenic (7.8×10^{-5}; 81 percent), where measured contributions are within natural background values.

The HI is 1.2, which is slightly greater than the EPA target HI of 1. Results in Table 6-39 show that all individual analytes that contribute greater than 1 percent of the HI also report a HQ less than 1. No COPCs were identified based on the results of this evaluation. Although the HQ for Cr(VI) is less than 1, it is identified as a COPC in Section 6.3.2.4 because concentrations are greater than the AWQC.

Table 6-36. Near-River Exposure Area – Summary of Tap Water Scenario --Cancer Risk Results for Nonradiological and Radiological Analytes in Groundwater

Analyte Name	90th Percentile Concentration in Groundwater (mg/L or pCi/L)	Volatilea	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Aluminum	0.043	--	--	--	--(b)	--	--
Arsenic	0.0023	--	5.11E-05	2.75E-07	--(b)	5.14E-05	38
Barium	0.045	--	--	--	--(b)	--	--
Boron	0.041	--	--	--	--(b)	--	--
Bromomethane	0.00057	Yes	--	--	--	--	--
Carbon disulfide	0.000051	Yes	--	--	--	--	--
Chloride	22	--	--	--	--(b)	--	--
Chloroform	0.0024	Yes	1.08E-06	9.52E-08	2.68E-07	1.45E-06	1.1
Chromium	0.053	--	--	--	--(b)	--	--
Cobalt	0.00018	--	--	--	--(b)	--	--
Copper	0.00072	--	--	--	--(b)	--	--
Fluoride	0.16	--	--	--	--(b)	--	--
Hexavalent Chromium	0.050	--	--	--	--(b)	--	--
Iron	0.17	--	--	--	--(b)	--	--
Lithium	0.0060	--	--	--	--(b)	--	--
Manganese	0.0073	--	--	--	--(b)	--	--
Molybdenum	0.0091	--	--	--	--(b)	--	--
Nickel	0.0050	--	--	--	--(b)	--	--
Nitrate	35	--	--	--	--(b)	--	--

Table 6-36. Near-River Exposure Area – Summary of Tap Water Scenario --Cancer Risk Results for Nonradiological and Radiological Analytes in Groundwater

Analyte Name	90th Percentile Concentration in Groundwater (mg/L or pCi/L)	Volatilea	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Selenium	0.0022	--	--	--	--(b)	--	--
Strontium	0.34	--	--	--	--(b)	--	--
Sulfate	65	--	--	--	--(b)	--	--
Thallium	0.00010	--	--	--	--(b)	--	--
Tin	0.00010	--	--	--	--(b)	--	--
Total petroleum hydrocarbons - diesel range	0.070	Yes	--	--	--	--	--
Trichloroethene	0.0019	Yes	2.45E-06	4.09E-07	2.30E-07	3.09E-06	2.3
Uranium	0.0057	--	--	--	--(b)	--	--
Vanadium	0.026	--	--	--	--(b)	--	--
Zinc	0.0095	--	--	--	--(b)	--	--
Cesium-137	1.6	--	9.25E-07	--	--(b)	9.25E-07	0.69
Gross alpha	3.9	--	--	--	--(b)	--	--
Strontium-90	38	--	4.01E-05	--	--(b)	4.01E-05	30
Technetium-99	21	--	1.07E-06	--	--(b)	1.07E-06	0.79
Tritium	33,200	Yes	3.18E-05	--	4.88E-06	3.67E-05	27
Total Cumulative ELCR			1.29E-04	7.87E-07	5.38E-06	1.35E-04	100

Table 6-36. Near-River Exposure Area – Summary of Tap Water Scenario --Cancer Risk Results for Nonradiological and Radiological Analytes in Groundwater

Analyte Name	90th Percentile Concentration in Groundwater (mg/L or pCi/L)	Volatilea	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution

a. Volatile contaminants as defined by EPA, 2009, "Regional Screening Levels for Chemical Contaminants at Superfund Sites" or as defined by EPA, 2001, Health Effects Assessment Summary Tables database, "April 16, 2001 Update: Radionuclide Toxicity," "Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors."

b. Nonvolatile constituents are not considered in the inhalation exposure route.

-- = Indicates toxicity criteria are not available to quantify contaminant's cancer risk via this exposure route.

Shading identifies analytes with a risk contribution of greater than or equal to 1 × 10-6.

Table 6-37. Near-River Exposure Area Summary of Tap Water Scenario -- Noncancer Hazard Results for Nonradiological Analytes in Groundwater

Analyte Name	90th Percentile Concentration in Groundwater (mg/L)	Volatile[a]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Aluminum	0.043	--	1.18E-03	6.17E-06	--(b)	<0.01	0.079
Arsenic	0.0023	--	2.09E-01	1.09E-03	--(b)	0.21	14
Barium	0.045	--	6.12E-03	4.56E-04	--(b)	<0.01	0.44
Boron	0.041	--	5.62E-03	2.93E-05	--(b)	<0.01	0.38
Bromomethane	0.00057	Yes	1.12E-02	3.55E-04	1.32E-03	0.013	0.86
Carbon disulfide	0.000051	Yes	1.40E-05	2.46E-06	8.44E-07	<0.01	0.0012
Chloride	22	--	--	--	--(b)	--	--
Chloroform	0.0024	Yes	6.44E-03	5.86E-04	2.78E-04	<0.01	0.49
Chromium	0.053	--	9.62E-04	3.86E-04	--(b)	<0.01	0.090
Cobalt	0.00018	--	1.62E-02	3.38E-05	--(b)	0.016	1.1
Copper	0.00072	--	4.94E-04	2.58E-06	--(b)	<0.01	0.033

Table 6-37. Near-River Exposure Area Summary of Tap Water Scenario -- Noncancer Hazard Results for Nonradiological Analytes in Groundwater

Analyte Name	90th Percentile Concentration in Groundwater (mg/L)	Volatile[a]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Fluoride	0.16	--	7.24E-02	3.78E-04	--(b)	0.073	4.9
Hexavalent Chromium	0.050	--	4.56E-01	1.90E-01	--(b)	0.65	43
Iron	0.17	--	6.77E-03	3.53E-05	--(b)	<0.01	0.46
Lithium	0.0060	--	8.22E-02	4.29E-04	--(b)	0.083	5.5
Manganese	0.0073	--	8.33E-03	1.09E-03	--(b)	<0.01	0.63
Molybdenum	0.0091	--	5.00E-02	2.61E-04	--(b)	0.050	3.4
Nickel	0.0050	--	6.85E-03	1.79E-04	--(b)	<0.01	0.47
Nitrate	35	--	1.36E-01	7.08E-04	--(b)	0.14	9.1
Selenium	0.0022	--	1.19E-02	6.22E-05	--(b)	0.012	0.80
Strontium	0.34	--	1.55E-02	8.10E-05	--(b)	0.016	1.0
Sulfate	65	--	--	--	--(b)	--	--
Thallium	0.00010	--	--	--	--(b)	--	--
Tin	0.00010	--	4.57E-06	2.38E-08	--(b)	<0.01	0.00031
Total petroleum hydrocarbons - diesel range	0.070	--	--	--	--(b)	--	
Trichloroethene	0.0019	Yes	--	--	6.12E-04	<0.01	0.041
Uranium	0.0057	--	5.25E-02	2.74E-04	--(b)	0.053	3.5
Vanadium	0.026	--	1.40E-01	7.29E-04	--(b)	0.14	9.4
Zinc	0.0095	--	8.68E-04	2.72E-06	--(b)	<0.01	0.058
Total Hazard Index			**1.3**	**0.20**	**0.0022**	**1.5**	**100**

Table 6-37. Near-River Exposure Area Summary of Tap Water Scenario -- Noncancer Hazard Results for Nonradiological Analytes in Groundwater

Analyte Name	90th Percentile Concentration in Groundwater (mg/L)	Volatile[a]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution

a. Volatile contaminants as defined by EPA, 2009, "Regional Screening Levels for Chemical Contaminants at Superfund Sites."

b. Nonvolatile constituents are not considered in the inhalation exposure route.

-- = Indicates toxicity criteria are not available to quantify contaminant's hazard via this exposure route.

Shading identifies analytes with a HQ of greater than or equal to 1.

Table 6-38. Upland Exposure Area – Summary of Tap Water Scenario -- Cancer Risk Results for Nonradiological and Radiological Analytes in Groundwater

Analyte Name	90th Percentile Concentration in Groundwater (mg/L or pCi/L)	Volatile[a]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Acetone	0.00034	Yes	--	--	--	--	--
Aluminum	0.023	--	--	--	--(b)	--	--
Arsenic	0.0035	--	7.75E-05	4.18E-07	--(b)	7.79E-05	81
Barium	0.047	--	--	--	--(b)	--	--
Beryllium	0.00010	--	--	--	--(b)	--	--
Boron	0.041	--	--	--	--(b)	--	--
Bromomethane	0.00033	Yes	--	--	--	--	--
Chloride	9.2	--	--	--	--(b)	--	--
Chloroform	0.0011	Yes	5.12E-07	4.50E-08	1.27E-07	6.84E-07	0.71
Chloromethane	0.00020	Yes	--	--	--	--	--
Chromium	0.028	--	--	--	--(b)	--	--
Cobalt	0.00010	--	--	--	--(b)	--	--

Table 6-38. Upland Exposure Area – Summary of Tap Water Scenario -- Cancer Risk Results for Nonradiological and Radiological Analytes in Groundwater

Analyte Name	90th Percentile Concentration in Groundwater (mg/L or pCi/L)	Volatile[a]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Copper	0.00075	--	--	--	--(b)	--	--
Fluoride	0.22	--	--	--	--(b)	--	--
Hexavalent Chromium	0.023	--	--	--	--(b)	--	--
Iron	0.093	--	--	--	--(b)	--	--
Lead	0.00021	--	--	--	--(b)	--	--
Lithium	0.0080	--	--	--	--(b)	--	--
Manganese	0.0060	--	--	--	--(b)	--	--
Molybdenum	0.0078	--	--	--	--(b)	--	--
Nickel	0.0040	--	--	--	--(b)	--	--
Nitrate	12	--	--	--	--(b)	--	--
Selenium	0.0022	--	--	--	--(b)	--	--
Strontium	0.24	--	--	--	--(b)	--	--
Sulfate	51	--	--	--	--(b)	--	--
Tin	0.00010	--	--	--	--(b)	--	--
Total petroleum hydrocarbons - diesel range	0.070	Yes	--	--	--	--	--
Trichloroethene	0.0024	Yes	3.18E-06	5.31E-07	2.98E-07	4.01E-06	4.1
Uranium	0.0022	--	--	--	--(b)	--	--
Vanadium	0.031	--	--	--	--(b)	--	--
Zinc	0.0065	--	--	--	--(b)	--	--

Table 6-38. Upland Exposure Area – Summary of Tap Water Scenario -- Cancer Risk Results for Nonradiological and Radiological Analytes in Groundwater

Analyte Name	90th Percentile Concentration in Groundwater (mg/L or pCi/L)	Volatile[a]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Gross alpha	2.4	--	--	--	--(b)	--	--
Strontium-90	1.2	--	1.27E-06	--	--(b)	1.27E-06	1.3
Technetium-99	11	--	5.46E-07	--	--(b)	5.46E-07	0.56
Tritium	11,000	Yes	1.05E-05	--	1.62E-06	1.22E-05	13
Total Cumulative ELCR			9.36E-05	9.93E-07	2.04E-06	9.66E-05	100

a. Volatile contaminants as defined by EPA, 2009, "Regional Screening Levels for Chemical Contaminants at Superfund Sites" or as defined by EPA, 2001, Health Effects Assessment Summary Tables database, "April 16, 2001 Update: Radionuclide Toxicity," "Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors."

b. Nonvolatile constituents are not considered in the inhalation exposure route.

-- = Indicates toxicity criteria not available to quantify contaminant's cancer risk via this exposure route.

Shading identifies analytes with a risk contribution of greater than or equal to 1 × 10-6.

Table 6-39. Upland Exposure Area—Summary of Tap Water Scenario -- Noncancer Hazard Results for Nonradiological Analytes in Groundwater

Analyte Name	90th Percentile Concentration in Groundwater (mg/L or pCi/L)	Volatile[a]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Acetone	0.00034	Yes	1.04E-05	--	1.27E-07	<0.01	0.00088
Aluminum	0.023	--	6.34E-04	3.31E-06	--(b)	<0.01	0.054
Arsenic	0.0035	--	3.17E-01	1.66E-03	--(b)	0.32	27
Barium	0.047	--	6.49E-03	4.84E-04	--(b)	<0.01	0.59
Beryllium	0.00010	--	1.37E-03	1.02E-03	--(b)	<0.01	0.20
Boron	0.041	--	5.62E-03	2.93E-05	--(b)	<0.01	0.47

Table 6-39. Upland Exposure Area—Summary of Tap Water Scenario -- Noncancer Hazard Results for Nonradiological Analytes in Groundwater

Analyte Name	90th Percentile Concentration in Groundwater (mg/L or pCi/L)	Volatile[a]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Bromomethane	0.00033	Yes	6.36E-03	2.02E-04	7.53E-04	<0.01	0.61
Chloride	9.2	--	--	--	--(b)	--	--
Chloroform	0.0011	Yes	3.04E-03	2.77E-04	1.31E-04	<0.01	0.29
Chloromethane	0.00020	Yes	--	--	2.57E-05	<0.01	0.0022
Chromium	0.028	--	5.06E-04	2.03E-04	--(b)	<0.01	0.060
Cobalt	0.00010	--	9.13E-03	1.91E-05	--(b)	<0.01	0.77
Copper	0.00075	--	5.11E-04	2.67E-06	--(b)	<0.01	0.043
Fluoride	0.22	--	1.02E-01	5.32E-04	--(b)	0.10	8.6
Hexavalent Chromium	0.023	--	2.14E-01	8.92E-02	--(b)	0.30	25
Iron	0.093	--	3.64E-03	1.90E-05	--(b)	<0.01	0.31
Lead	0.00021	--	--	--	--(b)	--	--
Lithium	0.0080	--	1.09E-01	5.68E-04	--(b)	0.11	9.2
Manganese	0.0060	--	6.85E-03	8.94E-04	--(b)	<0.01	0.65
Molybdenum	0.0078	--	4.26E-02	2.22E-04	--(b)	0.043	3.6
Nickel	0.0040	--	5.48E-03	1.43E-04	--(b)	<0.01	0.47
Nitrate	12	--	4.71E-02	2.46E-04	--(b)	0.047	4.0
Selenium	0.0022	--	1.18E-02	6.16E-05	--(b)	0.012	1.00
Strontium	0.24	--	1.11E-02	5.77E-05	--(b)	0.011	0.93
Sulfate	51	--	--	--	--(b)	--	--

Table 6-39. Upland Exposure Area—Summary of Tap Water Scenario -- Noncancer Hazard Results for Nonradiological Analytes in Groundwater

Analyte Name	90th Percentile Concentration in Groundwater (mg/L or pCi/L)	Volatile[a]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Tin	0.00010	--	4.57E-06	2.38E-08	--(b)	<0.01	0.00039
Total petroleum hydrocarbons - diesel range	0.070	--	--	--	--(b)	--	--
Trichloroethene	0.0024	Yes	--	--	7.95E-04	<0.01	0.067
Uranium	0.0022	--	1.99E-02	1.04E-04	--(b)	0.020	1.7
Vanadium	0.031	--	1.67E-01	8.72E-04	--(b)	0.17	14
Zinc	0.0065	--	5.94E-04	1.86E-06	--(b)	<0.01	0.050
Total Hazard Index			**1.1**	**0.097**	**0.0017**	**1.2**	**100**

a. Volatile contaminants as defined by EPA, 2009, "Regional Screening Levels for Chemical Contaminants at Superfund Sites."

b. Nonvolatile constituents are not considered in the inhalation exposure route.

-- = Indicates toxicity criteria are not available to quantify contaminant's hazard via this exposure route.

Shading identifies analytes with a HQ of greater than or equal to 1.

6.3.8 Uncertainties in the Groundwater Risk Assessment

The purpose of this groundwater risk assessment is to determine whether a groundwater remedial action is warranted under CERCLA. Estimating and evaluating health risk from exposure to environmental contaminants is a complex process with inherent uncertainties. Uncertainty reflects limitations in knowledge, and simplifying assumptions must be made to quantify health risks.

In this assessment, uncertainties relate to the selection of COPCs and the development of media concentrations to which receptors may be exposed, the assumptions about exposure and toxicity, and the characterization of health risks. Uncertainties exist regarding the quantification of health risks in terms of several assumptions about exposure and toxicity, including site-specific and general uncertainties. Based on the anticipation of uncertainty when quantifying exposure and toxicity, the health risks and hazards presented in this risk assessment are more likely to provide an upper bound on risk.

6.3.8.1 Uncertainties Associated with Sampling and Analysis Data

Sampling and analysis data used in this groundwater risk assessment were collected specifically to address the uncertainties identified in the RCBRA Report (DOE/RL-2007-21) and the 100-BC Work Plan (DOE/RL-2008-46–ADD3). These uncertainties were generally associated with the chemical, spatial, and temporal representativeness of the dataset used to evaluate current baseline conditions in the RCBRA. Uncertainties with chemical representativeness were related to the analysis of varying analytical methods between monitoring wells within the OU. Uncertainties with spatial and temporal representativeness were associated with varying sampling frequencies between monitoring wells because of differing monitoring programs.

Current baseline conditions are presented by groundwater data collected over an 8-month period between May 10, 2010 and September 7, 2010. Three sampling events were used to capture the effects that temporal fluctuations of river stage have on groundwater conditions. The proposed COPCs identified during the work plan phase were validated by using groundwater samples analyzed for the analytical methods documented in the 100-BC SAP (DOE/RL-2009-44). The groundwater data set used for COPC identification consists of sampling and analysis data collected from 18 monitoring wells within the 100-BC-5 Groundwater OU. The monitoring well network represents locations where human or ecological receptors could potentially encounter groundwater within the OU. The primary exposure pathway for humans is through groundwater obtained from a residential or community water well, assuming development of the land for future human habitation. The primary exposure pathways for aquatic organisms are direct discharge of groundwater to the Columbia River or through seeps. All samples were analyzed using methods that could accurately measure analytes to concentrations equal or less than the lowest chemical-specific ARAR. When analytical methods could not achieve the lowest chemical-specific ARAR, the action level defaulted to the MDL that could reasonably be achieved. These detection limits are documented in Table 2-14 of the 100-BC SAP (DOE/RL-2009-44).

6.3.8.2 Uncertainties Associated with Exposure Point Concentrations

The protectiveness and risk evaluation methodology uses an RME concentration for each COPC in an exposure area rather than performing the evaluation on a specific well or location. In general, EPA Superfund guidance recommends using a 95 percent UCL on the arithmetic mean for estimating EPCs that reflect a RME. However, experience indicates that averages and UCLs cannot be reliably calculated for Hanford Site groundwater datasets.

Groundwater datasets at the Hanford Site are highly skewed, with a large proportion of BDL values. EPA data analysis guidance (EPA/240/B-06/003) provides guidance for estimating parameters (whether means or upper percentiles) depending on the variability in the dataset, as expressed as the CV and the proportion of observation that are BDL. For datasets with CVs less than 1 and 50 percent or more observations that are BDL, EPA, 2006 recommends using upper percentiles as opposed to means to develop summary statistics.

EPA's ProUCL software is used to estimate EPCs and statistics for comparison with standards and background levels, in accordance with EPA Superfund risk assessment guidance (EPA, 1989). ProUCL contains computational methods for parametric and nonparametric UCLs, upper prediction limits (UPLs), and upper tolerance limits (UTLs) for use with datasets without non-detects as well as datasets with BDL observations. These computational methods can address skewed data sets with and without BDL observations. However, in practice, ProUCL will provide warning flags for 95 percent UCLs from datasets that are both highly skewed and that contain a large proportion (50 percent or greater) BDL observations.

Use of the 90th percentile value from a distribution of groundwater concentration data as an estimate of the EPC is an alternative approach for estimating EPCs in cases where ProUCL does not provide reliable UCL values. However, use of the 90th percentile exposure concentration to develop an EPC is consistent with other EPA risk assessment guidance for describing and characterizing health risks. EPA's guidance for risk characterization (EPA, 1995) states that risk assessments should provide an evaluation of risks at the high end of the distribution of exposure. Conceptually, the high end of the distribution means above the 90th percentile of the population distribution, but not higher than the individual in the population with the highest exposure (EPA. 1992), which is comparable to the definition of RME as defined in Superfund guidance (EPA, 1989). Therefore, use of the 90th percentile as the basis for a groundwater EPC yields risk estimates that correspond to an RME.

A comparison of the 90th percentile values used for the protectiveness and risk evaluations and the 95 percent UCLs is presented in Table 6-40. In addition, Table 6-44 also shows the frequency of detection and CVs for the COPCs in groundwater. As shown in Table 6-44, the datasets for most of the COPCs are characterized by a high proportion of BDL values, high CVs, or both; for those COPCs, the 90th percentile is the most appropriate statistic for an EPC. In addition, the 90th percentile concentrations are greater than the 95 percent UCL values for COPCs that are risk drivers in groundwater, such as Cr(VI) in the Near-River and Upland exposure areas.

Table 6-40. Percentile Concentrations and Summary Statistics for Analytes in the 100-BC-5 Groundwater OU Data Set

Analyte	Units	Number of Detections	Number of Nondetects	Frequency of Nondetects	Coefficient of Variation	90th Percentile of RI Data	Maximum	Mean	95% UCL	Is 95 Percent UCL > 90th Percentile?	Action Levela
Near River Exposure Area											
Aluminum	µg/L	11	13	54%	0.59	43	72	31	28	No	50
Arsenic	µg/L	21	3	13%	0.35	2.3	3.1	1.7	1.8	No	0.018 (4.0)
Barium	µg/L	24	0	0%	0.20	45	49	35	37	No	1,000
Boron	µg/L	1	23	96%	N/A	41	19	19	Not Calculated	N/A	3,200
Bromomethane	µg/L	9	15	63%	0.41	0.57	0.74	**0.44**	0.43	No	11
Carbon disulfide	µg/L	1	23	96%	N/A	0.051	0.074	**0.074**	Not Calculated	N/A	800
Chloride	µg/L	24	0	0%	0.54	21,800	25,700	**10,229**	12,182	No	230,000
Chloroform	µg/L	19	5	21%	1.5	2.4	3.0	**0.61**	1.5	No	1.4 (5.0)
Chromium	µg/L	24	0	0%	0.46	53	69	**30**	35	No	65
Cr(VI)	µg/L	24	0	0%	0.55	50	57	**25**	30	No	10
Cobalt	µg/L	5	19	79%	0.40	0.18	0.21	**0.14**	0.15	No	2.6
Copper	µg/L	11	13	54%	0.41	0.72	0.75	**0.49**	0.44	No	9.0
Fluoride	µg/L	15	9	38%	0.31	159	186	**115**	113	No	960
Iron	µg/L	13	11	46%	0.90	173	347	**101**	92	No	300
Lithium	µg/L	13	11	46%	0.12	6.0	6.0	**5.3**	5.2	No	32
Manganese	µg/L	4	20	83%	0.48	7.3	14	**8.4**	9.1	Yes	50
Molybdenum	µg/L	24	0	0%	0.77	9.1	11	**3.4**	5.8	No	80

Table 6-40. Percentile Concentrations and Summary Statistics for Analytes in the 100-BC-5 Groundwater OU Data Set

Analyte	Units	Number of Detections	Number of Nondetects	Frequency of Nondetects	Coefficient of Variation	90th Percentile of RI Data	Maximum	Mean	95% UCL	Is 95 Percent UCL > 90th Percentile?	Action Levela
Nickel	µg/L	6	18	75%	0.38	5.0	9.0	5.2	4.7	No	52
Nitrate	µg/L	24	0	0%	0.74	35,150	44,200	14,189	18,048	No	45,000
Selenium	µg/L	19	5	21%	0.50	2.2	4.2	1.5	1.7	No	5.0
Strontium	µg/L	24	0	0%	0.25	340	365	227	248	No	9,600
Sulfate	µg/L	24	0	0%	0.29	65,400	70,500	43,046	47,376	No	250,000
Thallium	µg/L	1	23	96%	N/A	0.10	1.0	1.0	Not Calculated	N/A	0.24 (2.0)
Tin	µg/L	1	23	96%	N/A	0.10	0.25	0.25	Not Calculated	N/A	519
TPH-diesel range	µg/L	1	23	96%	N/A	70	220	220	Not Calculated	N/A	500
Trichloroethene	µg/L	16	8	33%	0.78	1.9	2.2	0.82	0.83	No	0.49
Uranium	µg/L	24	0	0%	0.62	5.7	7.3	2.6	3.2	No	30
Vanadium	µg/L	8	16	67%	0.18	26	28	22	21	No	80
Zinc	µg/L	4	20	83%	0.62	9.5	21	11	13	Yes	91
Cesium-137	pCi/L	1	23	96%	N/A	1.6	2.0	2.0	Not Calculated	N/A	200
Gross alpha	pCi/L	4	20	83%	0.39	3.9	6.4	4.2	4.3	Yes	15
Strontium-90	pCi/L	14	10	42%	0.63	38	49	21	20	No	8
Technetium-99	pCi/L	14	10	42%	0.39	21	21	14	13	No	900
Tritium	pCi/L	24	0	0%	1.4	33,200	69,000	11,314	17,779	No	20,000

Table 6-40. Percentile Concentrations and Summary Statistics for Analytes in the 100-BC-5 Groundwater OU Data Set

Analyte	Units	Number of Detections	Number of Nondetects	Frequency of Nondetects	Coefficient of Variation	90th Percentile of RI Data	Maximum	Mean	95% UCL	Is 95 Percent UCL > 90th Percentile?	Action Levela
Upland Exposure Area											
Acetone	µg/L	1	29	97%	N/A	0.34	1.0	1.0	Not Calculated	N/A	7,200
Aluminum	µg/L	12	18	60%	0.55	23	41	18	15	No	50
Arsenic	µg/L	30	0	0%	0.23	3.5	3.9	2.8	3.0	No	0.018 (4.0)
Barium	µg/L	30	0	0%	0.76	47	88	26	32	No	1,000
Beryllium	µg/L	1	29	97%	N/A	0.10	0.13	0.13	Not Calculated	N/A	4.0
Boron	µg/L	1	29	97%	N/A	41	131	131	Not Calculated	N/A	3,200
Bromomethane	µg/L	7	23	77%	0.30	0.33	0.45	0.31	0.31	No	11
Chloride	µg/L	30	0	0%	0.34	9,195	9,350	6,579	7,263	No	230,000
Chloroform	µg/L	23	7	23%	0.93	1.1	1.6	0.48	0.53	No	1.4 (5.0)
Chloromethane	µg/L	6	24	80%	0.35	0.20	0.31	0.21	0.20	No	--
Chromium	µg/L	30	0	0%	0.62	28	39	15	19	No	65
Cobalt	µg/L	1	29	97%	N/A	0.10	0.67	0.67	Not Calculated	N/A	2.6
Copper	µg/L	12	18	60%	0.46	0.75	0.92	0.54	0.45	No	9.0
Cr(VI)	µg/L	24	5	17%	0.72	23	37	13	15	No	10
Fluoride	µg/L	27	3	10%	0.36	223	290	156	165	No	960
Iron	µg/L	11	19	63%	0.70	93	188	73	58	No	300

Table 6-40. Percentile Concentrations and Summary Statistics for Analytes in the 100-BC-5 Groundwater OU Data Set

Analyte	Units	Number of Detections	Number of Nondetects	Frequency of Nondetects	Coefficient of Variation	90th Percentile of RI Data	Maximum	Mean	95% UCL	Is 95 Percent UCL > 90th Percentile?	Action Levela
Lead	µg/L	4	26	87%	0.25	0.21	0.32	0.25	0.27	Yes	2.1
Lithium	µg/L	24	6	20%	0.24	8.0	10	6.2	6.3	No	32
Manganese	µg/L	3	27	90%	1.0	6.0	41	19	41	Yes	50
Molybdenum	µg/L	30	0	0%	0.50	7.8	8.6	4.1	4.8	No	80
Nickel	µg/L	4	26	87%	0.62	4.0	12	6.3	4.8	Yes	52
Nitrate	µg/L	30	0	0%	0.56	12,200	16,500	6,715	7,878	No	45,000
Selenium	µg/L	25	5	17%	0.54	2.2	4.0	1.4	1.5	No	5.0
Strontium	µg/L	30	0	0%	0.20	242	249	179	191	No	9,600
Sulfate	µg/L	30	0	0%	0.34	51,450	67,300	34,457	38,270	No	250,000
Tin	µg/L	1	29	97%	N/A	0.10	0.066	0.066	Not Calculated	N/A	519
TPH-diesel range	µg/L	1	29	97%	N/A	70	180	180	Not Calculated	N/A	500
Trichloroethene	µg/L	24	6	20%	0.69	2.4	3.3	1.2	1.3	No	0.49 (1.0)
Uranium	µg/L	30	0	0%	0.30	2.2	3.1	1.6	1.8	No	30
Vanadium	µg/L	17	13	43%	0.34	31	35	22	20	No	80
Zinc	µg/L	7	23	77%	0.30	6.5	10	6.5	6.3	No	91
Gross alpha	pCi/L	4	26	87%	0.12	2.4	3.0	2.6	2.7	Yes	15
Strontium-90	pCi/L	2	28	93%	0.18	1.2	8.6	7.7	7.6	Yes	8
Technetium-99	pCi/	12	18	60%	0.45	11	26	11	15	Yes	900

Table 6-40. Percentile Concentrations and Summary Statistics for Analytes in the 100-BC-5 Groundwater OU Data Set

Analyte	Units	Number of Detections	Number of Nondetects	Frequency of Nondetects	Coefficient of Variation	90th Percentile of RI Data	Maximum	Mean	95% UCL	Is 95 Percent UCL > 90th Percentile?	Action Levela
	L										
Tritium	pCi/L	23	7	23%	1.1	11,000	24,000	5,205	13,957	Yes	20,000

Notes:

a. Value in parentheses () represents the estimated quantitation limit reported in the 100-BC SAP (DOE/RL-2009-44).

Sufficient percentage of detections is considered to be 50% or greater.

Coefficient of Variation = Standard Deviation / Mean. Data is considered variable if greater than 0.5.

For the Near-River exposure area, the 90th percentile concentrations are greater than the 95percent UCL values for all analytes except manganese, gross alpha, and zinc. For manganese, the 95percent UCL of 9.1 μg/L is greater than the 90th percentile value of 7.3 μg/L. Both manganese concentrations are less than the secondary MCL value of 50 μg/L. For gross alpha, the 95percent UCL of 4.3 pCi/L is greater than the 90th percentile value of 3.9 pCi/L. Both gross alpha concentrations are less than the MCL value of 15 pCi/L. For zinc, the 95percent UCL of 13 μg/L is greater than the 90th percentile value of 9.5 μg/L. Both zinc concentrations are less than the AWQC of 91 μg/L. Manganese, gross alpha, and zinc were not identified as COPCs for the Near-River exposure area; use of the 95 percent UCL would not have resulted in a different outcome.

For the Upland exposure area, the 90th percentile concentrations are greater than the 95percent UCL values for all analytes except manganese, gross alpha, lead, nickel, strontium-90, and technetium-99. For manganese, the 95percent UCL of 41 μg/L is greater than the 90th percentile value of 6.0 μg/L. Both manganese concentrations are less than the secondary MCL value of 50 μg/L. For gross alpha, the 95 percent UCL of 2.7 pCi/L is greater than the 90th percentile value of 2.4 pCi/L. Both gross alpha concentrations are less than the MCL value of 15 pCi/L. For lead, the 95percent UCL of 0.27 μg/L is greater than the 90th percentile value of 0.21 μg/L. Both lead concentrations are less than the AWQC of 2.1 μg/L. For nickel, the 95percent UCL of 4.8 μg/L is greater than the 90th percentile value of 4.0 μg/L. Both nickel concentrations are less than the AWQC of 52 μg/L. For strontium-90, the 95percent UCL of 7.6 pCi/L is greater than the 90th percentile value of 1.2 pCi/L. Both strontium-90 concentrations are less than the MCL value of 8 pCi/L. For technetium-99, the 95percent UCL of 15 pCi/L is greater than the 90th percentile value of 11 pCi/L. Both technetium-99 concentrations are less than the MCL value of 900 pCi/L. Manganese, gross alpha, and technetium-99 were not identified as COPCs for the Upland exposure area, use of the 95 percent UCL would not have resulted in a different outcome. Strontium-90 was identified as a COPC in the Upland exposure area because of localized measurements greater than the MCL in the larger population of wells considered for the nature and extent evaluation discussed in Chapter 4.

6.3.8.3 Uncertainties Associated with Exposure Assumptions

The exposure assumptions used to develop the chemical-specific ARARs represent an RME. For estimating the RME, 95 percent UCL values (or upper-bound estimates of national averages) are generally used for exposure assumptions, and exposed populations and exposure scenarios are also selected to represent upper-bound exposures. The intent of the RME, as discussed by the EPA Deputy Administrator and the Risk Assessment Council (Habicht, 1992), is to present risks as a range from central tendency to high-end risk (above the 90th percentile of the population distribution). This descriptor is intended to estimate the risks that are expected to occur in small but definable "high-end" segments of the subject population ("Guidance on Risk Characterization for Risk Managers and Risk Assessors" [Habicht, 1992]). EPA distinguishes between those scenarios that are possible but highly improbable and those that are conservative but more likely to occur within a population, with the latter being favored in risk assessment. In general, these assumptions are intended to be conservative and yield an overestimate of the true risk or hazard.

6.3.8.4 Uncertainties Associated with Dermal Contact Exposure

The chemical-specific ARARs for use as a drinking water source consider ingestion and inhalation of vapors as complete and significant pathways for exposure. For the chemical-specific ARARs, the dermal contact pathway is considered a complete but insignificant pathway of exposure for the contaminants detected in groundwater. The exclusion of the dermal contact exposure route from the chemical-specific ARARs may have the potential to underestimate the actual cleanup level.

EPA considers the dermal contact route to be significant if it contributes at least 10 percent of the exposure derived from the oral pathway. These results are based on comparing two main household daily uses of water: as a source for drinking and for showering or bathing (*Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual [Part E, Supplemental Guidance for Dermal Risk Assessment]: Final* [EPA/540/R/99/005]). Exhibits B-3 and B-4 of *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual [Part E, Supplemental Guidance for Dermal Risk Assessment]: Final* (EPA/540/R/99/005) provide a screening tool to focus the dermal risk assessment on those chemicals that are more likely to make a contribution to the overall risk. Exhibit B-3 indicates that dermal exposure exceeds 10 percent of drinking water for hexavalent chromium and trichloroethene. The ratio of the dermal absorbed dose (DAD) from dermal to oral is 42 percent for hexavalent chromium and 17 percent for trichloroethene. Based on this comparison, the chemical-specific ARARs concentrations may have the potential to underestimate exposure to these COPCs.

6.3.8.5 Uncertainties Associated with Toxicity Assessment

The toxicological database was also a source of uncertainty. EPA has outlined some of the sources of uncertainty as defined in the risk assessment guidance (EPA/540/1-89/002) and in Superfund HHT Risk Assessment Values (Cook, 2003). These sources may include or result from the extrapolation from high to low doses and from animals to humans. This is contingent on the species, gender, age, and strain differences in the uptake, metabolism, organ distribution, and target site susceptibility of a toxin. The human population's variability with respect to diet, environment, activity patterns, and cultural factors are also sources of uncertainty.

Traditionally, EPA has developed toxicity criteria for carcinogens by assuming that all carcinogens are nonthreshold contaminants. However, EPA has recently published revised cancer guidelines (*Guidelines for Carcinogen Risk Assessment I* [EPA/630/P-03/001F]) in which they have modified their former position of assuming nonthreshold action for all carcinogens. This new guidance emphasizes establishing the specific toxicokinetic mode of action that leads to development of cancer. In the future, toxicity criteria for carcinogens in the United States will be developed assuming no threshold for contaminants that exhibit genotoxic modes of action, or where the mode of action is not known. However, currently available EPA toxicity criteria for carcinogens were all derived assuming a nonthreshold model.

In most of the world, nonthreshold toxicity criteria are developed only for those carcinogens that appear to cause cancer through a genotoxic mechanism (International Toxicity Estimates for Risk database, TERA, 2011). Specifically, for genotoxic contaminants, the cancer dose-response model is based on high- to low-dose extrapolation and assumes there is no lower threshold for the initiation of toxic effects. Cancer effects observed at high doses are found in laboratory animals or are extrapolated from occupational or epidemiological studies. Cancer effects observed at low doses are commonly found in environmental exposures. These models are essentially linear at low doses, so no dose is without some risk of cancer.

6.3.8.5.1 Slope Factors for Trichloroethene.

The oral cancer potency factor of 0.089 $(mg/kg\text{-}day)^{-1}$ used to develop the MTCA "Groundwater Cleanup Standards" (WAC 173-340-720) groundwater cleanup level was obtained from the CLARC database (Ecology, 2010). The factor is obtained from a draft EPA risk assessment prepared in 2001, which has since been updated; therefore, in this case, the oral cancer potency factor does not reflect the most current source of information.

The oral slope factor currently recommended by EPA for trichloroethene was published in IRIS in September 2011. The source of this toxicity value is consistent with the hierarchy of toxicity values recommended in Superfund HHT Risk Assessment Values (Cook, 2003). The oral slope factor is

0.046 (mg/kg-day)$^{-1}$ (*IRIS*). Trichloroethene is considered an "early-life exposure" carcinogen for kidney cancer because it acts through a mutagenic mode-of-action. Accounting for kidney cancer risks from early-life exposure would result in slightly more conservative value (by a factor of 2) for the oral slope factor.

The newly revised EPA value is lower than the value of 0.089 (mg/kg-day)$^{-1}$ for oral exposures published in the CLARC database (Ecology, 2010). However, the EPA value accounting for early life exposure is slightly greater than the value published by Ecology in the CLARC database.

If the revised EPA value was used to calculate the MTCA "Groundwater Cleanup Standards" (WAC 173-340-720) groundwater cleanup level, the groundwater concentration would increase from 0.49 to 0.95 µg/L. The groundwater risks at the 90th percentile would decrease from 3.9×10^{-6} to 2.0×10^{-6} in the Near-River exposure area and would decrease from 4.9×10^{-6} to 2.5×10^{-6} in the Upland exposure area. However, the cumulative risk would continue to remain below 1×10^{-5}. Use of the oral cancer potency factor from HEAST overstates risks when compared to the oral slope factor established by EPA.

6.3.8.5.2 Slope Factors for Hexavalent Chromium.

The oral reference dose of 0.003 mg/kg-day published by IRIS is used to develop the MTCA "Groundwater Cleanup Standards" (WAC 173-340-720) groundwater cleanup level for Cr(VI). An oral carcinogenic potency factor has recently been published by the NJDEP (2009, *Derivation of an Ingestion-Based Soil Remediation Criterion for Cr+6 Based on the NTP Chronic Bioassay Data for Sodium Dichromate Dihydrate*). The oral carcinogenic potency factor derived by NJDEP is 0.5 (mg/kg-day)$^{-1}$, as presented in *Derivation of an Ingestion-Based Soil Remediation Criterion for Cr+6 Based on the NTP Chronic Bioassay Data for Sodium Dichromate Dihydrate* (NJDEP, 2009). If the NJDEP value was used to calculate the MTCA "Groundwater Cleanup Standards" (WAC 173-340-720) groundwater cleanup level, the groundwater concentration would decrease from 48 to 0.18 µg/L.

6.3.8.6 Uncertainties Associated with Risk Characterization

In the risk characterization, the assumption was made that the total risk of developing cancer from exposure to site contaminants is the sum of the risk attributed to each individual contaminant. Likewise, the potential for the development of noncancer adverse effects is the sum of the HQs estimated for exposure to each individual contaminant. This approach, in accordance with EPA guidance, did not account for the possibility that constituents act synergistically or antagonistically.

As discussed in Section 6.3.4, MCLs for radionuclides are set at 4 mrem/yr for the sum of the doses from beta particle and photon emitters, 15 pCi/L for gross alpha emitter activity (including radium-226, but excluding uranium and radon), and 5 pCi/L combined for radium-226 and radium-228. A mass concentration MCL has been established for uranium as 30 µg/L. At this time, no additional federal or state standards are associated with evaluating the effects of exposure to radionuclides. Risks were estimated for radioisotopes identified as COPCs using inputs and equation 720-2 from MTCA "Groundwater Cleanup Standards," "Method B Cleanup Levels for Potable Groundwater" (WAC 173-340-720(4)(iii)(B)) and radionuclide slope factors from HEAST. The MCL concentrations reported for each of the radionuclide COPCs do not individually exceed the 10^{-4} ELCR end of the NCP (40 CFR 300) risk range (Table 6-41 and Table 6-42).

Table 6-41. Summary of 90th Percentile Groundwater Concentrations, Associated Cancer Risk, and Associated Sum of Fractions for Radioactive COPCs in the Near-River Exposure Area

COPC	90th Percentile Value (pCi/L)	Federal or State MCL (pCi/L)	ELCR at Federal MCL	Individual Fraction	Individual ELCR
Strontium-90	38	8	8.5×10^{-6}	4.8	4.0×10^{-5}
Tritium	33,200	20,000	1.9×10^{-5}*	1.7	3.2×10^{-5}
Sum of Fractions				**6.5**	-
Cumulative Annual Dose (mrem)				**26**	-
Cumulative ELCR for Radioactive COPCs				-	**7.2×10^{-5}**

* An excess lifetime cancer risk for tritium, which includes the ingestion and inhalation exposure routes, would be 1.3×10^{-4}. The ELCR for tritium would be 1.9×10^{-5} for the ingestion exposure route only.

Table 6-42. Summary of 90th Percentile Groundwater Concentrations, Associated Cancer Risk, and Associated Sum of Fractions for Radioactive COPCs in the Upland Exposure Area

COPC	90th Percentile Value (pCi/L)	Federal or State MCL (pCi/L)	ELCR at Federal MCL	Individual Fraction	Individual ELCR
Strontium-90	1.2	8	8.5×10^{-6}	0.15	1.3×10^{-6}
Tritium	11,000	20,000	1.9×10^{-5}*	0.55	6.9×10^{-5}
Sum of Fractions				**0.70**	-
Cumulative Annual Dose (mrem)				**2.8**	-
Cumulative ELCR for Radioactive COPCs				-	**1.2×10^{-5}**

* An excess lifetime cancer risk for tritium, which includes the ingestion and inhalation exposure routes, would be 1.3×10^{-4}. The ELCR for tritium would be 1.9×10^{-5} for the ingestion exposure route only.

6.3.8.6.1 Uncertainties Associated with the Native American Risk Assessments

As discussed in Section 6.1.3, the RCBRA Report (DOE/RL-2007-21) evaluated three residential scenarios that describe exposure related to rural land-use patterns that involved exposure assumptions which represented subsistence use. Of the three residential scenarios, two Native America scenarios were evaluated including the CTUIR and the Yakama Nation. While groundwater within the 100-BC OU is not anticipated to become a source of drinking water, contaminants in groundwater were assessed using the two Native American scenarios to provide estimates of human health risks under the assumption of full-time occupancy in the future. In addition, the risks calculated using the Native American scenarios were compared with risks estimated using EPA's standard default assumptions for residential tap water

use (the tap water scenario). As described in EPA guidelines ("Regional Screening Table," EPA, 2012), the residential tap water scenario reflects an RME scenario.

The groundwater risk assessment provided in this RI/FS provides an update to address the uncertainties associated with the assessment of groundwater risks presented in the RCBRA (see Section 6.3.2). The uncertainties in the RCBRA were associated with the ability of the groundwater dataset collected from 1998 to 2008 to represent current baseline conditions and potential exposure within each groundwater OU. The following paragraphs discuss the uncertainties with risks associated with groundwater contaminants based on current baseline conditions.

The Native American and tap water scenarios addressed direct exposure to contaminants in groundwater associated with household uses of groundwater, such as drinking and cooking (ingestion) and bathing (dermal absorption). If VOCs were measured in groundwater and identified as COPCs, indirect exposure by inhalation of VOCs in air while bathing or when using groundwater in the home for other purposes was also addressed. The CTUIR and Yakama Nation scenarios incorporated ingestion, inhalation, and dermal exposures to COPCs in groundwater used in a sweat lodge.

Exposure parameters for drinking water ingestion, VOC inhalation and dermal absorption differ between the Native American exposure scenarios and the EPA tap water scenario. Examples of these differences include the following: exposure frequency (Native American 365 day/yr; EPA tap water 350 day/yr); exposure duration (Native American 70 years; EPA tap water 30 years); drinking water ingestion rate (Native American 4 L/day [1 gal/day]; EPA tap water 2 L/day [0.5 gal/day]); and inhalation rate (CTUIR 25 m^3/day [883 ft^3/day], Yakama Nation 26 m^3/day [918 ft^3/day]; EPA tap water 20 m^3/day [706 ft^3/day]). As a result, the Native American exposure scenarios both produce higher total ELCR and HI that the EPA tap water scenario; depending on the contaminants and pathways involved, As described below, ELCR and HI for the Native American scenarios may be 4- to 5-fold greater than for the tap water scenario, for the drinking water ingestion, VOC inhalation and dermal absorption exposure pathways. COPCs are the same between each of the exposure scenarios; the percent contribution for each COPC is higher for the Native American scenarios than the EPA Tap Water scenario.

The largest uncertainties associated with the Native American scenarios are with the use of groundwater in a sweat lodge. When groundwater from the Near-River exposure area is used to produce steam in a sweat lodge, the total cumulative ELCRs for the CTUIR and Yakama Nation exposure scenarios are 3.4×10^{-2} and 7.0×10^{-2}, respectively (Appendix G, Attachment G-1). The major contributor to the cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR for both Native American scenarios is Cr(VI). The total HI for the CTUIR and Yakama Nation exposure scenarios are 8.9 and 18, respectively (see Appendix G, Attachment G-1). Primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of HI) are hexavalent chromium, manganese, and barium (Yakima Nation scenario only). All remaining individual analytes (barium [CTUIR scenario only], cobalt, fluoride, and nickel) that contribute greater than one percent of the HI also report a HQ less than 1. Contribution to HI is elevated for arsenic, where measured contributions are within natural background values.

When groundwater from the Upland exposure area is used to produce steam in a sweat lodge, the total cumulative ELCRs for the CTUIR and Yakama Nation exposure scenarios are 1.6×10^{-2} and 3.4×10^{-2}, respectively (see Appendix G, Attachment G-1). The major contributor to the cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR for both Native American scenarios is Cr(VI). The total HI for the CTUIR and Yakama Nation exposure scenarios are 6.8 and 14, respectively (Appendix G, Attachment G-1). Primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are hexavalent chromium, manganese, and barium

(Yakama Nation scenario only). All remaining individual analytes (barium [CTUIR scenario only], cobalt, fluoride, and nickel) that contribute greater than one percent of the HI also report a HQ less than 1. Contribution to HI is elevated for arsenic, where measured contributions are within natural background values.

Exposure point concentrations for air in a sweat lodge were calculated for the CTUIR Resident and Yakama Resident scenarios. Appendix 4 of *Exposure Scenario for CTUIR Traditional Subsistence Lifeways* (Harris and Harper, 2004) provides equations for estimating air-phase contaminant concentrations for volatile and semivolatile COPCs in the water used to create steam in the lodge, as well as separate equations for nonvolatile COPCs. Inhalation exposure to nonvolatile COPCs in the sweat lodge was evaluated in the CTUIR and Yakama Nation resident scenarios in spite of concerns with the model for calculating these air-phase EPCs. The Harris and Harper (2004) equation for calculating air-phase EPCs for nonvolatile analytes (Equation 3-2) calculates the concentration of a nonvolatile COPC in air as a function of the concentration of water vapor produced by the volatilization of water poured over hot rocks in a sweat lodge. Because nonvolatile contaminants have no vapor pressure, Equation 3-2 does not have a common physical basis with volatile chemicals. It is possible that inhalation of nonvolatile COPCs might occur by an alternative physical model, such as respiration of respirable-size aerosols, if such aerosols were formed when water is poured over the hot rocks in a lodge. However, a model of resuspension of nonvolatile impurities in aerosol form is inconsistent with other mechanical processes involving steam. For example, EPA does not address this pathway in shower volatilization models (*Volatilization Rates from Water to Indoor Air Phase II* [EPA 600/R-00/096]). It is also inconsistent with the widespread use of steam distillation for commercial water purification.

When groundwater is used as a drinking water source from the Near-River exposure area, the total cumulative ELCRs for the CTUIR and Yakama Nation exposure scenarios are 6.1×10^{-4} and 6.3×10^{-4}, respectively. The total cumulative ELCR for the EPA tap water scenario is 1.4×10^{-4}. All scenarios are greater than the EPA upper target risk threshold of 1×10^{-4}. Major contributors to risk for the Native American scenarios and the EPA tap water scenario are strontium-90, tritium, and trichloroethene. The total HI is 2.9 for both the CTUIR and Yakama Nation exposure scenarios. The HI for the EPA tap water scenario is 1.5. Cr(VI) is the primary contributor to the non-cancer HI for the Native American scenarios. All individual analyte report a HQ less than 1.0 for the EPA tap water exposure scenario.

When groundwater is used as a drinking water source from the Upland exposure area, the total cumulative ELCRs for the CTUIR and Yakama Nation exposure scenarios are 3.9×10^{-4} and 4.2×10^{-4}, respectively. The total cumulative ELCR for the EPA tap water scenario is 9.7×10^{-5}. The Native American scenarios are greater than the EPA upper target risk threshold of 1×10^{-4}. Major contributors to risk for the Native American scenarios and the EPA tap water scenario are tritium, trichloroethene, and strontium-90. The total HI is 2.4 for both the CTUIR and Yakama Nation exposure scenarios. The HI for the EPA tap water scenario is 1.2. All individual analytes report a HQ less than 1.0 for the Native American scenarios and the EPA tap water exposure scenario.

These results for the Near-River and Upland exposure areas are consistent with the screening level groundwater risk assessment provided in the RCBRA Report (DOE/RL-2007-21), which identified strontium-90, tritium, and trichloroethene in the 100-BC-5 Groundwater OU as the primary contributors to risk through ingestion and dermal contact with groundwater. As discussed above, the uncertainties associated with the sweat lodge scenario would considerably overstate the contribution of hexavalent chromium to total risks and noncancer hazards from contaminants in groundwater.

Groundwater within the 100-BC-5 OU is currently contaminated, and withdrawal is prohibited as a result of institutional controls placed on it by DOE through the interim action ROD. Under current site use

conditions, no complete human exposure pathways to groundwater are assumed to exist. Groundwater within this OU is not anticipated to become a future source of drinking water until cleanup criteria are met and groundwater is restored to its highest beneficial use.

6.4 Risk Assessment Conclusions of the Riparian and Nearshore Environment from RCBRA and the Columbia River Component

Human health risks were assessed in areas outside the footprints of waste sites as part of the RCBRA Volume II (DOE/RL-2007-21, Volume II) and the *Columbia River Component Risk Assessment, Volume II: Baseline Human Health Risk Assessment* (hereinafter called the CRC HHRA; DOE/RL-2010-117, Volume II). The following sections summarize the conclusions obtained from these two risk assessments. Table 6-43 presents a summary of the total risks and noncancer hazards associated with the riparian and nearshore area and the Columbia River. Several investigations conducted on effluent pipelines that discharged to the Columbia River are also summarized.

6.4.1 Risk Assessment Conclusions from the River Corridor Baseline Risk Assessment

The assessment of human health risks was based on "broad-area" environmental data that characterized concentrations of COPCs in upland and riparian surface soils, river water and sediment in nearshore areas, and fish tissue.

The exposure scenarios considered for riparian and nearshore areas were avid angler, casual user, and Tribal scenarios, including a nonresident Tribal scenario, and ingestion of fish in the CTUIR and Yakama residential scenarios. The casual user scenario addresses occasional recreational use. The scenario is focused on activities such as walking and picnicking in riparian areas near the river. The avid angler is focused on individuals who are not engaged in a subsistence lifestyle. The avid angler application is associated with exposure in the nearshore region of the River Corridor, and takes into consideration potential exposures to sediments and fish. The nonresident Tribal scenario is focused on individuals engaged in a subsistence lifestyle who reside offsite but use the River Corridor for various activities such as hunting, gathering plants, and fishing.

Table 6-43. Summary of Total Risks and Noncancer Hazards for the Riparian and Nearshore in the 100-BC OUs

Environment/Exposure Media	Excess Lifetime Cancer Risk	Primary Risk Drivers	Noncancer Hazard Index	Primary Noncancer Hazards	Comment	Source
Casual User Scenario						
Riparian Soil	3.0×10^{-6}	None	0.019	None	--	RCBRA Report (DOE/RL-2007-21) Tables 4-14 and 4-16
Avid Angler Scenario						
Nearshore – sediment, river water, dust	1.0×10^{-6}	None	0.012	None	--	RCBRA Report (DOE/RL-2007-21) Tables 4-17 and 4-19
Fish ingestion - Sculpin	NA	None	2.2	Metals	Screening-level result employing nearshore COPC concentrations in sculpin, a small fish with a limited home range.	
Nonresident Tribal Scenario						
Soil, sediment, water	7.0×10^{-5}	Arsenic	0.96	None	--	RCBRA Report (DOE/RL-2007-21) Tables 4-24 and 4-26
Plants and game	1.0×10^{-2}	Arsenic	78	Arsenic	Ingestion of contaminants plants and game modeled were using bio-transfer factors which overstated concentrations accumulated from soil.	
Fish Ingestion - Sculpin	NA	None	13	Metals	Screening-level result employing nearshore COPC concentrations in sculpin, a small fish with a limited home range.	

Table 6-43. Summary of Total Risks and Noncancer Hazards for the Riparian and Nearshore in the 100-BC OUs

Environment/Exposure Media	Excess Lifetime Cancer Risk	Primary Risk Drivers	Noncancer Hazard Index	Primary Noncancer Hazards	Comment	Source
Casual User Scenario (Child- Columbia River)						
100-A Study Area COPCs in Surface Water	0	None	0	None	Risks in each media summed across chemical carcinogens and radionuclides.	CRC (DOE/RL-2010-117), Tables 6-1 and 6-2.
100-A Study Area COPCs in Sediment	0	None	0	None		
100-B Study Area COPCs in Surface Water	0	None	0	None		
100-B Study Area COPCs in Sediment	$4.0\ 10^{-7}$	None	0.02	None		
100-B Study Area COPCs in Island Soil	6×10^{-9}	None	0.02	None		
Casual User Scenario (Adult- Columbia River)						
100-A Study Area COPCs in Surface Water	0	None	0	None	Risks in each media summed across chemical carcinogens and radionuclides.	CRC (DOE/RL-2010-117) Tables 6-13 and 6-14.
100-A Study Area COPCs in Sediment	3.0×10^{-6}	None	0.003	None		
100-B Study Area COPCs in Surface Water	0	None	0	None		
100-B Study Area COPCs in Sediment	$2 \times 10\text{-}^{6}$	None	0.002	None		
100-B Study Area COPCs in Island Soil	2×10^{-8}	None	0.003	None		

Table 6-43. Summary of Total Risks and Noncancer Hazards for the Riparian and Nearshore in the 100-BC OUs

Environment/Exposure Media	Excess Lifetime Cancer Risk	Primary Risk Drivers	Noncancer Hazard Index	Primary Noncancer Hazards	Comment	Source
Avid Angler Scenario (Child- Columbia River)						
300 Area, Fish Ingestion	0	None	0	None	--	CRC (DOE/RL-2010-117), Table 6-25
Avid Angler Scenario (Youth- Columbia River)						
100-A Study Area COPCs in Surface Water	0	None	0	None	Risks in each media summed across chemical carcinogens and radionuclides.	CRC (DOE/RL-2010-117) Tables 6-28 and 6-29.
100-A Study Area COPCs in Sediment	7.0×10^{-7}	None	0.005	None		
100-A Study Area COPCs in Fish	0[a]	None	0	None		
100-B Study Area COPCs in Surface Water	0	None	0	None		
100-B Study Area COPCs in Sediment	5.0×10^{-7}	None	0.003	None		
100-B Study Area COPCs in Island Soil	3.0×10^{-7}	None	0.006	None		
100-B Study Area COPCs in Fish	0	None	0	None		

Table 6-43. Summary of Total Risks and Noncancer Hazards for the Riparian and Nearshore in the 100-BC OUs

Environment/Exposure Media	Excess Lifetime Cancer Risk	Primary Risk Drivers	Noncancer Hazard Index	Primary Noncancer Hazards	Comment	Source
Avid Angler Scenario (Adult- Columbia River)						
100-A Study Area COPCs in Surface Water	1.0×10^{-7}	None	0.0008	None	Risks in each media summed across chemical carcinogens and radionuclides.	CRC (DOE/RL-2010-117) Tables 6-34 and 6-35.
100-A Study Area COPCs in Sediment	3.0×10^{-6}	None	0. 003	None		
100-A Study Area COPCs in Fish	0[a]	None	0	None		
100-B Study Area COPCs in Surface Water	0	None	0	None		
100-B Study Area COPCs in Sediment	2.0×10^{-6}	None	0.002	None		
300-B Study Area COPCs in Island Soil	5.0×10^{-7}	None	0.003	None		
300-B Study Area COPCs in Fish	0	None	0	None		

Notes:

Carbon-14 was detected in one sucker fillet at a concentration slightly higher than the minimum detectable activity of the instrument and is likely a false positive result. Risk contributions of carbon-14 were low relative to the contribution of risk from polychlorinated biphenyls and chlorinated pesticides. Carbon-14 was not detected in nearshore groundwater, seeps, or sediment but was detected in one soil sample collected from the riparian area.

Zero value indicates that there were not COPCs for that medium; therefore, no risks or noncancer hazards were calculated.

NA – not available. Carbon-14 in the 100-K area is the only COPC in sculpin.

Risks presented in this table are for COPCs identified in the Study Area (that is, along the River Corridor sites. COPCs for Reference Areas are presented in the CRC report. Note that risks associated with Reference Area COPCs typically are greater than risks associated with Study Area COPCs.

Risk estimates for the CTUIR and Yakama Nation scenarios are provided in the RCBRA Report (DOE/RL-2007-21) and CRC (DOE/RL-2010-117) reports.

EPCs in soil in the riparian environment were calculated using MULTI-INCREMENT® sampling from riparian locations in the 100-BC Area (RCBRA SAP [DOE/RL-2005-42]). Discrete sediment samples used to calculate EPCs were obtained from sites in the River Corridor selected from locations of known groundwater plumes, areas of groundwater discharge to the river, results of past biota sampling locations, or areas of fine-grained sediment deposits. Data from sculpin, clams, and benthic macroinvertebrates (primarily crayfish and clams) were used to estimate fish ingestion risks to avid angler and nonresident Tribal receptors.

The results of the broad area risk assessment in the 100-BC Area for the casual user and avid angler scenarios showed that lifetime cancer risk was 3×10^{-6} and below a noncancer HI of one for direct exposures to soil, sediment, and surface water.

Risks for riparian soils were higher than 1×10^{-4} cancer risk and above a noncancer HI of one for the nonresident Tribal scenario. Modeled concentrations of arsenic from riparian soil into native vegetation provided the largest contribution to cancer risks. Modeled concentrations of cadmium and zinc into native vegetation provided the largest contribution to noncancer hazard indices. However, as discussed in the RCBRA Report (DOE/RL-2007-21), uncertainties in the food chain modeling methods considerably overstate risks from plant ingestion exposure pathways. No carcinogenic COPCs were identified in fish, based on data in sculpin, clams, crayfish, and juvenile suckers. The noncancer HIs associated with fish ingestion, based on these biota data in sculpin, clams, crayfish and juvenile suckers was higher than one for the Tribal scenarios. The COPC providing the major contribution to noncancer hazard was copper detected in clams and crayfish. As discussed in the RCBRA Report (DOE/RL-2007-21), it is likely that the calculated HI values for copper considerably overstate the risks from ingestion of this metal. Copper is normally present in hemocyanin for carrying oxygen in the blood, both in crayfish and clams. In addition, HI values for ingestion of crayfish from reference areas are similar to the 300 Area. In addition, human health risks from copper are associated with gastrointestinal irritation by free copper ions in drinking water, which is an effect that may not be relevant to ingestion of copper in food.

6.4.2 Risk Assessment Conclusions from the Columbia River Component

The CRC HHRA provides a comprehensive assessment of human health risks for the Hanford Reach. The intent of the CRC risk assessment was to complete the assessment of the "bank-to-bank" Hanford Reach and downstream areas (i.e., Lake Wallula) of the Columbia River, characterizing risk in areas not previously addressed under the RCBRA Report (DOE/RL-2007-21). Human exposure scenarios addressed in the CRC HHRA were an avid angler, casual user, hypothetical future resident, and a Native American (Yakama Nation) subsistence fisher. As discussed in the CRC HHRA (DOE/RL-2010-117, Volume II), fish ingestion exposure provided the largest contribution to overall human health risks. A fish sampling program was created specifically to support the HHRA within the CRC RI, and provided a consistent sampling and analysis approach among species, tissue types, and analytes (Columbia River RI Work Plan [DOE/RL-2008-11]). The fish species targeted in the sampling program were intended to be the most representative of the exposure scenarios identified in the HHRA, and included the following:

- Common carp (*Cyprinus carpio*)
- Mountain whitefish (*Prosophium williamson*i)
- Walleye (*Stizostedion vitrium*)
- Smallmouth bass (*Micropterus dolomieui*)
- Bridgelip sucker (*Catostomus columbianus*)
- White sturgeon (*Acipenser transmonatnus*)

Separate fillets, carcass (including the head and skeleton), and combined livers and kidneys were analyzed. Fillet samples for all species except sturgeon were prepared with the skin on, as skin for these types of fish is often left on during preparation and consumption.

As described previously, the fish consumption pathway provided the largest contribution (99 percent contribution) to human health risks (evaluated for the avid angler and Native American scenarios). The fish consumption pathway was evaluated using two separate approaches. In the first approach, risk was quantified assuming a receptor consumed a varied diet consisting of all six species evaluated. In a second approach, risk was quantified for each individual fish species. Although the concentrations of COPCs, and hence, estimated hazard/risk, varied among the different species, the relative magnitude of risk remained similar among all six fish species. Relative magnitude of risk for the avid angler scenario was generally in the range of 2×10^{-3} to 8×10^{-3}, with bass and carp having the overall lowest and highest associated cancer risk. PCBs, chlorinated pesticides, cobalt, arsenic, and mercury were the primary risk drivers through fish ingestion. Throughout the Hanford Site study area, nearly all of the risk drivers also were identified as COPCs in upstream reference areas. Several radionuclides were detected in some fish tissue samples, at a very low (1 percent) frequency of detection. These radionuclides were eliminated as COPCs because it was concluded the concentrations were erroneous data quality or data consistency issues.

PCBs, mercury, and chlorinated pesticides in fish tissue, which are primary risk drivers, are prevalent in fish tissue in many waterbodies, because of their widespread historical use, atmospheric deposition and, consequently, high prevalence in abiotic media. The results from Chapter 4 and Riparian and Nearshore CSM in Appendix M show that there are unlikely to be sources or transport pathways from Hanford Site soils or groundwater that would have resulted in transport of PCBs, mercury, or chlorinated pesticides to Columbia River media (sediment or surface water) where they could have been accumulated into fish tissue. Based on the absence of transport pathways from 100-BC Area sites or groundwater, coupled with comparable risks associated with fish caught in reference areas, it is unlikely that Hanford Site activities in the 100-BC Area are associated with the fish ingestion risks projected in the CRC HHRA.

6.4.3 Risk Assessment Conclusions for River Pipelines

During operations, water used in fuel production to cool the reactors was discharged to the Columbia River via effluent pipelines. The release of this cooling water ended when the associated reactors and facilities were shut down. Today, one inactive 100-BC effluent pipeline remains in its original location in the Columbia River channel. Past characterization efforts obtained samples of the river effluent pipelines from the 100-BC, 100-D, and 100-F Areas. Characterization data collected during the river pipeline evaluations were used to evaluate potential risks from contaminants within the pipelines. The RCBRA Volume II (DOE/RL-2007-21, Volume II) provided a summary of the previous characterization efforts and risk assessment for these pipelines in Section 8.2.2.

In 1984, *River Discharge Lines Characterization Report* (UNI-3262) discussed samples of scale (flakes of mostly rust) from the interior surfaces and enclosed sediment of the effluent pipelines from the 105-C, 105-DR, and 105-F Reactors. The pipelines were also visually inspected underwater by a diver, and their positions and physical conditions were assessed. Samples of scale and sediment were analyzed for radionuclides. The major radionuclides detected included cobalt-60, cesium-137, europium-152, europium-154, and europium-155. Radionuclide concentrations were greater in the scale than in the sediment. Direct beta-gamma radiation measurements were also obtained for interior and exterior pipe surfaces. The HHRA determined that elevated human radiological exposure could occur if portions of the river pipelines became dislodged and washed ashore (RCBRA Report [DOE/RL-2007-21], Section 8.2.2).

In 1994, a comprehensive geophysical survey (*Columbia River Effluent Pipeline Survey* [WHC-SD-EN-TI-278]) located and mapped the reactor effluent pipelines. The study relied mainly on remote sensing geophysical techniques, including navigation and echo sounding, side-scanning radar, sub-bottom profiling, seismic reflection profiling, and ground-penetrating radar. The results indicated that the pipelines have neither broken loose nor moved from their original locations. However, portions of some pipelines are no longer buried.

In 1995, pipe scale and sediment from the interior of the effluent pipelines from the 100-BC and 100-D Areas were sampled and physically characterized using a robotic transporter (*100 Area River Effluent Pipelines Characterization Report* [BHI-00538]). Analytical data from these two pipelines were intended to complement the 1984 radionuclide data (*River Discharge Lines Characterization Report* [UNI-3262]) and were expected to represent "worst case" conditions with respect to radiological contamination. This assumption was based on the long years of pipeline service and the volume of effluent known to have been discharged from the 105-B and 105-D/DR Reactors.

The analytical results from the 1984 and 1995 effluent pipeline characterization studies at the 105-B, 105-C, 105-D/DR, and 105-F Reactors may reasonably be applied to effluent pipelines in 100-K because operations among these reactors were similar. Evaluations of human health and ecological risk have been performed for the river effluent pipelines, as they are today, located on or beneath the river channel bottom, and for a scenario in which a pipeline section breaks away from the main pipeline and is washed onto the shore of the river. Both the 1996 risk assessment effort (*100 Area River Effluent Pipelines Characterization Report* [BHI-00538]) and the 1998 risk assessment effort (*100 Area River Effluent Pipelines Risk Assessment* [BHI-01141]) relied on data collected from the 1984 and 1995 characterization work. The evaluation of human health and ecological risk performed in 1998 (*100 Area River Effluent Pipelines Risk Assessment* [BHI-01141]) concluded that the concentrations of chromium and mercury in the scale and sediment within the pipelines pose minimal ecological risk because they have been in contact with river water without dissolving since the reactors were shut down. The 1998 risk evaluation results indicated pipelines present no unacceptable risks; therefore, no remediation requirements under CERCLA. This is supported by the following:

- Minimal deteriorated condition of the pipelines
- Continued decrease of radionuclide concentrations due to decay
- Inaccessible location
- Unavailability of significant contaminants to affect human health and the environment

Based on available information, no elevated risk levels are expected to be associated with the pipeline.

6.5 Summary and Conclusions

The soil and groundwater risk assessments for the 100-BC Source OU and 100-BC-5 Groundwater OU accomplishes the following objectives:

- Proposes direct contact PRGs in soil for use in the FS from values presented in the RCBRA Report (DOE/RL-2007-21).
- Evaluates the effectiveness of source interim actions for the 100-BC Source OU.
- Qualitatively evaluates soil data from RI and LFI soil borings and wells to determine if results could be useful for risk management decisions.

- Confirms that wastes sites are remediated to the RAOs and RAGs published in the 100 Area RDR/RAWP (DOE/RL-96-17). In addition, confirms that waste sites achieve the direct contact PRGs proposed for the FS. In other words, sites cleaned up under interim action do not need to be revisited in the FS to demonstrate protection of human health.
- Identifies the waste sites and COCs in the vadose zone that require further evaluation in the FS.
- Confirms that waste sites that have not been remediated are carried forward into the FS based on process history and/or sampling results.
- Identifies the COCs in groundwater that require further evaluation in the FS.

The methodology used to assess risks for the RI/FS uses PRGs developed in the RCBRA Report (DOE/RL-2007-21), and incorporates the most current agency guidance. COPCs in the vadose zone and groundwater were identified in a conservative manner, using exclusions identified in the RCBRA to identify COPCs. The methods for developing EPCs are based on EPA's ProUCL guidance manual. The residential scenario used to develop PRGs and characterize risks to human health from contaminants in the vadose zone is drawn from the scenario that was used to develop cleanup levels for the 100 Area RDR/RAWP (DOE/RL-96-17), and was brought up to date to be consistent with most recent regulatory guidance. PRGs for the vadose zone were developed to reflect a range of exposure scenarios and include those that represent the RAOs (residential scenario) and reasonably anticipated future land use (the resident Monument worker and casual recreational user).

Contaminant concentrations in groundwater were compared with a range of groundwater and surface water standards for protection of human health and aquatic organisms. Risks from contaminants in groundwater were assessed using the EPA tap water scenario to confirm identification of COPCs. Tribal scenarios based on assumptions provided by the CTUIR and Yakama Nation were also evaluated. The EPA tap water scenario is also evaluated to provide a similar scenario using exposure assumptions that represent reasonable maximum exposure.

Cumulative risks were calculated for multiple contaminants and multiple exposure pathways by exposure media (that is, soil or groundwater). Cumulative risks summed across soil and groundwater were not calculated for the residential scenario because the RME for this scenario does not include combined exposures to both media; therefore, they are presented separately.

RI and LFI data were compared to PRGs developed in the RCBRA Report (DOE/RL-2007-21). Soil samples collected from depth intervals ranging from 0 to 4.6 m (15 ft) bgs from each individual soil boring or test pit were combined and compared to PRGs including those that represent the RAOs (residential scenario) and reasonably anticipate future land use (resident Monument worker and casual-recreational user). Soil samples collected from depth intervals greater than 4.6 m (15 ft) bgs from each individual soil boring or test pit were combined and compared to residential PRGs. The protection of groundwater and surface water from contaminants currently in the vadose zone was discussed in Chapter 5. The ecological risk assessment that evaluates the protection of terrestrial receptors is discussed in Chapter 7.

6.5.1 Conclusions for the Soil Risk Assessment

The contaminants that are the largest contributors to calculated risks and hazard indices in the vadose zone are radionuclides and metals. The radionuclides can be categorized as being related to waste disposal, including cesium-137, cobalt-60, europium-152, europium-154, and strontium-90.

6.5.1.1.1 Shallow Zone Results for Closeout Verification Data

Cancer risks associated with radionuclides within the top 4.6 m (15 ft) of soil are in the 10^{-3} range, based on the residential exposure scenario. The risks from those radionuclides in the top 4.6 m (15 ft) of soil that are related to waste disposal are less than 1×10^{-4}, under any of the exposure scenarios. Soil concentrations met target risk thresholds that were updated from a target annual dose rate of 15 mrem/yr to a target risk of 1×10^{-4} to be consistent with *Radiation Risk Assessment At CERCLA Sites: Q & A* (EPA/540/R/99/006).

The following waste sites were reported with risks greater than the EPA upper threshold of 1×10^{-4}; however, concentrations of radioisotopes that were the primary risk drivers have decayed to levels less than residential PRGs and do not warrant further evaluation in the FS.

- 116-B-14 (shallow decision unit) contained europium-152 at a concentration of 4.4 pCi/g, resulting in a risk of 1.2×10^{-4}, when sampled in year 1998. Europium-152 concentrations decayed to levels less than residential PRG in year 2002.

- 116-B-5 (shallow focused decision unit) contained europium-152 at a concentration of 7.3 pCi/g resulting in a risk of 2.0×10^{-4} and tritium at a concentration of 680 pCi/g resulting in a risk of 1.2×10^{-4}, when sampled in year 1995. Europium-152 and tritium concentrations decayed to levels less than residential PRGs in year 2008 and year 1997, respectively.

- 116-B-6A (shallow decision unit) contained strontium-90 at a concentration of 2.6 pCi/g, resulting in a risk of 1.1×10^{-4}, when sampled in year 1999. Strontium-90 concentrations decayed to levels less than the residential PRG in year 2004.

The following waste sites contain site-related COPCs, although they are assigned to shallow zone decision units the residual contamination is located at depths greater than 4.6 m (15 ft). These waste sites warrant further evaluation in the FS:

- 100-B-21:4 (shallow decision unit) contained cesium-137 at a concentration of 45 pCi/g, resulting in a risk of 1.0×10^{-3} and 100-B-21:4 (overburden focused decision unit) contained cesium-137 at a concentration of 8 pCi/g resulting in a risk of 1.8×10^{-4}, when sampled in 2009. Cesium-137 concentrations decay to levels less than residential PRGs by year 2110 in the shallow decision unit and by year 2035 in the overburden decision unit, warranting further evaluation in the FS. Although the samples from this decision unit were assigned to the shallow zone, the closeout documentation indicates that samples were collected from an excavation depth of 7.5 m (25 ft) bgs.

- 116-C-3 (shallow focused decision unit) contained cesium-137 at a concentration of 14 pCi/g, resulting in a risk of 3.2×10^{-4} and strontium-90 at a concentration of 18 pCi/g resulting in a risk of 8.0×10^{-4}, when sampled in 2007. Cesium-137 concentrations decay to levels less than residential PRG by year 2057 and strontium-90 concentrations decay to levels less than residential PRG by year 2094, warranting further evaluation in the FS. Although the samples from this decision unit were assigned to a shallow zone, the closeout documentation indicates that samples were collected from an excavation depth of 8.5 m (28 ft) bgs.

- 118-B-1 (shallow 3 decision unit) contained strontium-90 at a concentration of 4.4 pCi/g, resulting in a risk of 2.0×10^{-4} and 118-B-1 (shallow 5 decision unit) contained strontium-90 at a concentration of 2.4 pCi/g resulting in a risk of 1.1×10^{-4}, when sampled in year 2006 and year 2007, respectively. Strontium-90 concentrations in the shallow 3 decision unit decay to levels less than residential PRGs by year 2034 and decayed to levels less than residential PRGs in year 2009 in the shallow 5 decision unit. Although the samples from these decision units were assigned to the shallow zone, the closeout

documentation indicates that the remediation footprint is partially in the deep zone (greater than 4.6 m [15 ft] bgs), with the deepest portion of the excavated area being approximately 10 m (33 ft) bgs.

- 118-C-1 (staging pile area decision unit) contained carbon-14 at a concentration of 182 pCi/g, resulting in a risk of 2.3×10^{-4}. Carbon-14 concentrations do not decay to levels less than the residential PRG within a reasonable period, warranting further evaluation in the FS. The closeout documentation indicates that the staging pile material associated with this waste site was backfilled into the deep zone portions of the waste site.

6.5.1.1.2 Shallow Zone Results for RI and LFI Data

Soil samples were collected from depths ranging between 0 to 4.6 m (15 ft) bgs from two RI soil borings, one RI test pit, one LFI test pit, and three LFI soil borings. The conclusion from the evaluation of the shallow zone RI and LFI data are consistent with the conclusions of the soil risk assessment.

For the 100-B/C Source OU, three LFI soil borings (116-B-2 Fuel Storage Basin Trench, 116-B-3 Pluto Crib, and 116-C-5 Retention Basin) report soil concentrations greater than residential PRGs. These three waste sites have been subsequently remediated under the interim action ROD. The soil risk assessment did not identify risks associated with these sites based on current conditions.

The RI soil boring collected from the 118-B-8:1 Fuel Storage Basin (B Reactor Subsite) (C7847) reports concentrations of cesium-137, europium -152, and strontium-90 greater than residential PRGs at depths ranging between 3.8 m (12.5 ft) and 4.1 m (13.4 ft) bgs. Concentrations of cesium-137, europium-152, and strontium-90 in the RI borehole decay to levels less than residential PRGs by year 2203. These are results from the first attempted boring near the 105-B FSB and had to be abandoned following the collection of samples at four intervals because of refusal at 4.6 m (15 ft) bgs. These samples were collected to determine the nature and vertical extent of contamination in the vadose zone around the 105-B Reactor structure. The 118-B-8:1 waste site is an accepted site and remediation has not yet occurred.

The risk results for all remaining RI soil borings are within acceptable EPA risk thresholds.

6.5.1.1.3 Deep Zone Results for Closeout Verification Data

Deep vadose zone samples are compared to PRGs developed for the residential exposure scenario, although residents are unlikely to be exposed to contaminants in deep zone soil. Deep vadose zone samples are collected from depths greater than 4.6 m (15 ft) bgs and as a result, direct contact within the point of compliance is incomplete. Additionally, the residential exposure scenario does not reflect reasonably anticipated future land use in the River Corridor. This comparison is included because it is the most conservative land use basis for the evaluation of waste sites and presentation of these results is only included to provide additional information for risk management decisions. The following paragraphs summarize the waste sites that warrant further evaluation in the FS.

The following waste sites were reported with risks greater than the EPA upper threshold of 1×10^{-4}; however, concentrations of radioisotopes that were the primary risk drivers have decayed to levels less than residential PRGs and do not warrant further evaluation in the FS.

- 116-B-1 (deep decision unit) contained europium-152 at a concentration of 7.1 pCi/g, resulting in a risk of 1.9×10^{-4} when sampled in year 1999. Europium-152 concentrations decayed to levels less than residential PRG in year 2012.

- 116-B-14 (deep decision unit) contained cesium-137 at a concentration of 5.9 pCi/g, resulting in a risk of 1.3×10^{-4} when sampled in year 1998. Cesium-137 concentrations decayed to levels less than residential PRG in year 2011.

Fifteen waste sites are reported with concentrations of site-related COPCs at depths greater than 4.6 m (15 ft) bgs and warrant further evaluation in Chapter 8:

- 100-B-14:1 (deep focused decision unit) contained carbon-14 at a concentration of 275 pCi/g, resulting in a risk of 3.4×10^{-4}. Carbon-14 concentrations do not decay to levels less than the residential PRG within a reasonable period, warranting further evaluation in the FS.

- 100-B-5 (deep decision unit) contained cesium-137 at a concentration of 22 pCi/g resulting in a risk of 5.1×10^{-4} and europium-152 at a concentration of 15 pCi/g resulting in a risk of 4.2×10^{-4}, when sampled in year 2003. Cesium-137 and europium-152 concentrations decay to levels less than residential PRGs by year 2073 and year 2030, respectively.

- 100-B-8:1 (deep decision unit) contained cesium-137 at a concentration of 9.6 pCi/g, resulting in a risk of 2.2×10^{-4}, when sampled in year 2003. Cesium-137 concentrations decay to levels less than residential PRG by year 2037.

- 100-B-8:2 (deep decision unit) contained cesium-137 at a concentration of 13 pCi/g resulting in a risk of 2.9×10^{-4}, europium-152 at a concentration of 5.1 pCi/g resulting in a risk of 1.4×10^{-4}, and strontium-90 at a concentration of 2.7 pCi/g resulting in a risk of 1.2×10^{-4}, when sampled in year 2003. Cesium-137 concentrations decay to levels less than residential PRGs in year 2048. Europium-152 and strontium-90 concentrations both decayed to levels less than residential PRGs by year 2010.

- 100-B-8:2 (overburden decision unit) contained strontium-90 at a concentration of 29 pCi/g resulting in a risk of 1.3×10^{-3}, when sampled in year 2003. Strontium-90 concentrations decay to levels less than residential PRGs by year 2111.

- 116-B-11 (deep decision unit) contained cesium-137 at a concentration of 122 pCi/g resulting in a risk of 2.8×10^{-3}, cobalt-60 at a concentration of 40 pCi/g resulting in a risk of 1.3×10^{-3}, europium-152 at a concentration of 325 pCi/g resulting in a risk of 8.9×10^{-3}, europium-154 at a concentration of 42 pCi/g resulting in a risk of 9.6×10^{-4}, nickel-63 at a concentration of 2,702 pCi/g resulting in a risk of 4.4×10^{-4}, and strontium-90 at a concentration of 4.8 pCi/g resulting in a risk of 2.1×10^{-4}, when sampled in year 1998. Cesium-137, cobalt-60, europium-152, europium-154, nickel-63, and strontium-90 concentrations decay to levels less than residential PRGs by year 2142, year 2017, year 2084, year 2027, year 2205, and year 2029, respectively.

- 116-B-2 (deep decision unit) contained cesium-137 at a concentration of 47 pCi/g resulting in a risk of 1.1×10^{-3} and strontium-90 at a concentration of 7.2 pCi/g resulting in a risk of 3.2×10^{-4}, when sampled in year 1999. Cesium-137 and strontium-90 concentrations decay to levels less than residential PRGs by year 2102 and year 2047, respectively.

- 116-B-3 (deep decision unit) contained cesium-137 at a concentration of 20 pCi/g resulting in a risk of 4.5×10^{-4} and strontium-90 at a concentration of 3.2 pCi/g resulting in a risk of 1.4×10^{-4}, when sampled in year 1999. Cesium-137 and strontium-90 concentrations decay to levels less than residential PRGs by year 2064 and year 2013, respectively.

- 116-B-4 (deep decision unit) contained cesium-137 at a concentration of 112 pCi/g resulting in a risk of 2.5×10^{-3}, cobalt-60 at a concentration of 18 pCi/g resulting in a risk of 5.9×10^{-4}, europium-152 at

a concentration of 194 pCi/g resulting in a risk of 5.3×10^{-3}, and europium-154 at a concentration of 45 pCi/g resulting in a risk of 1.0×10^{-3}, when sampled in year 1999. Cesium-137, cobalt-60, europium-152, and europium-154 concentrations decay to levels less than residential PRGs by year 2139, year 2012, year 2075, and year 2028, respectively.

- 116-B-5 (deep focused decision unit) contained europium-152 at a concentration of 10 pCi/g, resulting in a risk of 2.7×10^{-4}, when sampled in year 1995. Europium-152 concentrations decay to levels less than the residential PRG by year 2014.

- 116-B-6A (deep decision unit) contained strontium-90 at a concentration of 21 pCi/g, resulting in a risk of 9.3×10^{-4}, when sampled in year 1999. Strontium-90 concentrations decay to levels less than residential PRGs by year 2093.

- 116-C-1 (deep focused decision unit) contained cesium-137 at a concentration of 5,690 pCi/g resulting in a risk of 1.3×10^{-1}, cobalt-60 at a concentration of 115 pCi/g resulting in a risk of 3.7×10^{-3}, europium-152 at a concentration of 1,120 pCi/g resulting in a risk of 3.1×10^{-2}, europium-154 at a concentration of 144 pCi/g resulting in a risk of 3.3×10^{-3}, nickel-63 at a concentration of 1,590 pCi/g resulting in a risk of 2.6×10^{-4}, and strontium-90 at a concentration of 88 pCi/g resulting in a risk of 3.9×10^{-3}, when sampled in year 1998. Cesium-137, cobalt-60, europium-152, europium-154, nickel-63, and strontium-90 concentrations decay to levels less than residential PRGs by year 2308, year 2025, year 2108, year 2042, year 2131, and year 2151, respectively.

- 116-C-2A (deep decision unit) contained cesium-137 at a concentration of 23 pCi/g resulting in a risk of 5.2×10^{-4}, cobalt-60 at a concentration of 12 pCi/g resulting in a risk of 3.9×10^{-4}, europium-152 at a concentration of 30 pCi/g resulting in a risk of 8.1×10^{-4}, and strontium-90 at a concentration of 6.2 pCi/g resulting in a risk of 2.7×10^{-4}, when sampled in year 1999. Cesium-137, cobalt-60, europium-152, and strontium-90 concentrations decay to levels less than residential PRGs by year 2071, year 2009, year 2039, and year 2041, respectively.

- 116-C-2A (overburden decision unit) contained cesium-137 at a concentration of 12 pCi/g resulting in a risk of 2.8×10^{-4}, when sampled in year 1999. Cesium-137 concentrations decay to levels less than the residential PRG by year 2043.

- 116-C-5 (deep decision unit) contained cesium-137 at a concentration of 52 pCi/g resulting in a risk of 1.2×10^{-3}, cobalt-60 at a concentration of 18 pCi/g resulting in a risk of 5.9×10^{-4}, europium-152 at a concentration of 73 pCi/g resulting in a risk of 2.0×10^{-3}, europium-154 at a concentration of 16 pCi/g resulting in a risk of 3.6×10^{-4}, nickel-63 at a concentration of 644 pCi/g resulting in a risk of 1.1×10^{-4}, and strontium-90 at a concentration of 4.4 pCi/g resulting in a risk of 1.9×10^{-4}, when sampled in year 1999. Cesium-137, cobalt-60, europium-152, europium-154, nickel-63, and strontium-90 concentrations decay to levels less than residential PRGs by year 2106, year 2012, year 2056, year 2015, year 2007, and year 2027, respectively.

- 118-B-6 (deep decision unit) contained tritium at a concentration of 2,780 pCi/g, resulting in a risk of 4.5×10^{-4}, when sampled in year 2006. Tritium concentrations decay to levels less than residential PRGs by year 2033.

- 118-C-3:2 (deep focused decision unit) contained cesium-137 at a concentration of 171 pCi/g resulting in a risk of 3.9×10^{-3}, europium-152 at a concentration of 9.2 pCi/g resulting in a risk of 2.5×10^{-4}, and strontium-90 at a concentration of 38 pCi/g resulting in a risk of 1.7×10^{-3}, when

sampled in year 1998. Cesium-137, europium-152, and strontium-90 concentrations decay to levels less than residential PRGs by year 2156, year 2016, and year 2116, respectively.

With the exception of four waste sites in the 100-BC Source OUs, the risks to the resident Monument worker from exposure to radionuclides in shallow soil are in EPA's target risk range of 10^{-4} to 10^{-6}. Waste site 100-B-21:4 and waste site 116-C-3 report concentrations of cesium-137 in the shallow decision unit that result in a risk of 7.3×10^{-4} and 2.3×10^{-4}, respectively. Waste site 116-B-14 and waste site 116-B-5 report concentrations of europium-152 in the shallow zone decision unit that result in a risk of 1.1×10^{-4} and 1.9×10^{-4}, respectively.

6.5.1.2 Deep Zone Results for RI and LFI Data

Soil samples were collected from depths greater than 4.6 m (15 ft) bgs from seven RI soil borings, nine RI wells, two test pits, one LFI test pit, eight LFI soil borings, and five LFI wells. The conclusions from the evaluation of the deep zone RI and LFI data are consistent with the conclusion of the soil risk assessment.

RI soil boring/well samples from 100-B-5 Trench (199-B4-15/C7846), 116-C-5 Retention Basin (116-B3-52/C7843), 118-B-6 Burial Ground (C7845), 118-B-8:1 (C8239), and 199-B5-6 (C7507) report radionuclide concentrations greater than residential PRGs. LFI soil boring samples from 199-B5-2 from the process effluent pipelines south of 116-C-5, 116-B-1 Trench (199-B3-48), 116-C-1 Liquid Waste Disposal Trench (199-B3-46), and 116-C-2A Pluto Crib (199-B9-4) also report radionuclide concentrations greater than residential PRGs. Radionuclide concentrations from each of the above soil borings were decayed to determine the year that activities would be reduced to levels less than the residential PRG. The following summarizes the results of the comparisons for the above waste sites:

- RI soil boring data and CVP/RSVP closeout data are available for the 100-B-5 Trench. The RI data analysis identifies cesium-137 and strontium-90 as contributors to risk and they are present at depths ranging between 8.5 m (27.9 ft) and 18.5 m (60.7 ft) bgs. The risk assessment for 100-B-5 Trench waste site (deep decision unit) identifies cesium-137 and europium-152 as contributors to risk. Based on the RI data analysis and the risk assessment, radioisotope concentrations decay to levels less than residential PRGs by year 2071 and year 2073, respectively.

- RI soil boring data, CVP/RSVP closeout data, and LFI data are available for 116-C-5 Retention Basin. The RI data analysis identifies cesium-137 as a contributor to risk and is present at depths ranging between 10.6 m (34.9 ft) and 12.3 m (40.3 ft) bgs. The risk assessment for 116-C-5 waste site (deep decision unit) identifies cesium-137, cobalt-60, europium-152, europium-154, nickel-63, and strontium-90 as contributors to risk. The LFI data indicate that individual risks from all detected analytes are less than the risk threshold of 1×10^{-4}. Based on the results of the RI data analysis and the risk assessment, radioisotope concentrations decay to levels less than residential PRGs by year 2029 and year 2106, respectively.

- RI soil boring data and CVP/RSVP closeout data are available for the 118-B-6 Burial Ground. The RI data analysis identifies strontium-90 and tritium as contributors to risk. Strontium-90 is present at depths ranging between 21.6 m (71 ft) and 24.0 m (78.9 ft) bgs and tritium is present at depths ranging between 9.5 m (31.1 ft) and 22.4 m (73.5 ft). The risk assessment identifies tritium as a contributor to risk. Based on the RI data analysis and the risk assessment, radioisotope concentrations decay to levels less than residential PRGs by year 2042 and year 2033, respectively.

- RI soil boring data are available for the 118-B-8:1 Fuel Storage Basin. The RI data analysis identifies carbon-14 and strontium-90 as contributors to risk. Carbon-14 is present at depths ranging between 5.3 m (17.4 ft) and 6.1 m (19.9 ft) bgs, and strontium-90 is present at depths ranging between 5.3 m (17.4 ft) and 25 m (82.2 ft) bgs. Concentrations of strontium-90 in the RI borehole decay to levels

less than residential PRG by year 2080. Concentrations of carbon-14 do not decay within a reasonable time frame.

- RI soil boring data are available for the 199-B5-6 monitoring well. The RI data analysis identifies tin-126 as a contributor to risk. Tin-126 is present at a depths ranging between 22.8 m (74.9 ft) and 23.6 m (77.4 ft) bgs. Concentrations of tin-126 do not decay within a reasonable time frame. Eight soil samples were collected and analyzed for Sn-126 from 199-B5-6. With the exception of the one depth interval, all tin-126 activity levels were not detectable. The single occurrence of tin-126 is likely an anomalous result because tin-126 is not known to be associated with releases at the Hanford Site.

- LFI data and CVP/RSVP closeout data are available for 116-B-1 Trench. The LFI data analysis identifies cesium-137, cobalt-60, europium-152, europium-154, and strontium-90 as contributors to risk and these radioisotopes are present at depths ranging between 4.6 m (15 ft) and 8.2 (27 ft) bgs. The risk assessment for 116-B-1 waste site (deep decision unit) identifies cesium-137, europium-152, and stronium-90 as contributors to risk. Based on the results of the LFI data analysis and the risk assessment, radioisotope concentrations decay to levels less than residential PRG by year 2092 and year 2012, respectively.

- LFI data and CVP/RSVP closeout data are available for 116-C-1 Liquid Waste Disposal Trench. The LFI data analysis identifies strontium-90 as a contributor to risk and is present at depths ranging between 10.7 m (35 ft) and 11.3 (37 ft) bgs. The risk assessment identifies cesium-137, cobalt-60, europium-152, europium-154, nickel-63, and strontium-90 as contributors to risk. Based on the results of the LFI data analysis and the risk assessment, radioisotope concentrations decay to levels less than residential PRG by year 2044 and year 2308, respectively.

- LFI data and CVP/RSVP closeout data are available for 116-C-2A Pluto Crib. The LFI data analyses identifies nickel-63 and strontium-90 as contributors to risk and are present at depths ranging between 7.0 m (22.9 ft) and 8.2 m (26.9 ft) bgs. The risk assessment identifies cesium-137, cobalt-60, europium-152, europium-154, and strontium-90 as contributors to risk. Based on the results of the LFI data analysis and the risk assessment, radioisotope concentrations decay to levels less than residential PRG by year 2223 and year 2071, respectively.

For nonradiological contaminants, the COPCs that are the largest contributors to calculated risks and hazard indices are metals and PAHs. For all exposure scenarios, the cancer risks and noncancer hazard indices for nonradioactive contaminants fell within EPA's target risk ranges. Concentrations of arsenic in soil are associated with cancer risks higher than 10^{-6} under unrestricted (residential) exposure assumptions. The concentrations of arsenic in soil posing risks greater than 10^{-6} are consistent with site-wide naturally occurring background in soil. Five waste sites were reported with PAH concentrations greater than the acceptable risk value of 1×10^{-6} for individual carcinogens but less than the MTCA HHRA Procedures "Multiple Hazardous Substances" (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5} for multiple contaminants and multiple pathways. No waste sites require further evaluation in the FS based on the presence of nonradiological COPCs.

In some cases, residual risks are higher than the state of Washington's cancer risk threshold; however, in most of those cases, the contaminant exceeding the state of Washington's cancer risk threshold is arsenic and is present at concentrations consistent with naturally occurring background. Cleanup of shallow vadose zone material (4.6 m [15 ft]) to achieve residential or unrestricted uses is also protective of a range of exposure scenarios, including a casual recreational user and a resident Monument worker. While concentrations of radionuclides in deep soil (deeper than 4.6 m [15 ft]) are associated with risks to

residents that are higher than EPA's risk reduction ranges, these concentrations do not pose significant risks, and would decay to levels protective of future residents within one to 211 years. In addition, data and process knowledge indicate that human health PRGs would be exceeded at unremediated waste sites and provides the basis for action. Table 8-6 lists the contaminants that are anticipated to exceed human health PRGs for unremediated waste sites.

6.5.2 Conclusions for the Groundwater Risk Assessment

The 100-BC-5 Groundwater OU was evaluated as two separate exposure areas including the Near-River (monitoring wells less than 500 m from the river shoreline) and Upland exposure areas (monitoring wells greater than 500 m from the river shoreline).

Cobalt moves forward into the FS because it has uncertainty associate with the data set and its occurrence in groundwater, but it is not a COPC. The nature and extent evaluation indicates that cobalt historically has been detected in groundwater at concentrations above the action level, but the presence was not associated with a specific location or a trend. Therefore, monitoring of this analyte will be performed to understand its persistence in the environment.

6.5.2.1 Near-River Exposure Area

The contaminants in groundwater that are the largest contributors to calculated risks, dose, and hazard indices are Cr(VI), tritium, strontium-90, and trichloroethene. The EPCs in groundwater were compared with federal and state surface water standards for protection of human health and aquatic organisms, federal and state primary and secondary DWSs, and state groundwater cleanup levels.

The EPC for Cr(VI) is greater than the federal and state water quality criteria. Cr(VI) is identified as a COPC, indicating the need to evaluate potential remedial technologies for this analyte in the FS.

The EPCs for strontium-90 and tritium are greater than the federal MCL developed for the protection of human health. strontium-90 and tritium are identified as COPCs, indicating the need to evaluate potential remedial technologies for tritium in the FS.

The EPC for trichloroethene is greater than the MTCA Method B groundwater cleanup level, which is based on a 1×10^{-6} target cancer risk level. However, the cumulative risk for trichloroethene is less than the MTCA HHRA Procedures (WAC 173-340-708) cumulative risk level of 1×10^{-5} for multiple contaminants. The EPC for trichloroethene is less than federal and state MCLs. The results of the evaluation for trichloroethene do not indicate the need to evaluate potential remedial technologies in the FS.

The COPC identification process for the 100-BC-5 Groundwater OU identified cobalt as a COPC and warrants further evaluation in the FS. The occurrence of cobalt in groundwater is uncertain because this analyte has been detected historically in groundwater at concentrations above the respective action level; however, its present was not associated with a specific location or a trend and the analytical methods used were not of sufficient accuracy for risk characterization purposes. Therefore, cobalt is considered a COPC and warrants further evaluation in the FS.

Risks associated with all analytes with available toxicity information were quantified using EPA's tap water scenario. This scenario was used to quantify risks from ingestion of tap water, inhalation of volatiles, and dermal exposure from showering, bathing, or performing other domestic activities. The risk posed by each analyte was then quantified and compared individually and collectively to the CERCLA (10^{-4} to 10^{-6}) acceptable risk range. Additionally, the quantified risks were used to confirm that the COPC identification process was reasonable and representative of the starting dataset. The results of this confirmation analysis indicate that the COPCs identified are representative and appropriate for assessing

risk and for making contaminant-specific remedial action decisions. If the contaminant had a quantified risk level that was above EPA's acceptable risk range, the contaminant was defined as a COPC subject to remedial technology review in the FS.

The cumulative ELCR is 5.6×10^{-5} for nonradiological analytes and 7.9×10^{-5} for radiological analytes, which are within the EPA risk range of 1×10^{-4} to 1×10^{-6}. Contributors to ELCR (those analytes that contribute greater than 1 percent of total ELCR) are strontium-90 (4.0×10^{-5}; 30 percent contribution), tritium (3.7×10^{-5}; 27 percent contribution), and trichloroethene (3.1×10^{-6}; 2.3 percent contribution). Strontium-90, tritium, and trichloroethene are identified as COPCs. Contribution to ELCR is elevated for arsenic (5.1×10^{-5}; 38 percent), where measured contributions are within natural background values. The HI is 1.5, which is slightly greater than the EPA target HI of 1. All individual analytes that contribute greater than 1 percent of the HI also reported a HQ less than 1. Although the HQ for Cr(VI) is less than 1, it is identified as a COPC because concentrations are greater than the AWQC.

In addition to the chemical-specific ARARs analysis, risks were evaluated using the Native American scenarios. The total cumulative ELCRs for the Near-River exposure area for the CTUIR and Yakama Nation exposure scenarios are 6.1×10^{-4} and 6.3×10^{-4}, respectively, when groundwater is used as a drinking water source. The primary contributors to risk for the Native American exposure scenarios are arsenic, strontium-90, tritium, and trichloroethene. The remaining analytes that are reported contributed less than 1 percent of the total cumulative risk. The total HI for the Near-River exposure area is 2.9 for both the CTUIR and Yakama Nation exposure scenarios. Cr(VI) is the primary contributor to the noncancer HI for the Native American scenarios.

The cumulative ELCR is 3.4×10^{-2} for the CTUIR scenario and 7.0×10^{-2} for the Yakama Nation scenario when groundwater is used as a source of steam for a sweat lodge. The cumulative risk for the native American scenarios is greater than the EPA upper target risk threshold of 1×10^{-4}. The individual ELCR values for Cr(VI) is greater than the EPA upper target risk threshold of 1×10^{-4}. The HI for the Near-River exposure area is 8.9 for the CTUIR scenario and 18 for the Yakama Nation scenario when groundwater is used as a source of steam for a sweat lodge, which is greater than the EPA target HI of 1.0. The primary contributors to the noncancer HI are Cr(VI), arsenic, manganese, and barium.

The results from the assessment of groundwater risks were based on three additional rounds of groundwater sampling across the 100-BC-5 Groundwater OU, which were intended to provide a more definitive identification of COPCs. The results of this groundwater risk assessment did not identify any COPCs in addition to those identified in the 100-BC Work Plan (DOE/RL-2008-46-ADD3). The results of the groundwater risk assessment for the Near-River exposure area identified Cr(VI), cobalt, strontium-90, tritium, and trichloroethene as contaminants warranting further evaluation in the FS.

6.5.2.2 Upland Exposure Area

The contaminants in groundwater that are the largest contributors to calculated risks, dose, and hazard indices are Cr(VI), strontium-90, tritium, and trichloroethene. The EPCs in groundwater were compared with federal and state surface water standards for protection of human health and aquatic organisms, federal and state primary and secondary MCLs, and state groundwater cleanup levels.

The EPC for Cr(VI) is greater than the federal and state water quality criteria. Cr(VI) is identified as a COPC indicating the need to evaluate potential remedial technologies for this analyte in the FS.

Although the EPC for strontium-90 is less than the MCL developed for the protection of human health, Strontium-90 is present at concentrations above the MCL in localized areas. Strontium-90 is identified as a COPC, indicating the need to evaluate potential remedial technologies for this analyte in the FS.

Although the EPC for tritium is less than the MCL developed for the protection of human health, tritium is present at concentrations above the MCL in localized areas. Tritium is identified as a COPC, indicating the need to evaluate potential remedial technologies for this analyte in the FS.

The EPC for trichloroethene is greater than the MTCA Method B groundwater cleanup level, which is based on a 1×10^{-6} target cancer risk level. However, the cumulative risk for trichloroethene is less than the MTCA HHRA Procedures (WAC 173-340-708) cumulative risk level of 1×10^{-5} for multiple contaminants. The EPC for trichloroethene is less than the federal and state MCLs. The results of the evaluation for trichloroethene do not indicate the need to evaluate potential remedial technologies in the FS.

The COPC identification process identified cobalt for the 100-BC-5 Groundwater OU that is considered a COPC and warrants further evaluation in the FS. The occurrence of cobalt in groundwater is uncertain because historically this analyte has been detected in groundwater at concentrations above the respective action level; however, its present was not associated with a specific location or a trend and the analytical methods used were not of sufficient accuracy for risk characterization purposes. Therefore, cobalt is considered a COPC and warrants further evaluation in the FS.

Risks associated with all analytes with available toxicity information were quantified using EPA's tap water scenario. This scenario was used to quantify risks from ingestion of tap water, inhalation of volatiles, and dermal exposure from showering, bathing, or performing other domestic activities. The risk posed by each analyte was then quantified and compared individually and collectively to the CERCLA (10^{-4} to 10^{-6}) acceptable risk range. Additionally, the quantified risks were used to confirm that the COPC identification process was reasonable and representative of the starting dataset. The results of this confirmation analysis indicate that the COPCs identified are representative and appropriate for assessing risk and for making contaminant-specific remedial action decisions. If the contaminant had a quantified risk level that was above EPA's acceptable risk range, the contaminant was defined as a COPC, subject to remedial technology review in the FS.

The cumulative ELCR is 8.3×10^{-5} for nonradiological analytes and 1.4×10^{-5} for radiological analytes, which are within the EPA risk range of 1×10^{-4} to 1×10^{-6}. Contributors to ELCR (those analytes that contribute greater than 1 percent of the total ELCR) are tritium (1.2×10^{-5}; 13 percent contribution), trichloroethene (4.0×10^{-6}; 4.1 percent contribution), and strontium-90 (1.3×10^{-6}; 1.3 percent contribution). Tritium, trichloroethene, and strontium-90 are identified as COPCs. Contribution to ELCR is elevated for arsenic (7.8×10^{-5}; 81 percent), where measured contributions are within natural background values. The HI is 1.2, which is slightly greater than the EPA target HI of 1. All individual analytes that contribute greater than 1 percent of the HI also report a HQ less than 1. Although the HQ for Cr(VI) is less than 1, it is identified as a COPC because concentrations are greater than the AWQC.

In addition to the chemical-specific ARARs analysis, risks were evaluated using the Native American scenarios. The total cumulative ELCRs for the Upland exposure area for the CTUIR and Yakama Nation exposure scenarios are 3.9×10^{-4} and 4.2×10^{-4}, respectively, when groundwater is used as a drinking water source. The primary contributors to risk for the Native American exposure scenarios are arsenic, tritium, trichloroethene, and strontium-90. The remaining analytes that are reported contributed less than 1 percent of the total cumulative risk. The total HI for the Upland exposure area is 2.4 for both the CTUIR and Yakama Nation exposure scenarios. All individual analytes are reported with a HQ less than 1.0.

The cumulative ELCR is 1.6×10^{-2} for the CTUIR scenario and 3.4×10^{-2} for the Yakama Nation scenario when groundwater is used as a source of steam for a sweat lodge. The cumulative risk for the native American scenarios is greater than the EPA upper target risk threshold of 1×10^{-4}. The individual ELCR values for Cr(VI) is greater than the EPA upper target risk threshold of 1×10^{-4}. The HI for the Upland

exposure area is 6.8 for the CTUIR scenario and 14 for the Yakama Nation scenario when groundwater is used as a source of steam for a sweat lodge, which is greater than the EPA target HI of 1.0. The primary contributors to the noncancer HI are Cr(VI), arsenic, manganese, and barium.

The results from the assessment of groundwater risks were based on three additional rounds of groundwater sampling across the 100-BC-5 Groundwater OU, which were intended to provide a more definitive identification of COPCs. The results of this groundwater risk assessment did not identify any COPCs in addition to those identified in the 100-BC Work Plan (DOE/RL-2008-46-ADD3). The results of the groundwater risk assessment for the Upland exposure area identified Cr(VI), cobalt, strontium-90, tritium, and trichloroethene as contaminants warranting further evaluation in the FS.

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7 Ecological Risk Assessment

The integration of past and ongoing ERAs supports the development of remedial alternatives for waste sites and contaminated groundwater in the 100-BC OUs. These risk assessments have been integrated with the cleanups performed under the interim action RODs to identify the need for further remedial action and development of ecological PRGs.

Highlights

- The ERA assessed soil contaminant concentrations at waste sites within the 100-BC OUs.
- The ERA relied on ecological PRGs presented in the RCBRA that are protective of populations and communities. The exposure area and the relative size of the waste sites were used in conjunction with the ecological PRGs to determine where ecological protection is required.
- Concentrations of radionuclides in upland soil verification samples did not exceed screening levels.
- Interim remedial actions at 100-BC under interim action ROD RAGs were protective of ecological receptors at all waste sites.
- An examination of the interrelationships between potential contaminant sources, transport mechanisms, exposure pathways, and receptors in the Columbia River concluded that Cr(VI) in the 100-BC-5 Groundwater OU is contributing to potential ecological risks identified in pore water at upwelling sites within the Columbia River.
- Data and process knowledge indicate ecological PRGs will be exceeded at unremediated waste sites. Those exceedances will be evaluated through the ERA process, including consideration of such factors as waste site size and wildlife home ranges within a scientific management decision point, to determine a basis for action.

As described in the previous chapters, the remedial actions completed to date in the River Corridor were implemented under interim action RODs. The RAOs in the 100 Area interim action RODs were developed to achieve protection of human health from direct contact with vadose zone material or to protect groundwater and surface water from contaminants leaching from vadose zone material. Protection of ecological receptors from direct contact with contaminated vadose zone material was not addressed directly in the interim action RODs, but indirectly with the assumption that attainment of standards for protection of human health or that reduced contaminant leaching would also be protective of ecological receptors. Protection of ecological receptors from discharges into the river was considered in the interim action RODs through consideration of state water quality standards and federal ambient water quality criteria.

CERCLA requires a baseline risk assessment to characterize current and potential threats to human health and the environment before issuance of the ROD. The source and groundwater component of the RCBRA Volume I (DOE/RL-2007-21) was prepared to address the regulatory requirement to perform a baseline risk assessment. The RCBRA (DOE/RL-2007-21, Volume I) was a comprehensive examination of current and potential risks in areas potentially affected by Hanford Site processes within the 100 and 300 Area OUs. One of the objectives of the RCBRA was to determine whether the interim actions were protective of ecological receptors (*Risk Assessment Work Plan for the 100 Area and 300 Area Component of the RCBRA* [DOE/RL 2004-37]). The scope of the RCBRA addressed the following portions of the River Corridor:

- Upland areas, including remediated CERCLA waste sites within 100-K, 100-D, 100-F, 100-H, 100-BC, and 100-N areas; the White Bluffs and Hanford townsites; and the 300 Area
- Riparian and nearshore aquatic zones on the south and west shoreline of the Columbia River on the Hanford Site
- Groundwater and areas of groundwater emergence on the south and west shoreline of the Columbia River on the Hanford Site

The RCBRA used multiple measures of exposure, ecological effect, and ecosystem/receptor characteristics to evaluate risks at 20 study sites across the River Corridor associated with remediated

waste sites (10 excavated/backfilled sites and 10 surface removal/native soil sites) and 10 reference areas, as described in the RCBRA SAP (DOE/RL-2005-42). The sites studied were selected from high-priority waste sites that had been remediated when the study was developed and represent the types of waste sites and remedial actions addressed by the interim action RODs. Based on this set of study sites, the results from the RCBRA Volume I (DOE/RL-2007-21) identified some contaminants in soil as contaminants of ecological concern. Contaminants of ecological concern principally were metals and pesticides.

The study design of the ERA in the RCBRA provided risk conclusions that applied across the entire River Corridor. The study design, coupled with results that identified contaminants of ecological concern across the River Corridor, required development of an ERA approach for the RI/FS that allowed assessment of risks on a site-by-site basis, as well as supported development of PRGs. That approach incorporates the use of ecological soil screening levels (SSLs) and ecological PRGs, which have been developed using the tiered process outlined in *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-00784) and *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311), respectively. This tiered process allows the incorporation of more sophisticated ERA methods and increasing levels of ecological site-specific information, to provide SSLs and PRGs that are more representative of Hanford Site conditions. Development of the risk-based concentration values (SSLs) and PRGs incorporates the problem formulation, the conceptual ecological exposure models, and selected bioaccumulation datasets developed in the RCBRA (DOE/RL-2007-21). These values were used to screen the waste sites in the 100-BC OUs with verification sampling and analytical information, to provide site-specific ecological risk information for each site.

The CRC (DOE/RL-2010-117) used analytical chemistry collected from surface water, sediment, pore water, and island soils to evaluate the potential for risk to ecological receptors including aquatic life living within the Columbia River and wildlife frequenting or inhabiting the islands within the river. Based on a screening level ERA, the CRC identified some contaminants in soil as contaminants of potential ecological concern. Contaminants of potential ecological concern principally were metals. The potential for these contaminants to have originated from the 100-BC Area is discussed later in this chapter.

For the 100-BC Source OUs, the results of the ERA presented in this chapter will be used to determine whether additional remedial action is necessary for waste sites where remediation has been completed, as demonstrated by verification sampling and analysis. It is important to note that another objective of the ERA is to determine and affirm a basis for action. Although the RI/FS risk assessment and the RCBRA focus on the protection of human health and the environment at waste sites that have been remediated, there are potential risks at unremediated sites that require continuation of cleanup actions.

The following approach has been used for addressing ecological risks potentially associated with waste sites in the 100-BC OUs:

- **Updating the identification of COPCs (Section 7.1).** The RCBRA went through a process to identify COPCs for ecological receptors, based on a Sitewide review of River Corridor data. This identification process has been updated to account for verification sampling data specifically in individual 100-BC Area waste sites.

- **Presenting the problem formulation (Section 7.2).** This section summarizes the problem formulation used in developing the risk-based concentration values used in this assessment as ecological SSLs. This problem formulation reflects conditions in upland environments across the Hanford Site, and incorporates information developed from the RCBRA.

- **Presenting effects and exposure assessments (Section 7.3).** This section summarizes the quantitative assessments used in developing the SSL and PRG risk-based concentration values,

including the wildlife exposure factors, biotransfer factors, and wildlife toxicity reference values (TRVs). The data and methods used to develop risk-based concentrations protective of plants and soil invertebrates are discussed in this section. More detailed descriptions of the data and methods used to calculate all of the ecological risk-based concentrations in soil are presented in *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-00784) and *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311). In addition, these values are also incorporated into the ERA of the RCBRA Volume I (DOE/RL-2007-21).

- **Updating the ecological risk characterization for 100-BC Area waste sites (Section 7.4).** Verification sampling and analysis data for the 81 waste sites in 100-BC Area waste sites were used to calculate EPCs, which were then compared with the ecological SSLs and, as appropriate, the PRGs. The results from these comparisons were used to identify receptors of interest and contaminants of ecological concern, for purposes of identifying the need for further action at the 100-BC Area sites. In addition, the results of this risk characterization were used to determine which of the risk-based concentration values should be recommended for use as PRGs.

- **Analyzing Risks in the Riparian and Nearshore Areas and the Columbia River (Section 7.5).** Final recommended contaminants of ecological concern in riparian and island soils and the surface water and sediments of the Columbia River as identified in the RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2010-117) were evaluated as to the potential for attribution to 100-BC OUs.

- **Preliminary Scientific Management Decision Point (SMDP) (Section 7.6).** Potential risks identified through the direct comparison of verification sampling soil data to SSLs and PRGs were considered in the context of a number of additional factors. Uncertainties in the risk characterization, spatial information, data quality, magnitude and aerial extent of risk, and confidence in risk-based values were included with other factors to make recommendations for which if any risks should be addressed further in the FS. A discussion of the process for developing final remediation goals was also included, along with recommendations for the SMDP for evaluating waste sites:

  - Size of the waste site relative to home range of wildlife receptors (e.g., developing and applying an area use factor (AUF) in the comparison of an exposure point concentration to the PRGs)
  - Estimation of exposure using a central tendency estimate such as the 95 percent UCL
  - Size of the waste site relative to area of adjacent uncontaminated habitat
  - Nature and extent of residual contamination following remediation
  - Potential presence of exposure pathways following remediation
  - The number and frequency of exceedances of the risk thresholds (PRGs)
  - The location of the samples exceeding thresholds, sample frequency, and proximity of other exceedances

Section 7.3 evaluates the protection of aquatic receptors from groundwater that has the potential to discharge to the Columbia River. The approach used to identify COPCs that warrant further evaluation in the FS presented in Section 7.3 is based on comparison of groundwater concentrations to the lowest available chemical-specific ARARs published for the protection of human health and aquatic receptors. Thus, risks to aquatic receptors have been considered in the context of evaluating the risks groundwater may contribute to surface water at the groundwater-surface water interface. Combining the assessment of

human health provides a streamlined approach that addresses the restoration of groundwater and the protection of aquatic receptors.

In addition to the analysis of waste sites, Chapter 7 summarizes an assessment of ecological risks in riparian and nearshore areas based on the analysis developed in the RCBRA (DOE/RL-2007-21) and risk in the Columbia River developed for the CRC. Appendix M evaluates ecological risks identified within the Columbia River and the relationship between potential sources to the Columbia River in the 100-BC OUs, transport pathways, and ecological receptors. The RCBRA (DOE/RL-2007-21) evaluated risks to an array of assessment endpoints using multiple measures of exposure, effect, and ecosystem/receptor characteristics at representative nearshore study sites. The study sites were selected to represent locations that may be adjacent to or directly affected by known contaminated media (groundwater seeps and springs, soil, sediment). The assessment conducted in the RCBRA (DOE/RL-2007-21) has been supplemented through the development of a conceptual model depicting the relationships between sources in the 100-BC OUs and riparian and nearshore media (soil, sediment, pore water, and surface water). This conceptual model is presented as Appendix M.

7.1 Identification of Contaminants of Potential Concern

This section describes the sources of data used in the ERA, the DQA and data validation process, and the identification process for COPCs in soil. CVP and RSVP data collected within waste sites in the 100-BC Source OU were used to identify COPCs. This chapter presents the risk assessment for individual waste sites using CVP/RSVP data. During the course of this ERA, COPCs were examined to identify a refined list of chemicals of potential ecological concern (COPECs) estimated to pose site-related ecological risks to receptor populations.

7.1.1 Data Summary

Remediation of waste sites in the 100-BC Source OUs began in 1996. This risk assessment focused on examining potential residual risk at all sites within the 100-BC Source OUs, including and primarily those that were not included in the RCBRA (DOE/RL-2007-21). Eighty-one waste sites have verification sampling data and analysis data and are included in this risk assessment. Forty-five of these 81 100-BC Source OU waste sites were evaluated in the RCBRA (DOE/RL-2007-21). An additional eight 100-BC Source OU sites, referred to as consolidated waste sites, have been remediated but are included in another waste site's sampling and closeout documentation. Table G-1 in Appendix G summarizes the waste sites, associated decision unit(s)[1]), and reclassification status for the 100-BC OUs. The waste sites listed in Table G-1 are a subset of the waste sites that were listed in Appendix B, Table B-1, of the 100-BC Work Plan (DOE/RL-2008-46-ADD3). A summary of the waste sites, associated decision unit(s), and reclassification status for the 100-BC Source OU was provided in Chapter 6, Table 6-7. CVP data residing in the HEIS database were used in the ERA. All of the closeout verification data used in this ERA are included in Appendix D.

7.1.2 Data Quality Assessment

A data quality assessment (DQA) is performed and reported in each closeout documentation report. The DQA compares the verification sampling approach and resulting analytical data with the sampling and data quality requirements specified by the project objectives and performance specifications. The DQA determines if the data are of the right type, quality, and quantity to support site cleanup verification decisions within specified error tolerances. The DQA also determines if the analytical data are found acceptable for decision making purposes and if the sample design was sufficient for the purpose of clean site verification. The cleanup verification sample analytical data and detailed DQA are

[1] As described in Section 6.2.2.2, the floor and sidewalls of an excavated waste site are divided into one or more decision units (e.g., shallow zone and overburden). A sampling design was developed for each decision unit.

summarized in the appendices associated with the CVPs. The results of each DQA are incorporated by reference and no further DQA was performed as part of this risk assessment.

All of the analytical data are evaluated and a portion is validated for compliance with QA project plan requirements as documented in the 100 Area RDR/RAWP (DOE/RL-96-17). Data evaluation is performed to determine whether the laboratory carried out all steps required by the RCBRA SAP (DOE/RL-2005-42) and the laboratory contract governing the conduct of analysis and reporting of the data. This evaluation also examines the available laboratory data to determine whether an analyte is present or absent in a sample and the degree of overall uncertainty associated with that determination.

7.1.3 Identification of COPCs

All analytes detected at least once in a waste site decision unit for the 81 waste sites in the 100-BC OU, included in the ERA, were identified as COPCs except those exclusions described below. Verification sampling and analysis data are collected according to sample design requirements for the type of decision unit. For this ERA, an "exposure area" and a "decision unit" are operationally defined as being the same. Verification sampling and analysis data are subsequently grouped to calculate EPCs.

The contribution from naturally occurring metals and anthropogenic radioisotopes is discussed in the risk characterization section in accordance with *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (EPA 540-R-01-003). The risk characterization discusses both elevated background concentrations and their contribution to site risks and naturally occurring elements that are not CERCLA hazardous substances, pollutants, and contaminants, but which exceed the risk-based screening levels.

The RCBRA Volume I (DOE/RL-2007-21) identifies a subset of analytes that are excluded from consideration as COPCs by agreement among the Tri-Parties based on relevant Hanford Site data. A total of 54 analytes for the 100-BC Source OUs meet the exclusion criteria and are listed in Table G-3 (Appendix G). The following exclusion lists employed in the RCBRA were also applied to the waste site verification data during the data reduction steps described in Section 6.2.2.2:

- **Radionuclides with a half-life of less than 3 years:** Radionuclides with half-lives less than 3 years would not be present as a result of historical Hanford Site operations because radioactive decay would have occurred since operations ceased.
- **Essential nutrients:** Essential nutrients that are present at relatively low concentrations and are toxic only at high concentrations were not considered in the quantitative risk assessment.
- **Water quality or soil physical property measurements:** These analytes were measured only to obtain information on water quality or soil properties to understand potential confounding factors for bioassays conducted for soil, sediment, or water or to interpret their influence on the toxicity of COPCs (e.g., grain size for soils, water hardness for metal effects).
- **Background radionuclides (potassium-40, radium-226, radium-228, thorium-228, thorium-230, and thorium-232):** As identified and implemented in the RCBRA, these background radionuclides were identified by consensus of Tri-Party managers as not directly related to Hanford operations or processes.

A list of the analytes that meet the exclusion criteria for the soil risk assessment is described in Section 6.2.2.2 and presented in Appendix G, Table G-3. The RCBRA includes two additional steps to identify COPCs that the soil risk assessment did not apply:

- For analytes that are commonly reported in waste site cleanup verification reports based on frequency of detection, inclusion list analytes were not consistently reported in the CVP and RSVP data; therefore, this step was not implemented.

- Evaluate remaining analytes as candidate COPCs, based on comparisons to Hanford Site background, reference areas, and an "analyte-specific" assessment.

As a result of not applying the last two steps used in the RCBRA to identify COPCs, more analytes are identified as COPCs in this ERA than were identified in the RCBRA. Identifying all detected analytes (except those on the exclusion list) as COPCs is a more streamlined approach that is consistent with *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (EPA 540-R-01-003).

In addition to the steps described above, aluminum and iron were excluded as COPCs for all decision units within the 100-BC OUs. The ecological soil screening levels (EcoSSLs) for aluminum and iron are based on soil pH (*Ecological Soil Screening Level for Aluminum: Interim Final* [OSWER Directive 9285.7-60]), and the potential for toxicity is only identified in soils when the pH is 5.5 or less. Although some concentrations of aluminum and iron may have exceeded a risk-based value, all measurements of soil pH in the River Corridor are greater than the 5.5 threshold for iron and aluminum. Data collected during the RCBRA (RCBRA [DOE/RL-2007-21]) indicated that pH in soils range between 7 and 9. Thus, aluminum and iron concentrations are not bioavailable and do not pose a risk to terrestrial ecological receptors.
The COPC list for these Source OUs will be evaluated to develop a COPEC list in this risk assessment. A COPEC is defined as a COPC with concentrations exceeding both the background concentration and ecological screening level. The process for identifying COPECs is discussed in Section 7.4.

7.2 Problem Formulation

The problem formulation includes the physical layout of the site, its history and ecology, and the development of a conceptual ecological site model (ecological CSM) that evaluates potential exposure pathways and identifies the representative species that were used to assess ecological risk to those and other similar species. The problem formulation includes identification of the important aspects of the 100-BC Source OU waste site decision units to be protected (referred to as "assessment endpoints") and the means by which the assessment endpoints are evaluated (measures of exposure and effects).

7.2.1 Site Setting

The 100-BC Source OU is situated between the IU2/IU6 and the 100-BC Area, and covers an area of approximately 11.54 km^2 (4.45 mi^2). The Columbia River section along the 100-BC Source OU defines a portion of the Hanford Reach, an important ecological, cultural, historical, and recreational feature. The upland environment is described in this section, and the riparian and nearshore habitats are described in Appendix M, which focuses on evaluating the potential for exposures in the riparian and nearshore environments to be of concern and to have originated from Hanford Site operations (i.e., from waste sites in the 100-BC OUs).

The predominant plant community in the 100 Areas is sagebrush/Sandberg's bluegrass/cheatgrass. Currently, no plant species on the Hanford Site are federally listed as threatened or endangered under the *Endangered Species Act of 1973*. Plant species listed as threatened or endangered by Washington State include the awned halfchaff sedge (*Lipocarpha aristulata*), grand redstem (*Ammannia robusta*), lowland toothcup (*Rotala ramosior*), and persistentsepal yellowcress (*Rorippa columbiae*). All of these plant species are restricted to wetlands in the riparian zone of the Columbia River (NEPA Characterization Report [PNNL-6415]). Table 3-18 presents the complete list of state-listed flora.

Shrub and grassland habitats dominate the Hanford Site and support a diverse and abundant variety of wildlife species, including in the uplands of the River Corridor. The 100 areas are mostly undisturbed or fully recovered and thus support these diverse and abundant wildlife communities, while wildlife use of the remaining disturbed and developed areas is expected to be reduced because these areas are less attractive and provide less of the needs of wildlife than do natural habitats. Common species include large animals like Rocky Mountain elk (*Cervus elaphus*) and mule deer (*Odocoileus hemionus*); predators such as coyote (*Canis latrans*), bobcat (*Lynx rufus*), and badger (*Taxidea taxus*); and herbivores including deer mice (*Peromyscus maniculatus*), harvest mice (*Riethrodontonomys megalotis*), ground squirrels (*Spermophilus* spp.), voles (*Lemmiscus curtatus, Microtus* spp.), and black-tailed jackrabbits (*Lepus californicus*). The most abundant mammal on the Hanford Site is the Great Basin pocket mouse (*Perognathus parvus*). Other nonburrowing animals including cottontails (*Sylvilagus nutalli*), jackrabbits, snakes, and burrowing owls (*Athene cunicularia*) may use abandoned burrows of other animals.

There are no species that regularly frequent the Hanford Site that are listed currently as threatened or endangered under the *Endangered Species Act of 1973*. Species listed as threatened or endangered by Washington State include the burrowing owl (*Athene cunicularia*), Merriam's shrew (*Sorex merriami*), and Washington ground squirrel (*Urocitellus washingtoni*). However, no species are known or expected to occur onsite because of the highly developed nature of this area. Table 3-19 presents the complete list of state-listed fauna.

Although the bald eagle has been removed from the list of federally endangered species, it is still protected under the *Bald and Golden Eagle Protection Act of 1940*. In addition, DOE has decided to continue to protect nest and roost sites on the Hanford Site under the Bald Eagle Management Plan (DOE/RL-94-150). This plan is currently under revision to account for the de-listing of the bald eagle. Changes have been made to reduce the buffer zones surrounding winter night roosts and nest sites from 800 to 400 m (2,625 to 1,312 ft).

Bald eagles have generally been observed at the Hanford Site from November to March (Fitzner and Hanson, 1979). During daylight hours, bald eagles perch along the Hanford Reach of the Columbia River and a few kilometers inland (Bald Eagle Management Plan [DOE/RL-94-150]). The primary perching areas occur in trees from the Hanford Townsite to the Vernita Bridge. Bald eagles predominantly forage on the banks of the river and the island where waterfowl roost and salmon carcasses can be found. Two roosting sites are located in this same area (Bald Eagle Management Plan [DOE/RL-94-150]). These areas along the Columbia River are primarily located between 100-D and 100-H, not near the 100-BC Area. The 100-B/C Source OUs are outside of the nesting buffer zones and important foraging areas. Additional consideration of these species is not required for this risk assessment. Additional Site setting discussion is located in Section 3.9 and Site history is described in Section 1.2.

7.2.2 Simplified Ecological Exposure Model

Development of the ecological CSM for this ERA involved characterizing the exposure pathways and ecological receptors that might be associated with the habitat types in the upland environment of the waste sites within the 100-BC Source OUs. Appropriate exposure pathways and representative endpoint species for the upland environment of the 100-BC Source OU were developed based on information from the RCBRA (DOE/RL-2007-21) and are discussed below. As mentioned earlier, full risk evaluations of the riparian area or the islands within the Columbia River are not presented because they were already completed for the RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2010-117); however, the same models and receptors were employed here as in those documents. The aquatic exposure models are described in Appendix M.2.5 with the evaluation of the aquatic exposure pathways. Results of those exposure and effects assessments (i.e., the risk characterization) are discussed in Chapter 4 and Appendix

M as well as Section 7.6 of this chapter with respect to the potential for 100-BC Source OUs to contribute to the final identified risks.

With consideration of the ecological setting, land use, and COPC release mechanisms and transport pathways known at the 100-BC Source OU upland environments, the ecological exposure pathways considered most plausible are graphically displayed on Figure 7-1 and included the following:

- Direct contact of vegetation with analytes in surface soil.
- Direct contact with, or ingestion of, surface soil by terrestrial invertebrates (e.g., beetles and ants).
- Direct contact with, or ingestion of, surface soil by terrestrial avian and mammalian wildlife.
- Dietary exposure of terrestrial and mammalian wildlife to COPCs bioaccumulated in food items (e.g., plants or prey).
- Dietary exposure to emissions from radionuclides bioaccumulated and retained within the tissues of plants, terrestrial invertebrates, and terrestrial wildlife.
- External exposure of plants, terrestrial invertebrates, and terrestrial wildlife to emissions from radionuclides in soil.
- Ecological receptors are not likely to have complete exposure pathways to soils below the biologically active zone. Therefore, deep soils were not evaluated in this ERA.

A food web model for the upland environment of the Hanford Site (Figure 7-2) has been developed based on an understanding of the ecology of the area and documented in the previous ERAs.

The following entities (represented by trophic guilds) and their associated organizational level have been identified for evaluation:

- Terrestrial plants—community level
- Terrestrial invertebrates—community level
- Soil microorganisms and microbial processes—community level
- Herbivorous birds—population level
- Herbivorous mammals—population level
- Insectivorous birds—population level
- Insectivorous mammals—population level
- Omnivorous birds—population level
- Omnivorous mammals—population level

- Carnivorous birds—population level
- Carnivorous mammals—population level
- Reptiles and amphibians[2]

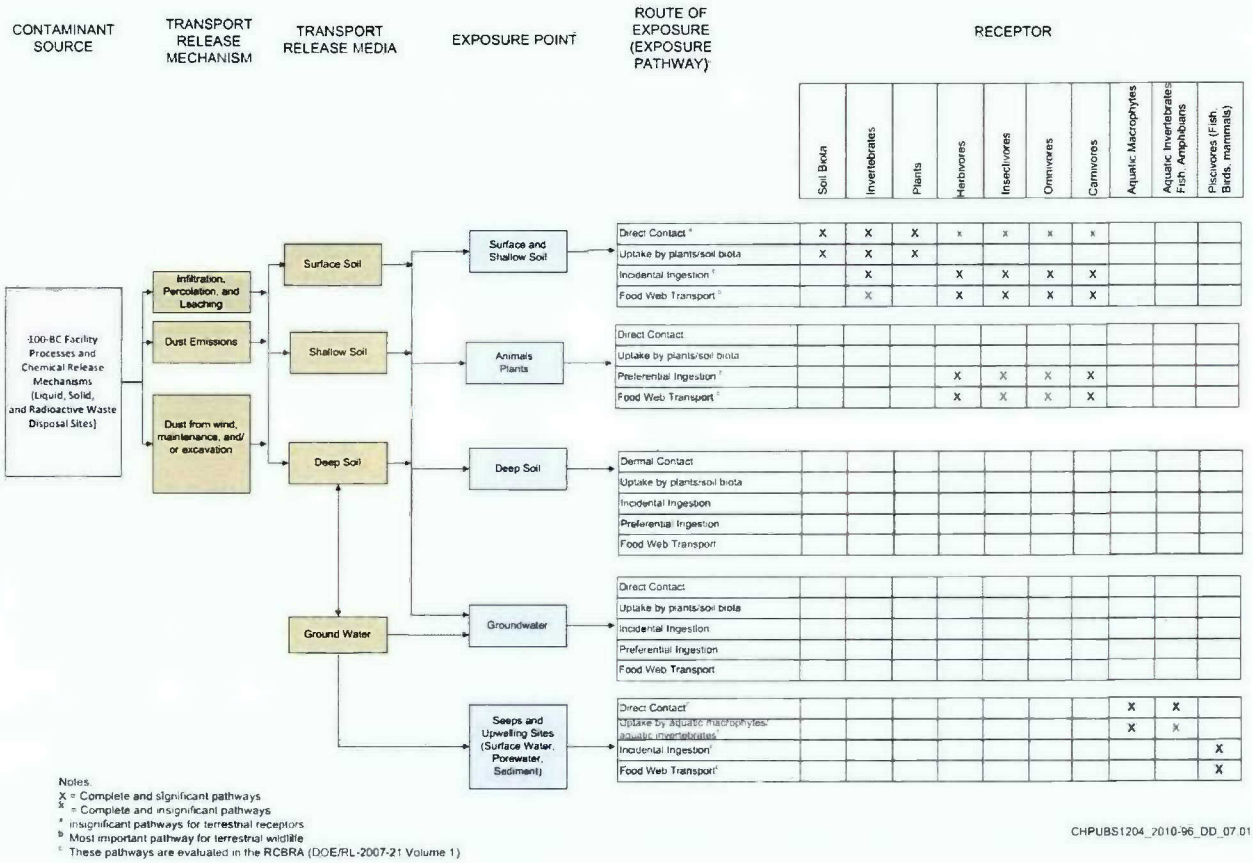

Figure 7-1. Conceptual Ecological Site Model for Terrestrial Habitats in Hanford Site Upland Environment

[2] Although part of the food web for the upland environment, effects data for reptiles and amphibians are limited. Therefore, SSLs were not developed for this trophic guild.

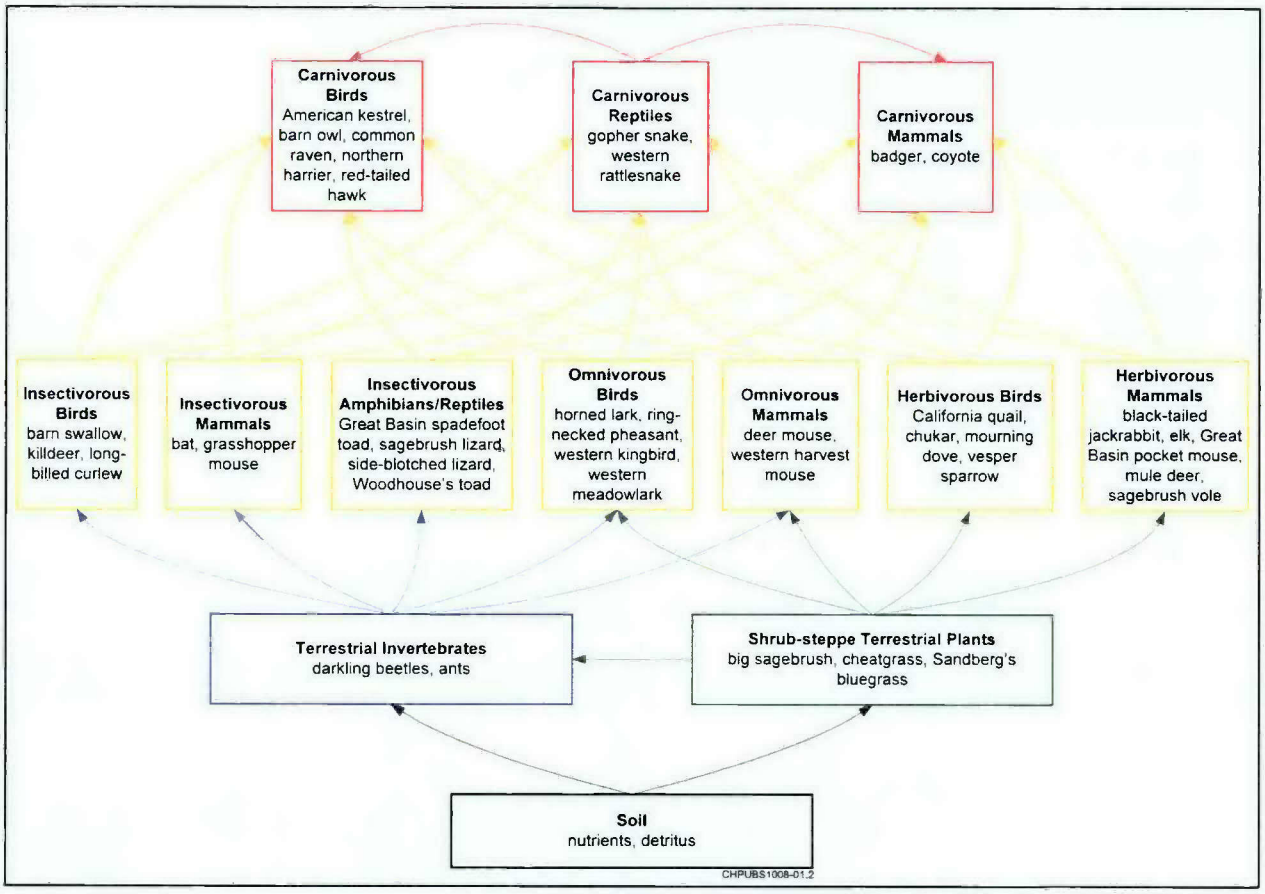

Figure 7-2. Hanford Site Upland Environment Terrestrial Food Web

Some endpoint entities are evaluated at the population level and others at the community level. As reported in *Summary Report: Risk Assessment Forum Technical Workshop on Population-Level Ecological Risk Assessment* (EPA/100/R-09/006), "Define ecological risk assessment..... as estimating the likelihood or probability of adverse effects (e.g. mortality to single species of organisms, reduction in populations of nontarget organisms due to acute, chronic, a reproductive effects, or disruption in community and ecosystem level functions." The EPA has developed guidance that can aid in distinguishing the assessment level including *Framework for Ecological Risk Assessment* (EPA/630/R-92/001), *Ecological Significance and Selection of Candidate Assessment Endpoints* (EPA/540/F-95/037), and *Generic Ecological Assessment Endpoints (GEAEs) for Ecological Risk Assessment* (EPA/630/P-02/004F). These guidelines intentionally do not specify a target level of organization to protect for an entity, allowing flexibility in setting the target organizational level that works for the individual project. The organizational levels described above align with the management goals originally defined in *DQO Summary Report for the 100 Area and 300 Area Component of the RCBRA* (BHI-01757), which focuses on the protection of individuals for special-status species, preventing adverse effects on Hanford biota from contaminants, protecting rare habitats, and minimizing contaminant loading into biota. With the ecosystem present at the Hanford Site, maintaining the health of wildlife populations and the function of a plant community are appropriate as opposed to focusing on populations of particular plant species within that community.

As noted in Appendix A to *Generic Ecological Assessment Endpoints (GEAEs) for Ecological Risk Assessment* (EPA/630/P-02/004F), EPA's principles for ecological risk assessment and risk management at Superfund sites state that "Superfund's goal is to reduce ecological risks to levels that will result in the recovery and maintenance of healthy local populations and communities of biota." Should a special-status species of plant (such as an endangered species of native grass or forb) be present at a given waste site at the Hanford Site, then protecting that population would be acceptable. However, the measurement endpoints described in the next section to align with these entities described above were selected appropriately to protect populations and communities. Although the endpoints identified may be expressed as single species toxicity tests, as these guidance documents express, interpretation of the results relative to lowest adverse effect concentration (LOEC) or lowest observed adverse effect level (LOAEL) endpoints for the protection of populations and communities is appropriate. Section III of *Issuance of Final Guidance: Ecological Risk Assessment and Risk Management Principles for Superfund Sites* (OSWER Directive 9285.7-28 P) states: "Levels that are expected to protect local populations and communities can be estimated by extrapolating from effects on individuals and groups of individuals using a lines-of-evidence approach. The performance of multi-year field studies at Superfund sites to try to quantify or predict long-term changes in local populations is not necessary for appropriate risk management decisions to be made. Data from discrete field and laboratory studies, if properly planned and appropriately interpreted can be used to estimate local population or community-level effects." *Issuance of Final Guidance: Ecological Risk Assessment and Risk Management Principles for Superfund Sites* (OSWER Directive 9285.7-28 P) further states that "Superfund ERAs gather effects data on individuals in order to predict or postulate potential effects on local wildlife, fish, invertebrates, and plant populations and communities that occur in specific habitats at sites." Finally, as noted in *Overview of the Ecological Risk Assessment Process in the Office of Pesticide Programs, U.S. Environmental Protection Agency—Endangered and Threatened Species Effects Determinations* (EPA, 2004): "If effects on the survival and reproduction of individuals are limited, it is assumed that risks at the population level from such effects will be of minor consequence."

To calculate ecological SSLs, endpoint representative species were selected for each entity identified above (trophic guilds/functional groups) that could use the site. For example, a red-tailed hawk may be considered representative of raptors visiting the site. Consistent with ERAGS (EPA 540-R-97-006); *Guidelines for Ecological Risk Assessment* (EPA/630/R-95/002F); and MTCA, "Site-Specific Terrestrial Ecological Evaluation Procedures" (WAC 173-340-7493), endpoint species should preferably be ones that have ecological relevance, are of societal value, are susceptible to chemical stressors at the site, or allow risk managers to meet policy goals. These factors were used to select representative receptor species common to the Hanford Site upland environment that are within the trophic guilds identified above. Selected receptors are conservative indicators of the potential for risk to the trophic guilds identified for assessment. The representative receptor species selected for each of the trophic guilds are as follows:

- Herbivorous birds—California quail (*Callipepla californica*)
- Herbivorous mammals—Great Basin pocket mouse (*Perognathus parvus*)
- Insectivorous birds—killdeer (*Charadrius vociferus*)
- Insectivorous mammals—northern grasshopper mouse (*Onychomys leucogaster*)
- Omnivorous birds—western meadowlark (*Sturnella neglecta*)
- Omnivorous mammals—deer mouse (*Peromyscus maniculatus*)
- Carnivorous birds (raptors)—red-tailed hawk (*Buteo jamaicensis*)
- Carnivorous mammals—badger (*Taxidea taxus*)

Unlike birds and mammals, methods to differentiate exposure and/or effects among different plant species or among different invertebrate species are unavailable. Therefore, individual species for terrestrial vegetation and invertebrates were not selected to represent the plant or invertebrate populations and communities for evaluation.

7.2.3 Assessment Endpoints

Assessment endpoints are an expression of the important ecological values that are to be protected at a site (*Ecological Risk Assessment* [Suter, 1993]; *Guidelines for Ecological Risk Assessment* [EPA/630/R-95/002F]; *Ecological Risk Assessment for Contaminated Sites* [Suter et al., 2000]). Assessment endpoints are based on known information concerning the analytes present, the study area, the ecological CSM, and risk hypotheses. There are three components to each assessment endpoint: an *entity* (e.g., migratory birds), an *attribute* of that entity (e.g., individual survival), and a *measure* (e.g., a measurable value, such as an effect level). Measures are described following the general description of assessment endpoints (*Guidelines for Ecological Risk Assessment* [EPA/630/R-95/002F]; *Ecological Risk Assessment for Contaminated Sites* [Suter et al., 2000]).

The assessment endpoint entities for the 100-BC OU waste sites were selected based on the following principal criteria:

- Ecological relevance
- Societal relevance
- Susceptibility (or high exposure) to known or potential stressors at the Hanford Site

The attribute selected for each entity was based on the organizational level of the entity and the primary criteria that were used to select it. Entities and attributes were selected for community and population levels of assessment. Measures of Exposure and Effects

Measures (formerly referred to as measurement endpoints) are measurable attributes used to evaluate the risk hypotheses and are predictive of effects on the assessment endpoints (*Guidelines for Ecological Risk Assessment* [EPA/630/R-95/002F]). The three categories of measures include the following:

- Measures of exposure are used to evaluate intake of a contaminant from contact with environmental media (e.g., soil). Measures of exposure can be an EPC of a COPC in an environmental medium or food item. A measure of exposure also can be a dose occurring through ingestion, inhalation, or dermal contact with a contaminant in an environmental medium. SSLs were estimated by back-calculating from a target dose associated with the selected assessment endpoint to a corresponding concentration in soil (see Section 7.3.1 for further discussion).

- The measure of exposure represents the exposure appropriate for the assessment endpoint (e.g., a wildlife population) throughout its exposure area (e.g., the entire home range of the target species). Thus, the average exposure to multiple individuals (e.g. the population of wildlife or the plant community) in a species is the basis for population or community level effects.

- Measures of effect are used to evaluate the response of an organism that is exposed to a stressor. Measures of effects included TRVs for wildlife and the LOECs in soil for plants and soil invertebrates (see Section 7.3.1). The maximum acceptable adverse effect levels generally selected for population- and community-level assessment endpoints are lowest LOECs or LOAELs, when available.

- Measures of ecosystem and receptor characteristics are used to evaluate the ecosystem characteristics that influence the assessment endpoints, the distribution of stressors, and the characteristics of the

assessment endpoints that may affect exposure or response to the stressor. Measures of ecosystem and receptor characteristics are used to characterize ecological risks as part of a baseline ERA. These kinds of ecological information were not used directly in calculating SSLs. However, measures of ecosystem and receptor characteristics may represent additional lines of evidence that can be used along with SSLs in evaluating remedial alternatives in the RI/FS.

7.3 Effects and Exposure Assessment

The effects and exposure assessments were conducted and then integrated to develop two levels of thresholds for evaluating the 100-BC Area data. This follows the tiered-process referred to earlier and as described in ERAGS (EPA 540-R-97-006). The initial evaluation versus conservative thresholds (SSLs) helps to focus the assessment down to those COPEC-receptor-waste site combinations that might require further evaluation. The additional assessment completed with a comparison to PRGs helps identify which COPEC-receptor-waste site combinations should be brought forward to the SMDP in Section 7.6.

For wildlife, the effects assessment presents TRVs that have been derived from available literature-based toxicity information on COPCs and that can be used in determining the potential for adverse effects to ecological receptors. Two types of effects-based values are presented in this ERA: initial conservative values from the published literature (e.g., Ecology, EPA, and DOE guidance or compendiums), and the more Hanford Site-specific values (values established using data collected at the Hanford Site). These values are then used within food chain exposure dose models from the exposure assessment to establish media benchmarks (thresholds). For plants and invertebrates, the effects data are incorporated more simply because the effects are measured relative to direct exposure. Thus, the concentration associated with an observed effect in the exposure medium (soil, water, sediment) becomes the benchmark (threshold).

The exposure assessment identifies exposure pathways associated with the representative receptor species listed in Section 7.2.2. As with the effects values, the exposure assessment employs two types of exposure evaluations: the avian and mammalian SSLs, and the more site-specific avian and mammalian PRGs. It also describes the models used to calculate SSLs and PRGs.

The TRVs were combined with the exposure information to calculate SSLs and PRGs. This section presents the salient features of the effects and exposure assessments as they were used to calculate the SSLs and PRGs. An overview of the development of the nonradionuclide and radionuclide SSLs and PRGs is described in the exposure assessment for each receptor group (i.e., plants, soil invertebrates, and wildlife). The methodology used to develop the SSLs is detailed in *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-00784). The methodology used to develop the PRGs for wildlife is detailed in *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311). The methodology used to develop the Hanford Site-specific risk thresholds and to select PRGs for plants and invertebrates is detailed in *Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site* (ECF-HANFORD-11-0158). These documents are presented in Appendix H of the 100-K RI/FS.

The effects and exposure assessment is organized as follows:

- Section 7.3.1 presents the effects assessment with separate sections for radionuclides (Section 7.3.1.1) and nonradionuclides (Section 7.3.1.2) because of the method of their derivation. Within each of these, effects for plants and invertebrates are discussed separately from wildlife. For non-radionuclides, plant and invertebrate effects are described relative to direct exposure, whereas

for wildlife, the effects are described relative to the ingested dose. For radionuclides, the effects assessment includes values that correspond to effects from a dose of radiation.

- Section 7.3.2 presents the exposure assessment with separate sections for plants and invertebrates (Section 7.3.2.1) and wildlife (Section 7.3.2.2). Exposure to wildlife is further broken out to describe the food chain models that estimate the concentration in ingested prey and how the assumptions of the model differ in the development of SSLs versus PRGs. Section 7.2.3.3 further describes specific differences in the modeling of wildlife exposure to radionuclides. The SSLs that result from the effects and exposure assessments are presented in these sections.
- Section 7.3.3 provides a description of wildlife exposure through drinking from seeps along the Columbia River.
- Section 7.3.4 describes and presents the PRGs that result from the effects and exposure assessment.
- Section 7.3.5 describes how soil and seep data were used to estimate EPCs for comparison with the SSLs and PRGs presented.

7.3.1 Effects Assessment

The ecological effects assessment consists of an evaluation of available toxicity or other effects information that can be used to interpret the significance of the exposures to COPCs relative to potential adverse effects to ecological receptors. Data that can be used include literature-derived or site-specific single chemical toxicity data (wildlife), site-specific ambient media toxicity tests (plants and invertebrates), and site-specific field surveys (*Ecological Risk Assessment for Contaminated Sites* [Suter et al., 2000]). The effects data used in this ERA are represented by single-chemical toxicity data from literature sources and are summarized below for radionuclides and nonradionuclides. The effects levels presented are used either directly (for plants and invertebrates) or within exposure dose models (for wildlife) to establish concentrations in exposure media (e.g., soil) that are protective of plant and invertebrate communities and wildlife populations.

7.3.1.1 Effects Assessment for Radionuclides

Radionuclide toxicity data for plants and wildlife are represented by DOE's Biota Concentration Guides (BCGs) for radionuclides presented in *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (hereinafter called Graded Approach for Radiation Doses to Biota [DOE-STD-1153-2002]). Two radionuclide effect thresholds, as determined by consensus of international radiation regulatory agencies, form the basis for effect thresholds used to develop screening levels of radionuclides in soil for the protection of plants and animals. General guidance from the International Council for Radiological Protection (*Recommendations of the International Commission on Radiological Protection* [ICRP-60]), the International Atomic Energy Agency *(Proliferation Resistance Fundamentals for Future Nuclear Energy Systems* [IAEA STR-332], and United Nations Scientific Committee on the Effects of Atomic Radiation *(Sources and Effects of Inonizing Radiation* [UNSCEAR, 2000]), with scientific annexes (Sales Publication No. E.00.IX.4) concluded that radiological doses to terrestrial plants and terrestrial vertebrates should not exceed 1.0 and 0.1 rad/day, respectively. If radiation exposure does not exceed these biota dose levels, the consensus opinion of the international radiological organizations is that ecological populations will be protected. DOE has adopted these effect thresholds and integrated them into Graded Approach for Radiation Doses to Biota (DOE-STD-1153-2002).

Graded Approach for Radiation Doses to Biota (DOE-STD-1153-2002) includes a screening method and three more detailed levels of analysis for demonstrating compliance with applicable dose limits for protection of biota:

- A general screening that involves comparing maximum radionuclide concentrations in environmental media (i.e., soil) with a set of BCGs to evaluate compliance with the biota dose limits.
- Site-specific screening using more realistic site representative lumped parameters (e.g., bioaccumulation factors [BAFs]) in place of conservative default parameters, using mean radionuclide concentrations in place of maximum values, and taking into account time dependence and spatial extent of contamination.
- Site-specific analysis employing a kinetic-allometric modeling methodology. Multiple parameters, which represent contribution to an organism's internal dose, can be modified to represent site- and organism-specific characteristics. These parameters include body mass, consumption rates of food or soil, inhalation rate, lifespan, and biological elimination rates. Development of the organism-specific characteristics involves using allometric equations that relate these parameters to body mass.
- Site-specific biota dose assessment involving the collection and analysis of biota samples.

BCGs can be calculated using dose models, equations, and default parameters that are presented in Graded Approach for Radiation Doses to Biota (DOE-STD-1153-2002). The values in soil calculated using these default methods are found in Table 6.4 in Graded Approach for Radiation Doses to Biota (DOE-STD-1153-2002). These dose models, equations, and default parameters are also incorporated into the RESRAD-BIOTA for Windows, Version 1.5 (ANL, 2009b) model (*RESRAD-BIOTA: A Tool for Implementing a Graded Approach to Biota Dose Evaluation, User's Guide, Version 1* [DOE/EH-0676]) to establish values protective of wildlife populations and plant communities. *Effects of Ionizing Radiation on Terrestrial Plants and Animals: A Workshop Report* (ORNL/TM-13141) also discusses populations of wildlife and communities of plants as the basis for the BCGs. RESRAD-BIOTA presents three levels of analysis, which correspond to the following levels in the graded approach:

- Level 1—general screening approach
- Level 2—site-specific screening with representative parameters
- Level 3—site-specific analysis using the kinetic/allometric modeling methodology

The BCGs for plants for this ERA were calculated using the Level 1 analysis in RESRAD-BIOTA and are shown in Table 7-1.

For wildlife (animals), more site-specific SSLs were developed using RESRAD-Biota Version 1.5 with Level 3 assumptions. Values were established for eight different species representing feeding guilds found at the Site. However, Hanford Site-specific tissue residue of radionuclides was insufficient for developing models, so values from relevant published literature were employed ("Derivation of Transfer Parameters for Use Within the ERICA Tool and the Default Concentration Ratios for Terrestrial Biota" [Beresford et al., 2008]). Final radionuclide SSLs for wildlife are shown in Table 7-2.

Because the dose from radionuclides is additive ("Principles and Issues in Radiological Ecological Risk Assessment" [Jones et al., 2003]), the total contribution of radionuclides known to be associated with Hanford Site processes was also calculated. A total radionuclide exposure estimate was calculated using the SOF method. With the SOF method, the contributions of various radionuclides were reviewed to determine their contribution to dose. Contributions were considered significant if the radionuclide EPC was greater than the SSL and was detected frequently.

7.3.1.2 Effects Assessment for Nonradionuclides

Effects data for the nonradionuclide COPCs are presented below for plants and invertebrates and for wildlife. Included is a description of the sources of the information employed and an explanation of the selection of effects data. The overarching theme was to employ the most recent of relevant toxicological information available as described within ERAGS (EPA 540-R-97-006) and MTCA, "Site-Specific Terrestrial Ecological Evaluation Procedures" (WAC 173-340-7493).

Plants and Invertebrates. Single-chemical, screening-level toxicity values for terrestrial plants and soil invertebrates were available from the following sources:

- EPA's Ecological Soil Screening Levels (http://www.epa.gov/ecotox/ecossl/).
- Screening benchmark concentrations in soil developed by the Oak Ridge National Laboratory (ORNL); many of the Ecological Indicator Soil Concentrations published by Ecology (see below) were drawn from ORNL screening benchmark concentrations.
- Ecology's Ecological Indicator Soil Concentrations, found in MTCA, "Site-Specific Terrestrial Ecological Evaluation Procedures" (WAC 173-340-7493(2)(a)(i)), Table 749-3.

The lowest available plant or invertebrate value from these sources was selected as the SSL for each analyte because they represent direct exposure of the receptors to the media. These SSLs are presented in Table 7-1. A brief discussion of each source is provided below.

EPA's EcoSSLs for plants and soil invertebrates were derived using data from tests performed within soil conditions favoring relatively high bioavailability for upland soils. The soil chemistry conditions of relatively high bioavailability were defined by organic matter content and by low soil pH. From the studies reviewed, the measure of toxic effects to either plants or soil invertebrates were grouped into one of four ecologically relevant endpoints: reproduction, population characteristics, growth, or physiological changes. Toxicity parameters used in deriving the Eco-SSLs were the EC20 (effective concentration affecting 20 percent of a test population), the maximum acceptable toxicant concentration (MATC), and the EC10 (effect concentration affecting 10 percent of a test population). The MATC was calculated by EPA from studies that reported a no-observed-adverse-effects concentration (NOAEC) and a lowest observed adverse effects concentration (LOAEC). The MATC was calculated as the geometric mean of the LOAEC and NOAEC. Studies that reported only a LOAEC or only a NOAEC were not considered to provide a reliable assessment of the dose response, and were not used for EcoSSL development.
The EcoSSL for plants and soil invertebrates was calculated as the geometric mean of all the toxicity parameters from studies conducted under conditions of high bioavailability. Note that use of the EC20, MATC, and EC10 as toxicity parameters means that EcoSSLs for plants and soil invertebrates are not based on NOAECs; thus, the recommended value is at a level where effects have been observed but to a percent of individuals considered acceptable within the ecological risk assessment practice as demonstrated by its use within the EcoSSL approach documents (*Guidance for Developing Ecological Soil Screening Levels* [OSWER Directive 9285.7-55]).
The ORNL benchmarks for the toxicity to plants from chemical analytes in soil were based on thresholds for effects on growth and reproduction derived from published toxicity studies conducted in soil or solution. The benchmarks are concentrations of chemicals that correspond to the LOEC for the 10th percentile of plant species tested. The ORNL benchmarks for toxicity to soil invertebrates and heterotrophic processes from analytes in soil represent thresholds (LOECs) for statistically significant effects on growth, reproduction, or activity. The toxicity benchmarks were derived by rank ordering the LOEC values and then selecting a value that approximated the 10th percentile.

Table 7-1. SSLs in Upland Soil for Plants and Soil Invertebrates

Group	Soil Constituent	Units	EPA EcoSSLs			ORNL - ES/ER/TM-85/R3, ES/ER/TM-126/R2		DOE BCGs		Washington Dept. of Ecology - MTCA (WAC 173-340, Table 749-3)		Lowest Screening Benchmark by Receptor Type			Background Soil Concentrations[a]	SSL for Plants and Soil Invertebrates[b]	Basis
			Plants	Invertebrate	Reference	Plants	Invertebrate	Terrestrial Plant	Terrestrial Animal	Plant	Soil Biota	Plant	Inverts	Overall Lowest Screening Benchmark			
Radionuclides	Americium-241	pCi/g	---	---	---	---	---	21500	3890	---	---	21500	---	21500	---	21500	Benchmark
	Antimony-125	pCi/g	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Carbon-14	pCi/g	---	---	---	---	---	60700	4760	---	---	60700	---	60700	---	60700	Benchmark
	Cesium-134	pCi/g	---	---	---	---	---	1090	11.3	---	---	1090	---	1090	---	1090	Benchmark
	Cesium 137	pCi/g	---	---	---	---	---	2210	20.8	---	---	2210	---	2210	1.05	2210	Benchmark
	Cobalt-60	pCi/g	---	---	---	---	---	6130	692	---	---	6130	---	6130	0.00842	6130	Benchmark
	Curium-244	pCi/g	---	---	---	---	---	153000	4060	---	---	153000	---	153000	---	153000	Benchmark
	Europium-152	pCi/g	---	---	---	---	---	14700	1520	---	---	14700	---	14700	---	14700	Benchmark
	Europium-154	pCi/g	---	---	---	---	---	12500	1290	---	---	12500	---	12500	0.0334	12500	Benchmark
	Europium-155	pCi/g	---	---	---	---	---	153000	15800	---	---	153000	---	153000	0.0539	153000	Benchmark
	Hydrogen-3 (tritium)	pCi/g	---	---	---	---	---	1680000	174000	---	---	1680000	---	1680000	---	1680000	Benchmark
	Neptunium-237	pCi/g	---	---	---	---	---	8150	3860	---	---	8150	---	8150	---	8150	Benchmark
	Nickel-63	pCi/g	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Plutonium-238	pCi/g	---	---	---	---	---	17500	5270	---	---	17500	---	17500	0.00378	17500	Benchmark
	Plutonium-239/240	pCi/g	---	---	---	---	---	12700	6110	---	---	12700	---	12700	0.0248	12700	Benchmark
	Radium-226	pCi/g	---	---	---	---	---	288	50.6	---	---	288	---	288	0.815	288	Benchmark
	Radium-228	pCi/g	---	---	---	---	---	245	43.9	---	---	245	---	245	---	245	Benchmark
	Strontium 90	pCi/g	---	---	---	---	---	3580	22.5	---	---	3580	---	3580	0.178	3580	Benchmark
	Technetium-99	pCi/g	---	---	---	---	---	21900	4490	---	---	21900	---	21900	---	21900	Benchmark
	Thorium-232	pCi/g	---	---	---	---	---	23500	1510	---	---	23500	---	23500	1.32	23500	Benchmark
	Uranium-234	pCi/g	---	---	---	---	---	51600	5130	---	---	51600	---	51600	1.1	51600	Benchmark
	Uranium-235	pCi/g	---	---	---	---	---	27400	2770	---	---	27400	---	27400	0.109	27400	Benchmark
	Uranium-238	pCi/g	---	---	---	---	---	15700	1580	---	---	15700	---	15700	1.06	15700	Benchmark

Table 7-1. SSLs in Upland Soil for Plants and Soil Invertebrates

Group	Soil Constituent	Units	EPA EcoSSLs			ORNL - ES/ER/TM-85/R3, ES/ER/TM-126/R2		DOE BCGs		Washington Dept. of Ecology - MTCA (WAC 173-340, Table 749-3)		Lowest Screening Benchmark by Receptor Type			Background Soil Concentrations[a]	SSL for Plants and Soil Invertebrates[b]	Basis
			Plants	Invertebrate	Reference	Plants	Invertebrate	Terrestrial Plant	Terrestrial Animal	Plant	Soil Biota	Plant	Inverts	Overall Lowest Screening Benchmark			
Metals	Aluminum	mg/kg	Narrative Statement		OSWER Dir. 9285.7-60	50	---	---	---	50	---	50	---	50	11800	11800	Background
	Antimony	mg/kg	---	78	OSWER Dir. 9285.7-61	5	---	---	---	5	---	5	78	5	5.2	5.2	Background
	Arsenic, Total all valence states	mg/kg	18	---	OSWER Dir. 9285.7-62	10	60	---	---	---	---	10	60	10	6.47	10	Benchmark
	Arsenic (III)	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Arsenic (V)	mg/kg	---	---	---	---	---	---	---	10	60	10	60	10	---	10	Benchmark
	Barium	mg/kg	---	330	OSWER Dir. 9285.7-63	500	---	---	---	500	---	500	330	330	132	330	Benchmark
	Beryllium	mg/kg	---	40	OSWER Dir. 9285.7-64	10	---	---	---	10	---	10	40	10	1.51	10	Benchmark
	Bismuth	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Boron	mg/kg	---	---	---	0.5	---	---	---	0.5	---	0.5	---	0.5	---	0.5	Benchmark
	Cadmium	mg/kg	32	140	OSWER Dir. 9285.7-65	4	20	---	---	4	20	4	20	4	0.78	4	Benchmark
	Chromium (total)[c,d]	mg/kg	---	---	OSWER Dir. 9285.7-66	1	0.4	---	---	42	42	1	0.4	0.4	18.5	18.5	Background
	Chromium (+3)	mg/kg	---	---	OSWER Dir. 9285.7-66	1	0.4	---	---	42	42	1	0.4	0.4	---	0.4	Benchmark
	Chromium (+6)	mg/kg	---	---	OSWER Dir. 9285.7-66	---	---	---	---	---	---	---	---	---	---	---	---
	Cobalt	mg/kg	13	---	OSWER Dir. 9285.7-67	20	---	---	---	20	---	13	---	13	15.7	15.7	Background
	Copper	mg/kg	70	80	OSWER Dir. 9285.7-68	100	50	---	---	100	50	70	50	50	22	50	Benchmark
	Lead	mg/kg	120	1700	OSWER Dir. 9285.7-70	50	500	---	---	50	500	50	500	50	10.2	50	Benchmark
	Lithium[d]	mg/kg	---	---	---	2	---	---	---	35	---	2	---	2	33.5	33.5	Background
	Manganese[d]	mg/kg	220	450	OSWER Dir. 9285.7-71	500	---	---	---	1100	---	220	450	220	512	512	Background
	Mercury	mg/kg	---	---	---	0.3	0.1	---	---	0.3	0.1	0.3	0.1	0.1	0.33	0.33	Background
	Molybdenum	mg/kg	---	---	---	2	---	---	---	2	---	2	---	2	6	6	Background
	Nickel	mg/kg	38	280	OSWER Dir. 9285.7-76	30	200	---	---	30	200	30	200	30	19.1	30	Benchmark
	Selenium	mg/kg	0.52	4.1	OSWER Dir. 9285.7-72	1	70	---	---	1	70	0.52	4.1	0.52	0.78	0.78	Background
	Silver	mg/kg	560	---	OSWER Dir. 9285.7-77	2	---	---	---	2	---	2	---	2	0.73	2	Benchmark
	Strontium	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Table 7-1. SSLs in Upland Soil for Plants and Soil Invertebrates

Group	Soil Constituent	Units	EPA EcoSSLs			ORNL - ES/ER/TM-85/R3, ES/ER/TM-126/R2		DOE BCGs		Washington Dept. of Ecology - MTCA (WAC 173-340, Table 749-3)		Lowest Screening Benchmark by Receptor Type			Background Soil Concentrations[a]	SSL for Plants and Soil Invertebrates[b]	Basis
			Plants	Invertebrate	Reference	Plants	Invertebrate	Terrestrial Plant	Terrestrial Animal	Plant	Soil Biota	Plant	Inverts	Overall Lowest Screening Benchmark			
	Thallium	mg/kg	---	---	---	1	---	---	---	1	---	1	---	1		1	Benchmark
	Tin	mg/kg	---	---	---	50	---	---	---	50	---	50	---	50	---	50	Benchmark
	Uranium	mg/kg	---	---	---	5	---	---	---	5	---	5	---	5	3.21	5	Benchmark
	Vanadium	mg/kg	---	---	OSWER Dir. 9285.7-75	2	---	---	---	2	---	2	---	2	85.1	85.1	Background
	Zinc[d]	mg/kg	160	120	OSWER Dir. 9285.7-73	50	200	---	---	86	200	50	120	50	67.8	67.8	Background
General Inorganics	Ammonia/Ammonium	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	9.23	9.23	Background
	Chloride	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	100	100	Background
	Cyanide	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Fluoride	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	2.81	2.81	Background
	Iodine	mg/kg	---	---	---	4	---	---	---	4	---	4	---	4	---	4	Benchmark
	Nitrate/Nitrite	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	52	52	Background
	Phosphate	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	0.785	0.785	Background
	Sulfate/Sulfite	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	237	237	Background
	Total Organic Carbon	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Volatile Organics	1,1-dichloroethane	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	1,1-dichloroethene	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	1,1,1-trichloroethane	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	1,1,2-trichloroethane	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	1,1,2,2-tetrachloroethane	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	1,2-dichlorobenzene	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	1,2-dichloroethane (DCA)	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	1,3-dichlorobenzene	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	2-butanone (Methyl Ethyl Ketone/MEK)	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	2-hexanone	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Benzene	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Table 7-1. SSLs in Upland Soil for Plants and Soil Invertebrates

Group	Soil Constituent	Units	EPA EcoSSLs			ORNL - ES/ER/TM-85/R3, ES/ER/TM-126/R2		DOE BCGs		Washington Dept. of Ecology - MTCA (WAC 173-340, Table 749-3)		Lowest Screening Benchmark by Receptor Type			Background Soil Concentrations[a]	SSL for Plants and Soil Invertebrates[b]	Basis
			Plants	Invertebrate	Reference	Plants	Invertebrate	Terrestrial Plant	Terrestrial Animal	Plant	Soil Biota	Plant	Inverts	Overall Lowest Screening Benchmark			
	Butanol	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Carbon Tetrachloride	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Chlorobenzene	mg/kg	---	---	---	---	40	---	---	---	40	---	40	40	---	40	Benchmark
	Chloroform	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Cis-1,2-dichloroethylene	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Dichloromethane (Methylene Chloride)	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Ethyl Benzene	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Methyl Isobutyl Ketone	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	n-butyl Benzene	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Tetrachloroethylene	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Toluene	mg/kg	---	---	---	200	---	---	---	200	---	200	---	200	---	200	Benchmark
	Trans-1,2-dichloroethylene	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Trichloroethylene (TCE)	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Xylene	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Polycyclic Aromatic Hydrocarbons	Acenaphthene	mg/kg	---	29	OSWER Dir. 9285.7-75	20	---	---	---	20	---	20	29	20	---	20	Benchmark
	Acenaphthylene	mg/kg	---	29	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	29	29	---	29	Benchmark
	Anthracene	mg/kg	---	29	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	29	29	---	29	Benchmark
	Benzo(a)pyrene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	18	18	---	18	Benchmark
	Benzo(a)anthracene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	18	18	---	18	Benchmark
	Benzo(b)fluoranthene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	18	18	---	18	Benchmark
	Benzo(ghi)perylene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	18	18	---	18	Benchmark
	Benzo[k]fluoranthene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	18	18	---	18	Benchmark
	Chrysene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	18	18	---	18	Benchmark
	Dibenz(ah)anthracene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	18	18	---	18	Benchmark
	Fluoranthene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	18	18	---	18	Benchmark
	Fluorene	mg/kg	---	29	OSWER Dir. 9285.7-75	---	30	---	---	---	30	---	29	29	---	29	Benchmark
	Indeno[1,2,3-cd]pyrene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	18	18	---	18	Benchmark
	2-Methylnaphthalene	mg/kg	---	29	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	29	29	---	29	Benchmark
	Naphthalene	mg/kg	---	29	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	29	29	---	29	Benchmark
	Phenanthrene	mg/kg	---	29	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	29	29	---	29	Benchmark

Table 7-1. SSLs in Upland Soil for Plants and Soil Invertebrates

Group	Soil Constituent	Units	EPA EcoSSLs			ORNL - ES/ER/TM-85/R3, ES/ER/TM-126/R2		DOE BCGs		Washington Dept. of Ecology - MTCA (WAC 173-340, Table 749-3)		Lowest Screening Benchmark by Receptor Type			Background Soil Concentrations[a]	SSL for Plants and Soil Invertebrates[b]	Basis
			Plants	Invertebrate	Reference	Plants	Invertebrate	Terrestrial Plant	Terrestrial Animal	Plant	Soil Biota	Plant	Inverts	Overall Lowest Screening Benchmark			
	Pyrene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	18	18	---	18	Benchmark
	Total PAHs	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Low MW PAHs[e]	mg/kg	---	29	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	29	29	---	29	Benchmark
	High MW PAHs[f]	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	18	18	---	18	Benchmark
Petroleum	Gasoline Range Organics	mg/kg	---	---	---	---	---	---	---	---	100	---	100	100	---	100	Benchmark
	TPH - diesel	mg/kg	---	---	---	---	---	---	---	---	200	---	200	200	---	200	Benchmark
	TPH - kerosene	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Semivolatile Organics	Normal paraffin hydrocarbons	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Phenol	mg/kg	---	---	---	70	30	---	---	70	30	70	30	30	---	30	Benchmark
	2-methylphenol (ocresol)	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	4-methylphenol (pcresol)	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	2,4-dinitrotoluene	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Bis[2-ethylhexyl] phthalate[g]	mg/kg	---	---	---	100	---	---	---	100	---	100	---	100	---	100	Benchmark
	Polychlorinated Biphenyls (PCB)[h,i]	mg/kg	---	---	---	40	---	---	---	40	---	40	---	40	---	40	Benchmark
	Aroclor 1016[h,i]	mg/kg	---	---	---	40	---	---	---	40	---	40	---	40	---	40	Benchmark
	Aroclor 1221[h,i]	mg/kg	---	---	---	40	---	---	---	40	---	40	---	40	---	40	Benchmark
	Aroclor 1232[h,i]	mg/kg	---	---	---	40	---	---	---	40	---	40	---	40	---	40	Benchmark
	Aroclor 1242[h,i]	mg/kg	---	---	---	40	---	---	---	40	---	40	---	40	---	40	Benchmark
	Aroclor 1248[h,i]	mg/kg	---	---	---	40	---	---	---	40	---	40	---	40	---	40	Benchmark
	Aroclor 1254[h,i]	mg/kg	---	---	---	40	---	---	---	40	---	40	---	40	---	40	Benchmark
	Aroclor-1260[h,i]	mg/kg	---	---	---	40	---	---	---	40	---	40	---	40	---	40	Benchmark
	Aroclor-1262[h,i,j]	mg/kg	---	---	---	40	---	---	---	40	---	40	---	40	---	40	Benchmark
Herbicide	Dichloroprop	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Pesticide	Aldrin	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	beta-1,2,3,4,5,6-Hexachlorocyclohexane[k,l]	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	alpha-Chlordane[m]	mg/kg	---	---	---	---	---	---	---	---	1	---	1	1	---	1	Benchmark
	gamma-Chlordane[m]	mg/kg	---	---	---	---	---	---	---	---	1	---	1	1	---	1	Benchmark
	Dichlorodiphenyldichloroethylene[n,o]	mg/kg	---	---	OSWER Dir. 9285.7-57	---	---	---	---	---	---	---	---	---	---	---	---
	Dichlorodiphenyltrichloroethane[o]	mg/kg	---	---	OSWER Dir. 9285.7-57	---	---	---	---	---	---	---	---	---	---	---	---
	Dieldrin	mg/kg	---	---	OSWER Dir. 9285.7-56	---	---	---	---	---	---	---	---	---	---	---	---

Table 7-1. SSLs in Upland Soil for Plants and Soil Invertebrates

Group	Soil Constituent	Units	EPA EcoSSLs			ORNL - ES/ER/TM-85/R3, ES/ER/TM-126/R2		DOE BCGs		Washington Dept. of Ecology - MTCA (WAC 173-340, Table 749-3)		Lowest Screening Benchmark by Receptor Type			Background Soil Concentrations[a]	SSL for Plants and Soil Invertebrates[b]	Basis
			Plants	Invertebrate	Reference	Plants	Invertebrate	Terrestrial Plant	Terrestrial Animal	Plant	Soil Biota	Plant	Inverts	Overall Lowest Screening Benchmark			
	Endosulfan I	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Endosulfan II	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Endosulfan sulfate	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Endrin aldehyde[p]	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Methoxychlor	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Note: Complete citations of OSWER Directives are provided in Chapter 11.

Sources: *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision* (ES/ER/TM-85/R3), .

Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision (ES/ER/TM-126/R2)

MTCA (WAC 173-340, "Model Toxics Control Act—Cleanup").

a. Background soil concentrations are selected according to the following hierarchy: the 90th percentile of Hanford Site background; Washington state-wide background. See the text for further discussion of sources.

b. The selected PRG is the higher of either the background in soil or the Overall Lowest Screening Value between plants and soil invertebrates.

c. When Cr (total) not available, the lower of either Cr+3 or Cr+6 as available were used as a surrogate.

d. MTCA plant and soil biota benchmarks were replaced by Washington State natural background concentration.

e. The Low MW PAHs screening values from EPA (OSWER Directive 9285.7-78 [*Ecological Soil Screening Levels for Polycyclic Aromatic Hydrocarbons (PAHs): Interim Final*]) represents the sum of the low molecular weight polycyclic aromatic hydrocarbons (PAHs). For the purposes of this assessment, the benchmark was also applied to the individual low molecular weight PAHs.

f. The High MW PAHs screening values from EPA (OSWER Directive 9285.7-78 [*Ecological Soil Screening Levels for Polycyclic Aromatic Hydrocarbons (PAHs): Interim Final*]) represents the sum of the high molecular weight PAHs. For the purposes of this assessment, the benchmark was also applied to the individual high molecular weight PAHs.

g. Values for diethyl phthalate were used as a surrogate for bis[2-ethylhexyl] phthalate.

h. Aroclor 1254 value was used as surrogate.

i. MTCA values represent screening value for PCB mixtures.

j. MTCA Aroclor-1260 values used as surrogate for Aroclor 1262.

k. Form of HCB not identified in *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision* (ES/ER/TM-126/R2).

l. MTCA value based on benzene hexachloride, including lindane.

m. MTCA values based on chlordane.

n. DDT values used as a surrogate for DDE.

o. MTCA value based on total DDT/DDE/DDD.

p. MTCA endrin aldehyde values based on endrin.

--- = Value not available

Table 7-2. Wildlife (Birds and Mammals) SSLs for Radionuclides

			NOAEL-based site-specific SSLs									LOAEL-based site-specific SSLs								
Group	**Soil Constituent**	**Units**	**California Quail**	**Meadow-lark**	**Killdeer**	**Red-tailed Hawk**	**Great Basin Pocket Mouse**	**Deer Mouse**	**Grass-hopper Mouse**	**Badger**	**NOAEL Lowest**	**California Quail**	**Meadow-lark**	**Killdeer**	**Red-tailed Hawk**	**Great Basin Pocket Mouse**	**Deer Mouse**	**Grass-hopper Mouse**	**Badger**	**LOAEL Lowest**
Radionuclides	Americium-241	pCi/g	--	--	--	--	--	--	--	--	--	28900	25000	11900	17800	72100	48700	41400	4840	4840
	Carbon-14	pCi/g	--	--	--	--	--	--	--	--	--	54	60	56	50	61	60	135	32	32
	Curium-244	pCi/g	--	--	--	--	--	--	--	--	--	389000	252000	105000	207000	2300000	722000	499000	50800	50800
	Cobalt-60	pCi/g	--	--	--	--	--	--	--	--	--	805	805	805	863	805	805	806	1000	805
	Cesium-134	pCi/g	--	--	--	--	--	--	--	--	--	1140	1190	1200	854	1160	1180	1270	562	562
	Cesium 137	pCi/g	--	--	--	--	--	--	--	--	--	2390	2700	2800	1430	2510	2630	3280	924	924
	Europium-152	pCi/g	--	--	--	--	--	--	--	--	--	1740	1740	1740	1880	1740	1740	1740	2220	1740
	Europium-154	pCi/g	--	--	--	--	--	--	--	--	--	1610	1610	1610	1740	1610	1610	1610	2060	1610
	Europium-155	pCi/g	--	--	--	--	--	--	--	--	--	33400	33400	33400	37300	33400	33400	33400	48600	33400
	Hydrogen-3 (tritium)	pCi/g	--	--	--	--	--	--	--	--	--	1430	1280	936	1130	3270	2290	2830	420	420
	Neptunium-237	pCi/g	--	--	--	--	--	--	--	--	--	8190	8140	7880	9150	8250	8170	8180	11200	7880
	Nickel-63	pCi/g	--	--	--	--	--	--	--	--	--									
	Plutonium-238	pCi/g	--	--	--	--	--	--	--	--	--	36300	56200	20900	26800	291000	161000	161000	5980	5980
	Plutonium-239/240	pCi/g	--	--	--	--	--	--	--	--	--	38800	60300	22300	28400	324000	175000	176000	6270	6270
	Radium-226	pCi/g	--	--	--	--	--	--	--	--	--	168	142	58	377	285	165	199	193	58
	Radium-228	pCi/g	--	--	--	--	--	--	--	--	--	169	140	55	418	306	165	203	193	55
	Antimony-125	pCi/g	--	--	--	--	--	--	--	--	--	4580	4580	4580	5040	4580	4580	4580	6130	4580
	Strontium 90	pCi/g	--	--	--	--	--	--	--	--	--	521	302	151	112	706	519	413	91	91
	Technetium-99	pCi/g	--	--	--	--	--	--	--	--	--	5360	11500	137000	280000	8670	12100	412000	128000	5360
	Thorium-232	pCi/g	--	--	--	--	--	--	--	--	--	5070	12900	5340	12400	34400	32500	86200	4560	4560
	Uranium-234	pCi/g	--	--	--	--	--	--	--	--	--	12700	21800	6370	40900	30300	24800	51600	14200	6370
	Uranium-235	pCi/g	--	--	--	--	--	--	--	--	--	6340	7810	4360	10200	8600	8130	9630	8060	4360
	Uranium-238	pCi/g	--	--	--	--	--	--	--	--	--	8020	10400	5150	22100	11900	11000	13900	13400	5150

NOAEL = no observed adverse-effect level

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If 10 or fewer values were available for a chemical, the lowest LOEC was used. If the 10th percentile fell between LOEC values, a value was chosen by interpolation. If a chemical concentration in soil represented a 50 percent or higher reduction in survivorship of plants, the concentration was divided by five to approximate the more sensitive endpoints of growth or production. Plant toxicity benchmarks for metals are usually lower than those for soil invertebrates or microbial processes, and they are lower than most PRGs calculated for wildlife.

Ecology's Ecological Indicator Soil Concentrations presented in Table 749-3 represent soil concentrations that are expected to be protective at any MTCA site and are provided for use in eliminating hazardous substances from further consideration under MTCA, "Site-Specific Terrestrial Ecological Evaluation Procedures" (WAC 173-340-7493(2)(a)(i)). The Ecological Indicator Soil Concentrations for plants are based on benchmarks published in *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision* (ES/ER/TM-85/R3). The Ecological Indicator Soil Concentrations for soil biota are based on benchmarks published in *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision* (ES/ER/TM-126/R2).

Wildlife (Birds and Mammals). Bird and mammal TRVs for both the NOAELs and LOAELs were used in the SSL and PRG development. The TRVs were employed within models relating the ingested dose of the chemicals (exposure assessment, Section 7.3.2) with the TRVs to establish SSLs or PRGs that represent adverse effects thresholds. The TRVs were obtained from various sources and focus was given to the most recent sources and those derived or endorsed by EPA and Ecology (as evidenced by their use in either EcoSSLs or in MTCA [WAC 173-340]). The primary literature sources used were EcoSSLs. The toxicity studies used were selected initially from the following sources, which have been listed in order of preference:

- Office of Solid Waste and Emergency Response (OSWER) Directives
  - 9285.7-56, *Ecological Soil Screening Levels for Dieldrin: Interim Final*
  - 9285.7-57, *Ecological Soil Screening Levels for DDT and Metabolites: Interim Final*
  - 9285.7-60, *Ecological Soil Screening Level for Aluminum: Interim Final*
  - 9285.7-61, *Ecological Soil Screening Levels for Antimony: Interim Final*
  - 9285.7-62, *Ecological Soil Screening Levels for Arsenic: Interim Final*
  - 9285.7-63, *Ecological Soil Screening Levels for Barium: Interim Final*
  - 9285.7-64, *Ecological Soil Screening Levels for Beryllium: Interim Final*
  - 9285.7-65, *Ecological Soil Screening Levels for Cadmium: Interim Final*
  - 9285.7-66, *Ecological Soil Screening Levels for Chromium: Interim Final*
  - 9285.7-67, *Ecological Soil Screening Levels for Cobalt: Interim Final*
  - 9285.7-68, *Ecological Soil Screening Levels for Copper: Interim Final*
  - 9285.7-69, *Ecological Soil Screening Level for Iron: Interim Final*
  - 9285.7-70, *Ecological Soil Screening Levels for Lead: Interim Final*

- 9285.7-71, *Ecological Soil Screening Levels for Manganese: Interim Final*
- 9285.7-72, *Ecological Soil Screening Levels for Selenium: Interim Final*
- 9285.7-73, *Ecological Soil Screening Levels for Zinc: Interim Final*
- 9285.7-75, *Ecological Soil Screening Levels for Vanadium: Interim Final*
- 9285.7-76, *Ecological Soil Screening Levels for Nickel: Interim Final*
- 9285.7-77, *Ecological Soil Screening Levels for Silver: Interim Final*
- 9285.7-78, *Ecological Soil Screening Levels for Polycyclic Aromatic Hydrocarbons (PAHs): Interim Final*

- MTCA (WAC 173-340), Table 749-5.
- Other available literature—primarily *Toxicological Benchmarks for Wildlife: 1996 Revision* (ES/ER/TM-86/R3).
- NOAEL and LOAEL values selected for chemicals and reported in Integrated Risk Information System.
- NOAEL and LOAEL values presented in Wildlife Toxicity Assessments developed by United States Army Center for Health Promotion and Preventive Medicine.

An EPA panel of experts developed a process for reviewing and selecting TRVs for EcoSSL development for wildlife. The process was to select NOAELs to develop EcoSSLs for wildlife. Selected TRVs were either the highest NOAEL for population level effects (e.g., survival, growth, and reproduction endpoints) below the lowest LOAEL for population level effects or the geometric mean of NOAELs, depending on the number and quality of data available. Selection of the TRVs for development of Hanford SSLs and PRGs attempted to draw on the work of this expert panel. Thus, for analytes for which EPA has developed EcoSSLs for birds and mammals, those same NOAELs were used for wildlife SSL and PRG development for Hanford (see Appendix H of 100-K RI/FS, *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-00784], for a full detailed description). In some cases, the NOAEL-based TRV for the EcoSSL was the highest NOAEL below the lowest LOAEL identified for studies evaluating survival, growth, and reproduction endpoints. In these cases, the paired LOAEL from the study was selected as the LOAEL for Hanford SSL and PRG development. In other cases, the geometric mean of the NOAELs for growth and reproduction endpoints was selected to derive the Eco-SSL. In these cases, the LOAEL for Hanford SSL and PRG development was selected as the lowest LOAEL from the Eco SSL dataset above the geometric mean NOAEL.

The only exception to this TRV selection process was for the arsenic TRV for avian receptors, in which case the selected study was not identified and reviewed by the EPA panel. The selected study ("Main and Interactive Effects of Arsenic and Selenium on Mallard Reproduction and Duckling Growth and Survival" [Stanley et al., 1994]) was conducted by USFWS at Patuxent Wildlife Research Center over a period of 92-173 days that resulted in both a NOAEL and LOAEL for reproductive effects. The EcoSSL document considered nine studies on the effects of arsenic to have sufficient quality to consider in developing the avian SSL. "Arsenic Residues in Eggs from Laying Hens Fed with a Diet Containing Arsenic (III) Oxide" (Holcman and Stibilj, 1997) presented an unbound NOAEL that was selected because it was the lowest value. The Stanley study was conducted by a reliable research group over a much longer time frame, and produced bounded results (i.e., the NOAEL was bound by a LOAEL). The

intent of the EcoSSLs is to provide a value that can be used to provide a reliable conservative screen whereas TRV selection for this ERA is for use in PRG development for remedial decisions. Given all of this information, the NOAEL and LOAEL from "Main and Interactive Effects of Arsenic and Selenium on Mallard Reproduction and Duckling Growth and Survival" (Stanley et al., 1994) were selected over the EcoSSL recommendation.

For analytes lacking EcoSSLs, other primary and secondary sources of studies were used. Whenever possible, the primary literature sources were obtained and evaluated. Appropriate toxicity studies were selected from these sources based on several criteria:

- Studies were of chronic exposures or exposures during a critical stage of life (e.g., reproduction).
- Exposure was oral through food ingestion to be sure data were representative of oral exposures expected for wildlife in the field.
- Emphasis was placed on studies of reproductive impacts to achieve relevancy to population level effects.
- Studies presented adequate information to evaluate and determine the magnitude of exposure and effects (or no effects concentrations).

Specifically, toxicity studies were selected to serve as the TRV if exposure was chronic or was measured during a critical life stage, the dosing regime was sufficient to identify both a NOAEL and a LOAEL, and the study considered ecologically relevant effects (e.g., growth, reproduction, or survival). If multiple studies for a given COPC meet these criteria, the study generating the lowest reliable toxicity value was selected to be the TRV.

The full explanations of the TRVs selected, the method of calculating the SSLs and PRGs, and the resulting SSLs and PRGs are found in 100-K RI/FS Appendix H (*Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-00784]) for SSLs and 100-K RI/FS Appendix H (*Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-01311]) for PRGs.

7.3.2 Exposure Assessment

A summary of the exposure assessment for plants and invertebrates, wildlife, and radionuclide exposures is provided below. Additionally, a brief description of SSL and PRG development as a relationship between the effects assessment described in Section 7.3.1 and the exposure assessment is provided. For wildlife this description is provided with distinct sections for nonradionuclide SSLs, radionuclide SSLs, and nonradionuclide PRGs, which all included unique details in the estimation of exposure.

7.3.2.1 Exposure Assessment for Terrestrial Plants and Soil Invertebrates

Terrestrial plants and soil invertebrates experience exposure primarily through the soil in which they live. This exposure occurs as a consequence of living in a contaminated medium (i.e., receptors are directly exposed to COPCs). Although other exposure pathways (e.g., dietary exposure for invertebrates or foliar uptake for plants) may contribute to total exposure for these receptors, exposure through the soil predominates. Consequently, estimates of exposure for terrestrial plants and soil invertebrates are represented by the concentration of COPCs in the soil (mg/kg). As such, the concentrations of chemicals in soil that correspond to adverse effects described in the effects assessment (Section 7.3.1) were also assigned as the SSLs. The assumption is the same for PRG selection for plants and invertebrates but is described separately in Section 7.3.4.

7.3.2.2 Exposure Assessment for Wildlife (Birds and Mammals)

In contrast to plants and soil invertebrates, birds and mammals experience chemical exposure through multiple pathways, including the ingestion of surface water, sediment/soil, and biotic media (food), inhalation, and dermal contact. Modeling is often employed to assess exposure via these multiple exposure pathways. The end product, or exposure estimate, for birds and mammals is a dose estimate that quantifies the amount of chemical in milligrams per kilogram receptor body weight per day [mg/kg/day]). The general form of the model used to estimate exposure of birds and mammals to chemicals in environmental media is as follows (*Ecological Risk Assessment for Contaminated Sites* [Suter et al., 2000]):

$$Et = Eo + Ed + Ei$$

where:

Et	=	total chemical exposure experienced by wildlife
Eo	=	oral exposure
Ed	=	dermal exposure
Ei	=	inhalation exposure

Oral exposure occurs through the consumption of contaminated food, water, or sediment/soil; dermal exposure occurs when contaminants are absorbed directly through the skin; and inhalation exposure occurs when volatile compounds or fine particulates are inhaled into the lungs. Although methods are available for assessing dermal exposure to humans (*Dermal Exposure Assessment: Principles and Applications* [EPA/600/8-91/011B]), data necessary to estimate dermal exposure generally are not available for wildlife (*Wildlife Exposure Factors Handbook, Vol. 1 and II* [EPA/600/R-93/187b]). Similarly, methods and data necessary to estimate wildlife inhalation exposures are poorly developed (*Wildlife Exposure Factors Handbook, Vol. 1 and II* [EPA/600/R-93/187b]) or limited.[3] Additionally, a wildlife receptor's exposure to contaminants by inhalation and dermal contact usually contributes little to its overall exposure. Dermal exposure is low, even to burrow-dwelling animals, because of the presence of protective dermal layers (e.g., feathers, fur, or scales). Therefore, for the purposes of developing the SSL values, both dermal and inhalation exposure were assumed to be negligible.[4] Therefore, only oral exposures via ingestion of soil and food were included in the development of risk-based concentrations for birds and mammals.

Large mammalian wildlife using the upland 100-BC Area waste site areas can and do move down to the Columbia River riparian area and drink from the freshwater seeps and from the more abundant Columbia River. Bats and birds frequenting or residing in these areas also can use the seeps along the Columbia River to meet their daily needs. A semi-quantitative evaluation of the ingestion of seep water was performed and is discussed with the risk characterization in Section 7.4.4.

Total chemical exposure experienced by wildlife (E_t) is assumed to be equal to oral exposure (E_o). By replacing E_o with a generalized exposure model modified from *Ecological Risk Assessment for Contaminated Sites* (Suter et al., 2000) to include only soil and food ingestion, the previous equation was rewritten as follows:

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[3] For assessing inhalation exposures, some data for mammals are available through the IRIS database, and a limited set of inhalation benchmarks for wildlife have been developed ("Wildlife Ecological Screening Levels for Inhalation of Volatile Organic Chemicals" [Gallegos et al., 2007].

[4] If the CSM had indicated that volatile organic compounds are a significant COPEC, focused analyses of the inhalation pathway may have been warranted, but VOCs were not COPECs in soil at 100-BC.

$$E_t = \left[\left[\sum_{i=1}^{n} B_{ij} \times P_i \times FIR\right] + \left[Soil_j \times P_s \times FIR\right]\right] x\, AUF$$

where:

E_t = total exposure (mg/kg/day)

$Soil_j$ = chemical concentration in soil (mg/kg dry weight)

P_s = soil ingestion rate as proportion of diet (unitless)

FIR = food intake rate (kg food/kg body weight/day, dry weight)

B_{ij} = chemical concentration in biota type (i) (mg/kg, dry weight)

P_i = proportion of biota type (i) in diet (unitless)

AUF = area use factor (area of site/home range of receptor) (unitless).

The bird and mammal effects data (Section 7.3.1.1) were combined with the wildlife exposure model to calculate avian/mammal SSLs and avian/mammal PRGs for nonradionuclides. These SSLs and PRGs consist of soil concentrations that are associated with estimated dietary exposures equivalent to a selected effect level, and were calculated using the following basic equation:

$$1 = \frac{TRV}{\sum (SSLorPRG \times DFI) \times \left[(Frac_v \times C_v) + (Frac_i \times C_i) + (Frac_m \times C_m) + (Frac_s)\right]}$$

where:

TRV = toxicity reference value (mg/kg body weight/day)

SSL = wildlife soil screening level (mg/kg)

PRG = wildlife preliminary remediation goal (mg/kg)

$Frac_v$ = fraction of diet represented by vegetation (unitless)

DFI = daily ingestion rate of all food items (kg/kg body weight/day dry wt.)

C_v = concentration in vegetation tissue (mg/kg dry wt.)

$Frac_i$ = fraction of diet represented by terrestrial invertebrates (unitless)

C_i = concentration in soil invertebrate tissue (mg/kg dry wt.)

$Frac_m$ = fraction of diet represented by small mammals/birds (unitless)

C_m = concentration in small mammal tissue (mg/kg dry wt.)

$Frac_s$ = fraction of diet represented by incidentally ingested soil (unitless).

The TRV denotes the level of toxicity of the chemical, as reported from literature sources. The wildlife SSLs and PRGs use the LOAELs, which is consistent with protecting ecological receptors at the population and community level. The daily ingestion rate and dietary fractions are specific to bird and mammal receptors identified for the upland environment of the Hanford Site. The chemical concentration in the food item (vegetation, soil invertebrate, and small mammal) is estimated by using BAFs or bioaccumulation regression models to extrapolate to the food source. This equation is solved for wildlife

SSLs or PRGs using the Microsoft Office Excel® goal seek tool, such that exposure (the denominator) equals the TRV (the numerator).

For the purposes of this risk assessment, the LOAEL-based wildlife SSLs and wildlife PRGs were used to evaluate residual risks at the 100-BC Source OU remediated waste sites. The SSLs and PRGs were compared to EPCs developed for the 100-BC Source OU as described in Section 7.4.1.

Wildlife Exposure Factors. Within the exposure models described above, species-specific exposure parameters are required to estimate exposure. These include body weight, food ingestion rate, diet composition represented by dietary fractions, and percent or fraction of diet as incidental soil ingestion. The following assumptions were part of the calculation of wildlife exposures used to develop the wildlife SSLs and wildlife PRGs:

- For SSL and PRG development, it was conservatively assumed that wildlife forage exclusively within the waste site being evaluated, resulting in an area use factor (AUF) of one. In other words, the resulting SSLs and PRGs did not attempt to account for wildlife home range, instead assuming that prey tissue concentrations from food obtained outside the waste site boundaries might contain lower concentrations of contaminants. This assumption is discussed in more detail in the risk conclusions and the SMDP discussed in Section 7.6, including accounting for home range and development of site-specific AUFs as warranted.
- Incidental soil ingestion was not included as part of the total dietary composition, but instead was added to the total; for calculation purposes, it was treated as a percentage of total dietary intake.
- All animals were assumed year-round residents, and migration away from areas contaminated with COPCs was not assumed to occur.
- Bioavailability of analytes was assumed equivalent to the chemical form used for developing TRVs in the toxicity studies.
- 100 percent of the estimated soil concentrations (the EPCs) were assumed to be bioavailable for uptake into tissues within the exposure models.

The exposure parameters and source references used for each representative receptor species are summarized in Appendix H, Table H-3. All weight-based exposure parameters are listed on a dry-weight basis. Species-specific biological information was unavailable for some parameters. When this occurred, allometric equations that express general biological relationships for broader classes of animals were used to estimate the exposure parameters ("Food Requirements of Wild Animals: Predictive Equations for Free-living Mammals, Reptiles, and Birds" [Nagy, 2000]). These allometric conversions are detailed in the Environmental Calculation document (Appendix G).

Estimation of Bioaccumulation into Food Items. A major component of the desktop food-chain model described above is modeling the concentration of contaminates within the prey consumed by wildlife within the waste sites being evaluated. This modeled dose received through ingesting food was considered in the final estimate of the soil concentration that represents a toxic threshold (i.e., the SSL or PRG). Bioaccumulation models and assumptions that were used within the calculation of wildlife SSLs and PRGs are described below. These models and assumptions represent the most recent equations used in the ecological risk assessment practice, and are now the standard. While some of them are the same as those within MTCA, "Site-Specific Terrestrial Ecological Evaluation Procedures" (WAC 173-340-7493), much advancement was subsequently made in the publication of the EPA's Eco SSLs (*Guidance for*

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Developing Ecological Soil Screening Levels [OSWER Directive 9285.7-55]) as additional bioaccumulation data became available from which to develop updated models:

- **Estimating Prey Tissue Concentration for SSLs**—The concentrations of COPCs in each food item were estimated rather than measured. For the purposes of exposure estimation, partitioning of analytes from environmental media to prey was estimated from literature values and models. The models presented in the EPA EcoSSLs methodology (*Guidance for Developing Ecological Soil Screening Levels* [OSWER Directive 9285.7-55]) were used preferentially for estimation of bioaccumulation into biota from soil. Consistent with the approach employed for the EcoSSLs, regression-based models (if available) and median BAFs from the source selected by EPA were used. In the absence of applicable bioaccumulation models, a default value of one was assumed. In all cases, it was assumed that tissue uptake occurs under steady-state conditions. Bioaccumulation models used to derive wildlife SSLs are presented in Appendix H, Table H-4. The wildlife SSLs are presented in Table 7-2 for radionuclides and Table 7-3 for nonradionuclides.

- **Estimating Prey Tissue Concentration for PRGs**—Development of the PRGs for birds and mammals focused on the integration of available site-specific bioaccumulation data for plants, terrestrial arthropods, and small mammals with data from existing bioaccumulation models (i.e., those from *Guidance for Developing Ecological Soil Screening Levels* [OSWER Directive 9285.7-55]) that were used to develop the EcoSSLs in order to develop a set of partially site-specific bioaccumulation models[5]. The following Hanford Site-specific and literature-based data-sets were used to develop these bioaccumulation models:

  - Hanford Site-specific bioaccumulation data have been collected in support of the RCBRA (DOE/RL-2007-21) and other projects at the site. Data representing tissue from terrestrial plants (foliage, shoots, and other aboveground parts of grasses, shrubs, and trees), small mammals (whole single mice or composites of multiple whole mice), and terrestrial arthropods (whole individual invertebrates or composites of multiple whole invertebrates), and collocated soil data were extracted from HEIS. Only paired samples in which the target analytes were detected in both tissue and in soil were retained for the bioaccumulation database; observations that were nondetects in either the soil or tissue of a sample pair were excluded from consideration.

  - Data from previously developed and published bioaccumulation models for plants and small mammals were used to augment the Hanford Site-specific data. Specifically, the plant bioaccumulation database from *Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants* (BJC/OR-133) and "Ecotoxicity Test Data for Total Petroleum Hydrocarbons in Soil: Plants and Soil-Dwelling Invertebrates" (Efroymson et al., 2004) was used. In addition, the small mammal bioaccumulation database from *Development and Validation of Bioaccumulation Models for Small Mammals* (ES/ER/TM-219) was used. Electronic copies of the original databases were obtained from the authors to facilitate integration with Hanford Site-specific data.

  - Estimating exposures to insectivorous or omnivorous wildlife involved estimating bioaccumulation into soil invertebrates. Soil invertebrate bioaccumulation models used for SSLs consisted of the earthworm models from *Development and Validation of Bioaccumulation Models for Earthworms* [ES/ER/TM-220] and "Literature-Derived Bioaccumulation Models for Earthworms: Development and Validation" [Sample et al., 1999]). Hanford Site-specific

[5] These bioaccumulation models are defined as partially site-specific because they are based on both site-specific data and data from published literature sources. This combining of Hanford-specific and literature data was performed to maximize utility of the Hanford-specific data collected over comparatively narrow concentration ranges by expanding the dataset to include literature data collected across a wider concentration range.

observations (as detailed in the RCBRA Volume I [DOE/RL-2007-21,] and *Central Plateau Ecological Risk Assessment Data Package Report* [DOE/RL-2007-50]) indicate that earthworms are nonexistent in upland soils, and have little or no contribution to the invertebrate portion of bird and mammal diets at the Hanford Site. Rather, insects and other arthropods (e.g., beetles, ants, spiders, etc.) are the primary prey of invertebrate-feeding birds and mammals at the site. Consequently, the data collected to address Hanford Site-specific bioaccumulation into invertebrate prey of birds and mammals focused on arthropods (RCBRA [DOE/RL-2007-21]). Additional bioaccumulation data for terrestrial arthropods were identified and extracted from published literature to supplement the Hanford Site-specific data.

- A literature search was performed for studies that reported chemical concentrations in collocated biota and media samples. Literature databases searched included those hosted by EPA (ECOTOX Database Systems), and the National Library of Medicine (TOXLINE: Toxicology Data Network).

- The Hanford Site-specific plant, soil invertebrate, and small mammal data were integrated with the literature-derived bioaccumulation data. Bioaccumulation analyses were performed once biota data were converted to standard units (mg/kg-dry weight). Analyses were restricted to observations where the chemical of interest was detected in both soil and the matched tissue sample; all observations in which either soil or tissue concentrations were nondetects were excluded from the analyses. Analyses consisted of development of BAFs and nonlinear regression analyses. BAFs are simply the ratio between concentrations measured in tissue and that in soil. BAFs for all paired soil tissue observations and summary statistics (arithmetic mean, standard deviation, minimum, maximum, median, and 90th percentile) were calculated.

- To evaluate if a log-linear relationship between the chemical concentration in soil and that in terrestrial biota existed, simple log-linear regressions were performed using SAS PROC REG (*SAS/STAT User's Guide* [SAS Institute, 1999]). Chemical concentrations in both soil and biota tissues were transformed to natural-log (ln) before regression analyses. Regression analyses were considered significant and suitable for estimation purposes if all three of the following criteria were met: $p>0.05$, $r2>0.1$, and a positive slope. If regression analyses did not meet any one of these criteria, the median BAFs were used to estimate tissue concentrations in exposure models.

The wildlife SSLs for nonradionuclides are presented in Table 7-3 and the wildlife PRGs (metals only) are first presented in Table 7-4. For the purposes of this ERA, the LOAEL-based SSLs (SSLs that used lowest effect levels from the Effects Assessment) were used to evaluate residual risks at the 100-BC Area remediated waste sites. To focus the assessment on COPEC-receptor-waste site combinations that might require further evaluation, the SSLs were compared to EPCs developed for the 100-BC Area as described in Section 7.4.1. Then, to identify which COPEC-receptor-waste site combinations should be brought forward to the SMDP to identify community or population level impacts to be addressed in the FS, EPCs were compared to PRGs for COPCs that exceeded SSLs and background as described in Section 7.4.3.

Table 7-3. Wildlife (Birds and Mammals) SSLs for Nonradionuclides

Group	Soil Constituent	Units	NOAEL-based site-specific SSLs									LOAEL-based Site-specific SSLs								
			California Quail	Meadow-lark	Killdeer	Red-tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	NOAEL Lowest	California Quail	Meadow-lark	Killdeer	Red-tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grass-hopper Mouse	Badger	LOAEL Lowest
Metals	Aluminum	mg/kg	22020	18602	4921	61782	687	271	380	710	271	--	--	--	--	6872	2708	3799	7101	2708
	Antimony	mg/kg	--	--	--	--	8.8	0.7	0.6	16.7	0.6	--	--	--	--	97	7	6	167	6
	Arsenic, Total all valence states	mg/kg	1800	1981	425	10344	265	105	171	549	105	8104	10559	2132	45439	459	190	318	881	190
	Arsenic (III)	mg/kg	1800	1981	425	10344	265	105	171	549	105	8104	10559	2132	45439	459	190	318	881	190
	Arsenic (V)	mg/kg	1800	1981	425	10344	265	105	171	549	105	8104	10559	2132	45439	459	190	318	881	190
	Barium	mg/kg	1229	1271	660	14442	2082	1889	4605	18843	660	2464	2548	1323	28954	3470	3148	7676	31405	1323
	Beryllium	mg/kg	--	--	--	--	14	18	101	283	14	--	--	--	--	--	--	--	--	--
	Bismuth	mg/kg	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Boron	mg/kg	63.9	86.5	139.7	796.7	40	50	284	767	40	222	300	485	2766	133	167	949	2563	133
	Cadmium	mg/kg	151.1	2.8	0.9	1374.9	76	1	1	455	1	278	5	2	2335	2065	28	24	5228	2
	Chromium (total)	mg/kg	334.3	96.5	36.5	1286.5	320	75	78	752	37	349	101	38	1355	1284	299	313	3536	38
	Chromium (+3)	mg/kg	334.3	96.5	36.5	1286.5	320	75	78	752	37	349	101	38	1355	1284	299	313	3536	38
	Chromium (+6)	mg/kg	--	--	--	--	1233.4	287.7	300.2	3379.9	287.7	--	--	--	--	5340	1245	1300	16583	1245
	Cobalt	mg/kg	1425.3	305.3	108.8	1601.4	2174.4	260.9	250.1	1346.1	108.8	1461	313	111	1633	3233	388	372	1869	111
	Copper	mg/kg	485.2	85.3	35.8	3727.7	872.9	99.9	109.4	2640.1	35.8	1914	272	107	13021	1894	176	182	4672	107
	Lead	mg/kg	247	49	16	979	1204	151	153	2005	16	537	115	36	2433	2544	332	336	4108	36
	Lithium	mg/kg	--	--	--	--	3189	1258	1749	257	257	--	--	--	--	6379	2517	3498	515	515
	Manganese	mg/kg	16369	24184	9588	113951	4227	4115	18430	20464	4115	31823	48820	19636	221536	5828	5798	27720	28213	5798
	Mercury	mg/kg	3	0	0	25	0	0	0	9	0	36	21	4	134	8	2	3	43	2
	Molybdenum	mg/kg	35	27	18	98	2	1	3	7	1	345	270	179	977	17	14	28	71	14
	Nickel	mg/kg	1081	79	31	6037	303	18	16	637	16	1912	136	53	11078	676	36	33	1438	33
	Selenium	mg/kg	6	4	2	158	2	1	2	32	1	10	8	4	417	3	2	3	60	2
	Silver	mg/kg	345	13	5	2044	1442	35	30	3097	5	3453	128	50	20437	14418	346	300	30969	50
	Strontium	mg/kg	--	--	--	--	9442	4849	6476	4228	4228	--	--	--	--	--	--	--	--	--
	Thallium	mg/kg	--	--	--	--	5	2	2	3	2	--	--	--	--	25	9	12	13	9
	Tin	mg/kg	82	128	231	1852	187	252	2691	5107	82	204	318	575	4603	279	377	4025	7639	204
	Uranium	mg/kg	2501.563	2690.655	785.3842	18729.66	610	393	748	1694	393	--	--	--	--	1217	786	1494	3383	786
	Vanadium	mg/kg	67	58	16	268	1363	577	835	1864	16	134	116	31	537	2723	1153	1668	3723	31

Table 7-3. Wildlife (Birds and Mammals) SSLs for Nonradionuclides

Group	Soil Constituent	Units	NOAEL-based site-specific SSLs									LOAEL-based Site-specific SSLs								
			California Quail	Meadow-lark	Killdeer	Red-tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	NOAEL Lowest	California Quail	Meadow-lark	Killdeer	Red-tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grass-hopper Mouse	Badger	LOAEL Lowest
	Zinc	mg/kg	4973	714	67	70825	4612	633	794	38590	67	5015	726	68	71294	4661	644	810	38866	68
General	Ammonia/Ammonium	mg/kg	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Inorganics	Chloride	mg/kg	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Cyanide	mg/kg	--	--	--	--	27971	20693	78123	38061	20693	--	--	--	--	--	--	--	--	--
	Fluoride (fluorine)	mg/kg	1492	2812	556	9206	9825	8216	35673	17379	556	6123	11539	2281	37771	16521	13816	59985	29224	2281
	Iodine	mg/kg	--	--	--	--	159	183	1558	759	159	--	--	--	--	1594	1834	15579	7590	1594
	Nitrate/Nitrite	mg/kg	--	--	--	--	206422	152711	576537	280885	152711	--	--	--	--	460073	340361	1284984	626035	340361
	Phosphate	mg/kg	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Sulfate/Sulfite	mg/kg	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Total Organic Carbon	%	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 7-3. Wildlife (Birds and Mammals) SSLs for Nonradionuclides

Group	Soil Constituent	Units	NOAEL-based site-specific SSLs									LOAEL-based Site-specific SSLs								
			California Quail	Meadow-lark	Killdeer	Red-tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	NOAEL Lowest	California Quail	Meadow-lark	Killdeer	Red-tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grass-hopper Mouse	Badger	LOAEL Lowest
Volatile Organics	1,1-dichloroethane	mg/kg	3615	217	83	13955	20357	574	502	22894	83	7230	435	165	27909	--	--	--	--	165
	1,1-dichloroethene	mg/kg	3615	217	83	11433	12214	344	301	12238	83	7230	434	165	22866	--	--	--	--	165
	1,1,1-trichloroethane	mg/kg	3615	217	82	8936	407144	11444	10016	349074	82	7230	433	165	17871	--	--	--	--	165
	1,1,2-trichloroethane	mg/kg	3615	217	83	12031	407144	11472	10041	420572	83	7230	434	165	24063	--	--	--	--	165
	1,1,2,2-tetrachloroethane	mg/kg	3615	217	82	9549	3636	102	89	3255	82	7230	433	165	19098	36358	1022	894	32554	165
	1,2-dichlorobenzene	mg/kg	88	91	82	4343	282	294	854	17612	82	176	182	164	8687	--	--	--	--	164
	1,2-dichloroethane (DCA)	mg/kg	3615	222	84	16084	20357	586	513	24710	84	7230	444	169	32168	--	--	--	--	169
	1,3-dichlorobenzene	mg/kg	96	96	82	4051	310	314	854	16652	82	192	192	164	8103	--	--	--	--	164
	2-butanone (Methyl Ethyl Ketone/MEK)	mg/kg	2102	1041	312	11538	721052	159713	176661	970851	312	21017	10406	3123	115382	1861055	412224	455968	2505793	3123
	2-hexanone	mg/kg	2102	548	186	9653	2036	244	237	2512	186	21017	5483	1856	96532	14698	1759	1708	18135	1708
	Benzene	mg/kg	8554	513	195	27053	285	8	7	286	7	--	--	--	--	2850	80	70	2856	70
	Butanol	mg/kg	--	--	--	--	50893	2906	2626	67049	2626	--	--	--	--	203572	11625	10503	268194	10503
	Carbon Tetrachloride	mg/kg	3615	216	82	7382	6514	183	160	4904	82	7230	433	165	14765	--	--	--	--	165
	Chlorobenzene	mg/kg	3615	216	82	6672	7939	223	195	5561	82	7230	433	165	13345	15756	442	387	11036	165
	Chloroform	mg/kg	3615	217	83	13003	6107	172	151	6600	83	7230	434	165	26006	16693	470	412	18041	165
	Cis-1,2-dichloroethylene	mg/kg	3615	217	83	13446	18403	518	453	20271	83	7230	434	165	26892	--	--	--	--	165
	Dichloromethane (Methylene Chloride)	mg/kg	3615	218	83	17281	2382	67	59	2999	59	7230	436	166	34562	20357	576	504	25632	166
	Ethyl Benzene	mg/kg	159	183	194	12721	342	384	1357	33025	159	--	--	--	--	1027	1151	4075	99076	1027
	Methyl Isobutyl Ketone	mg/kg	2102	573	193	10211	721052	90040	87996	915292	193	21017	5729	1927	102114	1861055	232395	227119	2362393	1927
	n-butyl Benzene	mg/kg	301	263	193	7857	530	485	1092	18135	193	--	--	--	--	1589	1454	3275	54406	1454
	Tetrachloroethylene	mg/kg	3615	216	82	7733	570	16	14	443	14	7230	431	164	15467	2850	80	70	2216	70
	Toluene	mg/kg	8554	512	195	17200	21171	594	520	15763	195	--	--	--	--	211715	5944	5202	157633	5202
	Trans-1,2-dichloroethylene	mg/kg	3615	217	83	11881	18403	518	453	18869	83	7230	434	165	23763	--	--	--	--	165
	Trichloroethylene (TCE)	mg/kg	3615	217	82	7498	285	8	7	217	7	7230	434	165	14996	2850	80	70	2169	70
	Xylene	mg/kg	149	175	194	13419	422	481	1787	45266	149	--	--	--	--	826	940	3494	88509	826

Table 7-3. Wildlife (Birds and Mammals) SSLs for Nonradionuclides

Group	Soil Constituent	Units	NOAEL-based site-specific SSLs									LOAEL-based Site-specific SSLs								
			California Quail	Meadow-lark	Killdeer	Red-tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	NOAEL Lowest	California Quail	Meadow-lark	Killdeer	Red-tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grass-hopper Mouse	Badger	LOAEL Lowest
Polycyclic Aromatic Hydrocarbons	Acenaphthene	mg/kg	6831	285	110	38362	71250	1396	1211	96952	110	68306	2849	1096	383617	142500	2793	2422	193905	1096
	Acenaphthylene	mg/kg	3506	19	7	38362	24321	91	78	96952	7	43766	186	74	383617	54132	183	156	193905	74
	Anthracene	mg/kg	3405	170	68	38362	178811	4784	4213	554013	68	43405	1716	678	383617	--	--	--	--	678
	Benzo(a)pyrene	mg/kg	47	6	2	767	60	8	8	554	2	--	--	--	--	635	81	76	5540	76
	Benzo(a)anthracene	mg/kg	118	5	2	767	307	7	6	554	2	--	--	--	--	3636	73	64	5540	64
	Benzo(b)fluoranthene	mg/kg	22	3	1	767	25	4	4	554	1	--	--	--	--	247	41	39	5540	39
	Benzo(ghi)perylene	mg/kg	12	3	1	767	13	3	3	554	1	--	--	--	--	89	32	35	5540	32
	Benzo[k]fluoranthene	mg/kg	136	3	1	767	406	5	4	554	1	--	--	--	--	4069	46	39	5540	39
	Chrysene	mg/kg	118	4	1	767	307	5	4	554	1	--	--	--	--	3636	51	45	5540	45
	Dibenz(ah)anthracene	mg/kg	44	4	1	767	54	5	4	554	1	--	--	--	--	543	49	44	5540	44
	Fluoranthene	mg/kg	15	3	1	767	1957	421	420	69252	1	--	--	--	--	3915	841	839	138503	839
	Fluorene	mg/kg	6831	45	18	38362	50893	157	134	69252	18	68306	446	175	383617	101786	313	267	138503	175
	Indeno[1,2,3-cd]pyrene	mg/kg	49	3	1	767	63	4	4	554	1	--	--	--	--	626	40	36	5540	36
	2-Methylnaphthalene	mg/kg	5	6	155	38362	5	5	500	27867	5	8	9	1547	383617	6	7	1132	63047	6
	Naphthalene	mg/kg	34	37	416	38362	33	36	116	27701	33	340	369	378	383617	100	109	348	83102	100
	Phenanthrene	mg/kg	4329	236	94	38362	301134	6731	5919	554013	94	56061	2406	943	383617	--	--	--	--	943
	Pyrene	mg/kg	11	4	2	767	825	360	436	41551	2	--	--	--	--	1375	600	727	69252	600
	Total PAHs	mg/kg	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Low MW PAHs	mg/kg	6592	12623	2316	38362	25369	19170	74597	36343	2316	67600	128679	23165	383617	130652	97560	372987	181716	23165
	High MW PAHs	mg/kg	40	72	46	767	29	39	699	341	29					157	209	3491	1701	157
Petroleum	Gasoline Range Organics	mg/kg																		
	TPH- diesel	mg/kg	105086	199535.4	35638.2	590179	407144	301204.8	1137154	554013	35638.2	1050862	1995354	356382	5901794	610716	451807	1705732	831020	356382
	TPH- kerosene	mg/kg	105086	199535.4	35638.2	590179	407144	301204.8	1137154	554013	35638.2	1050862	1995354	356382	5901794	610716	451807	1705732	831020	356382

Table 7-3. Wildlife (Birds and Mammals) SSLs for Nonradionuclides

Group	Soil Constituent	Units	NOAEL-based site-specific SSLs									LOAEL-based Site-specific SSLs								
			California Quail	Meadow-lark	Killdeer	Red-tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	NOAEL Lowest	California Quail	Meadow-lark	Killdeer	Red-tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grass-hopper Mouse	Badger	LOAEL Lowest
Semivolatile Organics	Normal paraffin hydrocarbons	mg/kg	170870	324444.5	57947.6	959632	407144	301204.8	1137154	554013	57947.6	--	--	--	--	610716	451807	1705732	831020	451807
	Phenol	mg/kg	--	--	--	--	4886	526.1	503.7	5919	503.7	--	--	--	--	14657	1578	1511	17756	1511
	2-methylphenol (ocresol)	mg/kg	--	--	--	--	127436	10037.6	9293.3	134503	9293.3	--	--	--	--	--	--	--	--	--
	4-methylphenol (pcresol)	mg/kg	--	--	--	--	127436	10101.7	9358	136361	9358	--	--	--	--	--	--	--	--	--
	2,4-dinitrotoluene	mg/kg	0	0.3	0.2	7	14	13.5	35.6	286	0.2	38	39	26	932	29	28	74	597	26
	Bis[2-ethylhexyl] phthalate[a]	mg/kg	111	0.4	0.1	263	1733	5	5	3599	0.1	--	--	--	--	17332	54	45	35994	45
	Polychlorinated Biphenyls (PCB)[b]	mg/kg	10	1	0	25	3	0	0	8	0.3	100	4	2	251	29	2	1	85	1
	Aroclor 1016[b]	mg/kg	6	0.6	0.3	22	35	2.8	2.5	150	0.3	64	4	2	218	88	5	5	377	2
	Aroclor 1221[b]	mg/kg	3	0.6	0	24	0.7	0.3	0	8	0.3	27	3	2	240	7	1	1	82	1
	Aroclor 1232[b]	mg/kg	2	1	0	26	1	0.2	0	9	0.2	22	3	2	262	5	1	1	88	1
	Aroclor 1242[b]	mg/kg	10	1	0	26	3	0	0	9	0.3	104	4	2	256	31	2	1	87	1
	Aroclor 1248[b]	mg/kg	9	0.6	0.3	24	0	0	0	1	0.1	94	4	2	243	3	0	0	11	0
	Aroclor 1254	mg/kg	12	1	0	27	3	0	0	9	0.270947	115	4	2	273	35	2	1	91	1
	Aroclor-1260[b]	mg/kg	20	1	0	51	8	0	0	15	0	204	4	2	515	77	2	1	154	1
	Aroclor-1262[b]	mg/kg	38	72	13	212	28	20	77	38	13	378	718	128	2125	277	205	773	377	128
Pesticide	Aldrin	mg/kg	0	0	0	1	10	2	2	27	0	2	0	0	5	51	10	10	134	0
	beta-1,2,3,4,5,6-Hexachlorocyclo hexane	mg/kg	4	4	3	112	2	2	4	67	2	6	5	4	168	9	9	20	335	4
	alpha-Chlordane	mg/kg	122	24	10	302	93	21	21	264	10	608	121	50	1508	925	205	207	2641	50
	gamma-Chlordane	mg/kg	122	24	10	302	93	20	21	264	10	608	121	50	1508	925	204	206	2641	50
	Dichlorodiphenyldichloroethane (DDD)[c]	mg/kg	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Dichlorodiphenyldichloroethylene (DDE)[c]	mg/kg	30	0	0	0	20	0	0	0	0	300	2	1	2	136	1	1	0	0
	Dichlorodiphenyltrichloroethane	mg/kg	30.37	0.3	0.1	2.53	20.48	0.16	0.14	1.41	0.1	300	3	1	46	136	1	1	13	1
	Dieldrin	mg/kg	1.93	0.06	0.02	1.64	0.28	0.01	0.01	0.35	0.01	6	0	0	5	1	0	0	1	0
	Endosulfan I	mg/kg	93.44	66.32	41.4	1671.48	0.92	0.71	1.29	21.88	0.71	--	--	--	--	--	--	--	--	--
	Endosulfan II	mg/kg	93.44	66.32	41.4	1671.48	0.92	0.71	1.29	21.88	0.71	--	--	--	--	--	--	--	--	--

Table 7-3. Wildlife (Birds and Mammals) SSLs for Nonradionuclides

Group	Soil Constituent	Units	NOAEL-based site-specific SSLs									LOAEL-based Site-specific SSLs								
			California Quail	Meadow-lark	Killdeer	Red-tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	NOAEL Lowest	California Quail	Meadow-lark	Killdeer	Red-tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grass-hopper Mouse	Badger	LOAEL Lowest
	Endosulfan sulfate	mg/kg	62.89	55.4	41.4	2159.84	0.61	0.56	1.29	27.15	0.56	--	--	--	--	--	--	--	--	--
	Endrin aldehyde	mg/kg	2.56	0.52	0.23	52.86	0.51	0.14	0.14	14.04	0.14	--	--	--	--	5	1.4	1.4	140	1.4
	Methoxychlor	mg/kg	--	--	--	--	59.78	11.2	10.92	441.01	10.92	--	--	--	--	120	22.4	21.8	882	21.8

a. Values for diethyl phthalate and di-n-butyl phthalate were used as a surrogate for bis(2)ethylhexyl phthalate
b. Aroclor 1254 value was used as surrogate.

7.3.2.3 Radionuclide Exposures

Exposure to radionuclides differs from chemical exposure. Terrestrial biota receive exposure to radionuclides through a combination of both internal and external pathways. Internal exposure is a function of radiation emitted from radionuclides that are retained in tissues. At a terrestrial site such as the 100-BC Source OU, external exposure is caused by radiation from radionuclides in soil with which biota come into contact (or come near). For the purposes of developing SSLs, radionuclide exposure was estimated based on the internal and external radiation exposure models used to develop BCGs as described in Graded Approach for Radiation Doses to Biota (DOE-STD-1153-2002).

The BCGs for terrestrial plants and animals represent SSLs for radionuclides in soil for assessing ecological risks at the 100-BC Source OU waste sites (Tables 7-1 and 7-2). The BCGs for radionuclides use conservative assumptions for internal and external exposure. Although existing effects data support the application of these dose limits to representative individuals within populations of plants and animals, the assumptions and parameters applied in the derivation of the BCGs are based on a maximally exposed individual, representing a conservative approach for screening purposes. The following assumptions are used for estimating doses from external exposure for purposes of developing BCGs:

- The source medium is infinite in extent and contains uniform concentrations of radionuclides (i.e., there are no "hot spots").
- One hundred percent of the radionuclide energies are absorbed (despite the small size of some of the receptors).
- Organisms exposed to soil are uniformly surrounded by the source medium.

The following assumptions are used in estimating doses from internal exposure for purposes of developing BCGs:

- All radionuclide decay energies are retained in tissue (100 percent of energies absorbed).
- Exposure for a given radionuclide includes all decay chain progeny.
- All radionuclides are uniformly distributed such that all target tissues may be affected.

7.3.3 Drinking Water Exposure

The estimates of exposure from drinking water ingestion by wildlife include the use of a simplified model whereby the rate of ingestion is standardized to the body weight of the receptor on a per kilogram basis. The simplified allometric scaling equations presented in "Scaling of Osmotic Regulation in Mammals and Birds" (Calder and Braun, 1983) were used to estimate water ingestion as the number of liters consumed per kilogram body weight per day. These rates of ingestion were then multiplied by the concentration of COPECs to calculate the total dose from the drinking water pathway as shown below:

$$Dose = \left[\left[Water \times DWIR\right]\right] x\, AUF$$

where:

$Dose$ = drinking water exposure (mg/kg body weight/day)

$Water$ = chemical concentration in seep water (mg/L)

$DWIR$ = drinking water ingestion rate (L/kg body weight/day)

AUF = area use factor (area of site/home range of receptor) (unitless)

Drinking water ingestion was estimated for several species of birds and mammals expected to occur in the 100-BC riparian area along the Columbia River, with the initial assumption that they reside at the site and fulfill their drinking water requirements exclusively from the seeps, but only for 9 months of the year. For all species, seeps are not available when the river stage is high from snowmelt[6]. For one quarter of the year between mid-April and mid-July, which coincides with when migratory species are present, the seeps are below the river and are inaccessible. In addition, bats use a combination of hibernating and seeking alternative sources of emergent insects during the winter months (*Living with Wildlife: Bats* [WDFW, 2004). Therefore, the conservative assumption of exclusively drinking from the seeps lends to an over-estimation of seep use for drinking water.

Assuming that wildlife meet their daily drinking water requirements from the seeps, instead of a more available source such as the river, is a conservative approach meant to evaluate a worst-case scenario. Terrestrial mammals at Hanford have large home ranges (e.g., elk [167 ha] and badgers [480 ha]), and thus may not use the seeps along the 100-BC Area as an exclusive source of drinking water. Home ranges for selected Hanford receptors are presented in Appendix H, Table H-5. Aerial species including bats and some of the bird species present at the site (e.g., swallows) are not present on the site year- round. Although some species may use the seeps daily when present, the migratory species (e.g., swallows) only forage at the site a portion of the year and for these species use of the seeps along the river is not an exclusive source of chronic exposure. Therefore, an AUF of 0.75 was employed for all species except bats. For bats, an AUF of 0.5 was used because bats use a combination of hibernating and seeking alternative sources of emergent insects during the winter months (*Living with Wildlife: Bats* [WDFW, 2004]).

Estimates are not included for small mammals because they maintain water balance through excreting concentrated urine, obtaining water from food and water generated during metabolism ("*Perognathus parvus*" [Verts and Kirkland, 1988]).

Although filtered water data are used in evaluations of the effects on aquatic receptors because those are the concentrations that are bioavailable, unfiltered concentrations are more appropriate for drinking water, because bioavailability may change within the digestive tract. Both were included in order to be comprehensive, because in rare cases filtered measurements can be higher than unfiltered. Results of filtered concentration and unfiltered concentration data were evaluated separately. Results were not pooled so as to not bias any one sampling event at which both measurements occurred. Results of potential drinking water exposure are presented in Appendix H.

7.3.4 PRGs

The PRGs presented in this report represent Hanford Site-specific values as presented in *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311). Much of the modeling used to develop PRGs for wildlife is presented in this report because the PRGs build on the SSLs (*Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-00784]), using the same receptors, exposure models, life history parameters, and TRVs. The only deviations from the SSL development were the uses of bioaccumulation models that reflect a food chain for an arid environment such as the Hanford Site, and integration of Hanford Site-specific data. The SSLs included prey tissue estimation models that were generic and included a wide variety of species, only some of which are likely to occur within the arid environment at Hanford. Most invertebrate data included in the food web models for SSL development for invertivores and omnivores relied on bioaccumulation data from earthworms and other soil invertebrates. Soil

[6] More information on river stage is found in Chapter 4 and in CH2M-51535-VA, *River Corridor Decision Unit Risk Assessment Sampling Program.*

invertebrates such as earthworms are rarely encountered in the arid upland soils found at the Hanford Site. Thus, modeling for PRG development (*Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-01311]) incorporated additional Hanford Site-specific tissue data and data from other closely related ecosystems and more recent data specific to insects found at Hanford that had not been available when either MTCA, "Site-Specific Terrestrial Ecological Evaluation Procedures" (WAC 173-340-7493) or EPA EcoSSLs were developed.

The development of PRGs corresponds to an exposure and effects assessment, conducted as part of a baseline ERA within ERAGS (EPA 540-R-97-006), and reflects*Ecological Risk Assessment and Management Principles for Superfund Sites* (OSWER Directive 9385.7-28P), which encourages the use of site-specific ecological risk data to support cleanup decisions, whenever practicable. The process for development of PRGs also is consistent with MTCA, "Site-Specific Terrestrial Ecological Evaluation Procedures" (WAC 173-340-7493). None of the differences were recalculations of the original datasets and models used to derive the WAC values. Rather, all of the changes from MTCA (WAC 173-340) Table 749-3 are based on updated exposure models (from *Guidance for Developing Ecological Soil Screening Levels* [OSWER Directive 9285.7-55]) and toxicological literature reviews that were not available at the time MTCA (WAC 173-340) Table 749-3 was developed. These PRGs are intended to be applied to all upland environments across the Hanford Site. Although additional receptors may also be present in riparian areas, the wildlife PRGs and the supporting bioaccumulation and exposure models and TRVs are applicable for riparian areas and can be used in conjunction with values for those additional receptors.

Hanford Site-specific wildlife PRGs are presented in Table 7-4. Hanford Site-specific PRGs were researched for inorganic and organic constituents, but not radionuclides. Ultimately, Hanford-specific PRGs were only recommended for inorganics, because Hanford Site-specific data were limited for organics. Confidence in these PRGs as a whole is greater than for the SSLs because they were developed specifically for use at Hanford using Site-specific data. Relative to each other, confidence in some PRGs is greater than in others. The additional confidence is the result of a combination of the total number of Hanford Site-specific paired soil and tissue samples and the strength of the relationship between tissue and soil concentration (correlation). Details regarding the confidence in specific PRGs were included in the SMDP in Section 7.6 as needed.

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Table 7-4. PRGs for Wildlife (Birds and Mammals)

Analyte Group	Analyte	Units	California Quail	Western Meadowlark	Killdeer	Red-Tailed Hawk	Lowest Avian PRG	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	Lowest Mammal PRG	Lowest Wildlife PRG
General Inorganic	Fluorine	mg/kg	NBD	2,686	**845**	11,074	845	NBD	3,877	4,061	13,833	3,877	845
Metal	Silver	mg/kg	4,238	3,973	**983**	20,186	983	24,465	9,806	14,362	30,778	9,806	983
Metal	Aluminum	mg/kg	19,217	31,220	7,214	74,599	7,214	4,883	**3,988**	13,059	7,811	3,988	3,988
Metal	Arsenic	mg/kg	4,776	7,403	2,284	40,102	2,284	201	**127**	302	847	127	127
Metal	Boron	mg/kg	248	144	91	2,714	91	122	**91**	170	2,516	91	91
Metal	Barium	mg/kg	1,721	2,335	**1,687**	8,101	1,687	2,265	2,617	11,873	12,430	2,265	1,687
Metal	Beryllium	mg/kg	NTD	NTD	NTD	NTD	NTD	**18**	22	181	NBD	18	18
Metal	Cadmium	mg/kg	294	103	**29**	1,711	29	2,203	624	858	4,704	624	29
Metal	Cobalt	mg/kg	1,397	2,050	**484**	4,798	484	2,901	2,136	5,610	4,234	2,136	484
Metal	Chromium	mg/kg	193	221	**109**	2,595	109	544	517	1,424	4,918	517	109
Metal	Copper	mg/kg	2,020	1,532	**213**	12,881	213	2,176	579	1,217	4,631	579	213
Metal	Mercury	mg/kg	36	4.7	2	92	2	7.9	**1.6**	1.8	33	1.6	1.6
Metal	Lithium	mg/kg	-	-	-	-	-	**1,664**	1,797	8,347	6,522	1,664	1,664
Metal	Manganese	mg/kg	20,746	26,026	14,407	150,899	14,407	**3,322**	3,467	11,780	21,916	3,322	3,322
Metal	Molybdenum	mg/kg	125	117	95	515	95	5.9	**5.7**	14	38	5.7	5.7
Metal	Nickel	mg/kg	2,051	1,127	361	11,625	361	711	**247**	342	1,520	247	247
Metal	Lead	mg/kg	559	664	**156**	2,300	156	2,672	1,578	3,807	3,966	1,578	156
Metal	Antimony	mg/kg	-	-	-	-	-	231	**146**	366	NBD	146	146
Metal	Selenium	mg/kg	10	4.9	2.4	24	2	2.7	**1.4**	1.9	8.8	1.4	1.4
Metal	Strontium (Elemental)	mg/kg	-	-	-	-	-	**1,214**	1,449	6,540	8,256	1,214	1,214
Metal	Tin	mg/kg	97	98	**84**	335	84	130	133	365	693	130	84
Metal	Thallium	mg/kg	-	-	-	-	-	8.7	**6.2**	12	25	6.2	6.2
Metal	Uranium (Calculated Total)	mg/kg	2,002	339	139	82	82	812	123	119	**40**	40	40
Metal	Vanadium	mg/kg	81	107	**43**	505	43	260	297	4,531	3,596	260	43
Metal	Zinc	mg/kg	6,289	4,662	**856**	906	856	6,711	3,331	12,666	1,037	1,037	856

Notes: **Bold values** represent lowest PRG for that analyte.
Shaded values are based on NOAELs because of the lack of LOAELs.
NBD = no (or incomplete) bioaccumulation data (for estimation of dietary exposure)
NTD = No toxicity data (for selected analyte)

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PRGs for inorganic chemicals protective of plants and invertebrates are presented in Table 7-5. When Hanford Site-specific toxicological data on the effects of plants and soil invertebrates were available, these data were considered for PRG selection. These data are summarized in the following three documents: *Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site* (ECF-HANFORD-11-0158, found in Appendix H of 100-K RI/FS), the RCBRA (DOE/RL-2007-21), and *Ecological Soil Screening Levels for Arsenic and Lead in the Tacoma Smelter Plume Footprint and Hanford Site Old Orchards Ecology* (Ecology Publication 11-03-006). All of the site-specific toxicological thresholds presented in these documents are NOECs. Thus, for each chemical studied in one or more of these documents, the greatest NOEC among these documents was selected as the PRG for that chemical. When Hanford Site-specific thresholds for plants and invertebrates were not presented in these three documents, the EcoSSL was selected as the PRG because it included more recent information than what was available when MTCA (WAC 173-340) Table 749-3 was developed. When an EcoSSL was not available, the value from WAC was selected. The two exceptions were as follows:

- The Hanford Site-specific background value for cobalt was selected as the PRG for both plants and invertebrates. There is no WAC or EcoSSL value for invertebrates. The background value of 15.7 mg/kg is greater than the plant EcoSSL of 13 mg/kg. Although the WAC plant value of 20 mg/kg is greater than the background value, it is based on the value from ORNL and the original authors gave the value low confidence. Site-specific plant and invertebrate NOEC values of 11.2 mg/kg and 12.2 mg/kg were also available from the RCBRA but these values were the highest concentrations tested and were lower than background.

- The cadmium value for invertebrates of 20 mg/kg from WAC was selected as the PRG over the EcoSSL of 140 mg/kg. The WAC value was based on an ORNL recommendation where the authors gave a moderate to high confidence in the recommendation and this was considered of equal weight with the EcoSSLs, so the lower of the values of equal confidence was selected.

The final recommended PRG represented the most appropriate value, leaning toward the most recent data available that met the criteria set forth in EPA (ERAGS [EPA 540-R-97-006]) and MTCA "Site-Specific Terrestrial Ecological Evaluation Procedures" (WAC 173-340-7493) guidelines for selecting site-specific criteria. In selection of values that differ from MTCA (WAC 173-340) Table 749-3, when multiple recent toxicological data sources were available, the value of the highest confidence or the lower of two values with equally high confidence was chosen. The site-specific values are preferred over those from published literature in that they are more recent data that were not available at the time MTCA guidance or EcoSSLs were developed and they reflect the potential for toxicity under conditions found specifically at the site. However, with some COPECs, more recent site-specific sampling efforts were unable to obtain concentration ranges above those from published literature. With all of the site-specific studies conducted for the RCBRA (DOE/RL-2007-21), by Ecology, and recently by CH2M HILL Plateau Remediation Company, no clear significant toxicity to plants and invertebrates attributable to site soil contaminants was observed; thus, recommended toxicological values are unbound NOECs. Hence, in some cases, published literature values above these unbound NOECs were selected as PRGs over site-specific values. Final selection of the PRGS for plants and invertebrates is discussed in detail in *Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site* (ECF-HANFORD-11-0158). As with the wildlife PRGs, details regarding the confidence in specific PRGs were included in the SMDP in Section 7.6 as needed.

Table 7-5. Final Recommended Soil PRGs for Plants and Invertebrates

Chemical	Plant NOEC (mg/kg)	Invertebrate NOEC (mg/kg)
Antimony	842	842
Arsenic	128	128
Barium	500	358
Beryllium	10	40
Boron	29.6	58
Cadmium	9.84	20
Chromium	259	149
Cobalt	15.7	15.7
Copper	70	58
Lead	9090	1700
Manganese	1260	1260
Mercury	0.3	12.5
Molybdenum	2	28
Nickel	38	280
Selenium	2.02	4.1
Silver	560	2.99
Thallium	1	0.459
Tin	838	838
Uranium	250	100
Vanadium	89.4	116
Zinc	621	8980

7.3.5 Estimation of Exposure Point Concentrations in Waste Sites

As mentioned earlier, assuming that wildlife forage exclusively within the boundaries of a waste site or that the data collected from within a waste site represent the central tendency of exposure to wildlife is a highly conservative assumption. In reality, the concentration of contaminants to which a wildlife population is exposed includes points both in and out of the waste site being investigated unless there are physical barriers preventing exposure. Thus, a true exposure estimate would include data points both in and out of the site boundary; and in some investigations for other sites, the points outside have been generated by either measured data or have been assumed to be at background. However, methods for this type of estimate of exposure are not defined in guidance and are not commonplace. What is common in ecological risk assessment practice, and what was done for this ERA, is to initially characterize risks assuming an area use factor of 1 (all exposure is within the site) and then refining that assumption should

the highly conservative exposure estimate and risk characterization suggest an unacceptable risk warranting further evaluation. Hence, this section describes the method by which EPCs were derived within the waste sites that assumed an AUF of 1. The SMDP in Section 7.6 describes in detail how AUFs should be used for evaluating waste sites.

A total of 81 waste sites at the 100-BC Source OUs were verification sampled and were included in this ERA. Section 6.1.2 details the computation of the EPCs for the waste sites at the 100-BC Source OU. Briefly, the 95 percent UCL of the arithmetic mean was calculated as the EPC for each decision unit (shallow, staging pile area, and overburden) within each waste site. Two separate statistical evaluations were performed, one used for the closeout documentation and one used for human health and ecological risk assessments, as follows:

- **Statistical Evaluation Used for Closeout Documentation:** For the closeout documentation, the primary statistical calculation to support cleanup verification was the 95 percent UCL on the arithmetic mean of the data. As in *Statistical Guidance for Ecology Site Managers* (Ecology Publication 92-54), a 95 percent UCL on the mean based on the Student's t-test statistic was used for normally distributed data, and the Land method using the H-statistic was used for lognormal data. This guidance also employs the use of a proxy value of one-half the detection limits for nondetect values. For small datasets (n less than10), typically the maximum detected concentration was used as the EPC.

- **Statistical Evaluation Used for Soil Risk Assessment:** Both *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (hereinafter called Calculating UCL for EPCs [OSWER 9285.6-10]), which is the most recent EPA guidance for UCL calculation, and "Statistical Software ProUCL 4.1.00 for Environmental Applications for Data Sets with and without Nondetect Observations," (ProUCL Software) were used to recalculate EPCs for the human health and ecological risk assessments of the 100-K OU waste site decision units. Although *Statistical Guidance for Ecology Site Managers* (Ecology Publication 92-54) has been used to calculate EPCs for all closeout documentation to date, EPCs were recalculated according to Calculating UCL for EPCs (OSWER 9285.6-10) to allow for the use of more rigorous statistical methods to estimate exposure concentration and to eliminate the use of the one-half the detection limit used in *Statistical Guidance for Ecology Site Managers* (Ecology Publication 92-54), which has the potential to underestimate exposure concentrations.

The process used to calculate EPCs for each waste site and decision unit is documented in *Computation of Exposure Point Concentrations for the 100-BC-1 and 100-BC-2 Source Operable Units* (ECF-100BC-11-0012) in Appendix G. The purpose of *Computation of Exposure Point Concentrations for the 100-BC-1 and 100-BC-2 Source Operable Units* (ECF-100BC-11-0012) is to document the data processing and reduction steps, methodology, decision logic, assumptions, input files, and output files used to determine the EPCs. EPCs generated for use in this evaluation for each waste site, decision unit, and detected analyte at the 100-BC Source OU is provided in Appendix H, Table H-6.

For the drinking water evaluation included in Section 7.4.4, limited data are available and estimating exposure can be complicated because of the presence of seeps and observed concentrations dependent on river stage; and for several species of birds, migration patterns are also a factor. EPCs of the seep concentrations in the 100-BC OU were used for simplicity, calculated using Pro UCL software in the same way as were soil EPCs.

7.4 Risk Characterization

The outcome of this step is a list of COPECs for each medium-pathway-receptor combination evaluated. Risks at the 100-K Source OU waste sites were estimated using the HQ method as follows:

$$HQ=EPC/SSL \text{ or } PRG$$

where:

HQ = Ecological hazard quotient (unitless)

EPC = Soil concentration (µg/kg for nonradionuclides and pCi/g for radionuclides)

SSL = Plant/invertebrate or wildlife soil screening level (µg/kg for nonradionuclides and pCi/g for radionuclides)

PRG = Plant/invertebrate or wildlife preliminary remediation goal (µg/kg for nonradionuclides)

HQ values less than 1.0 indicate that adverse effects associated with exposure to a given analyte are unlikely (ERAGS [EPA 540-R-97-006]). These analytes were not considered to present a significant risk and were excluded from further evaluation. An HQ greater than or equal to 1.0 indicates data are insufficient to exclude the potential for risk, but does not indicate that risks are actually present; therefore, these COPCs were carried forward for further evaluation by comparing the EPCs to the background values (Appendix H, Table H-7) as summarized in Table 7-6 and Section 7.4.2.

Table 7-6 Remediated Waste Sites Exceeding SSLs and Background for Surface Soils (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances based on comparisons to SSLs and Background	
	Plant/Invertebrate SSL-based HQ	Wildlife SSL-based HQ
100-B-11_Shallow_Focused	Boron (11.4)	--
100-B-14:1_Overburden_2	--	Carbon-14 (1.4) Europium-155 (0.000001)
100-B-14:2_Overburden_Focused	Mercury (4.7)	--
100-B-14:2_Shallow_2	Mercury (1.2) Zinc (1.7)	Zinc (1.3)
100-B-14:5_Shallow_Focused	Boron (8.8) Zinc (1.5)	Zinc (1.1)
100-B-14:6_Shallow_Focused	Barium (1.1) Boron (11.6) Chromium (122.8) Mercury (14.0)	Chromium (1.3)
100-B-14:7_Shallow_Focused	Boron (10.8) Chromium (63.5) Zinc (1.6)	Zinc (1.2)
100-B-18_Shallow_Focused	Antimony (1.9) Barium (3.9)	Antimony (1.6) Cadmium (8.1)

Table 7-6 Remediated Waste Sites Exceeding SSLs and Background for Surface Soils (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances based on comparisons to SSLs and Background	
	Plant/Invertebrate SSL-based HQ	Wildlife SSL-based HQ
	Boron (68.4) Cadmium (3.3) Mercury (22.0) Zinc (1.6)	Mercury (1.2) Zinc (1.1)
100-B-19_Shallow_1	Chromium (97.1)	Chromium (1.0)
100-B-19_Shallow_2	Selenium (1.7)	--
100-B-19_Shallow_5	Mercury (61.0)	Mercury (3.3)
100-B-19_Shallow_Focused	Mercury (171.0) Vanadium (45.7)	Mercury (9.2) Vanadium (2.9)
100-B-19_Staging pile area	Selenium (1.7)	--
100-B-20_Shallow_Focused	Mercury (3.3) Zinc (6.5)	Zinc (4.8)
100-B-21:4_Shallow	Chromium (80.1) Selenium (2.0)	--
100-B-22:2_Shallow_Focused	Boron (18.5) Chromium (62.0) Copper (1.3) Lead (2.5) Mercury (3.2) Molybdenum (1.0) Zinc (3.5)	Lead (3.5) Zinc (2.6)
100-B-22:2_Staging pile area_Focused	Boron (8.2) Mercury (1.6) Zinc (1.6)	Zinc (1.2)
100-B-23_Shallow_Focused	Boron (28.2) Lead (1.5) Mercury (82.0) Zinc (26.2)	Cadmium (1.0) Lead (2.1) Mercury (4.4) Zinc (19.3)
100-B-26_Shallow_Focused	Chromium (98.3) Zinc (2.2)	Chromium (1.0) Zinc (1.6)
100-B-27_Staging pile area	Boron (20.3)	--
100-B-28_Overburden_Focused	Selenium (1.9)	Zinc (1.4)

Table 7-6 Remediated Waste Sites Exceeding SSLs and Background for Surface Soils (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances based on comparisons to SSLs and Background	
	Plant/Invertebrate SSL-based HQ	Wildlife SSL-based HQ
	Zinc (1.9)	
100-B-28_Shallow_1	Boron (10.0)	--
100-B-28_Shallow_3	Manganese (2.4) Mercury (1.6) Zinc (11.4)	Zinc (8.4)
100-B-28_Shallow_5	Chromium (48.4)	--
100-B-28_Shallow_Focused	Chromium (125.3) Mercury (8.0) Selenium (1.9) Vanadium (53.0) Zinc (1.6)	Chromium (1.3) Vanadium (3.4) Zinc (1.2)
100-B-28_Staging pile area_2	Boron (14.4) Mercury (2.4) Zinc (1.5)	Zinc (1.1)
100-B-28_Staging pile area_4	Mercury (46.3) Selenium (1.6)	Mercury (2.5)
100-B-31_Shallow	Lead (1.6) Mercury (1.1) Molybdenum (2.2) Selenium (1.6)	Lead (2.2)
100-B-33_Shallow_Focused	Boron (9.3) Selenium (1.7)	--
100-B-8:1_Shallow	--	Lead (1.1)
100-C-9:1_Shallow_2	Mercury (18.4)	--
100-C-9:2_Shallow	Zinc (5.3)	Zinc (3.9)
100-C-9:2_Shallow_Focused	Boron (10.2) Copper (1.3) Lead (3.0) Mercury (8.5) Zinc (2.2)	Lead (4.3) Zinc (1.6)
116-B-10_Shallow	Chromium (59.5) Mercury (13.0)	--

Table 7-6 Remediated Waste Sites Exceeding SSLs and Background for Surface Soils (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances based on comparisons to SSLs and Background	
	Plant/Invertebrate SSL-based HQ	Wildlife SSL-based HQ
116-B-11_Shallow	Mercury (1.2)	--
116-B-14_Shallow	Chromium (84.0)	--
116-B-5_Shallow_Focused	Antimony (1.1) Mercury (160.0)	Mercury (8.6) Tritium (1.6) Cesium-137 (0.001) Cobalt-60 (0.001) Europium-152 (0.004) Europium-154 (0.0004)
116-B-7, 132-B-6, 132-C-2_Shallow	Chromium (47.7)	--
116-B-9_Shallow	Mercury (3.9)	--
116-C-2A_Shallow	Mercury (1.2)	--
116-C-3_Shallow	Boron (14.5)	Carbon-14 (1.3) Plutonium-239/240 (0.00002) Total beta radiostrontium (0.006) Tritium (0.02)
116-C-3_Shallow_Focused	Boron (48.6) Chromium (66.0)	--
116-C-3_Staging pile area_Focused	Selenium (3.1)	--
118-B-1_Overburden_1	Mercury (20.0)	Mercury (1.1)
118-B-1_Overburden_9	Selenium (1.5)	--
118-B-1_Shallow_2	Boron (11.0)	--
118-B-1_Shallow_3	Boron (17.8) Mercury (3.0)	--
118-B-1_Shallow_4	Boron (7.8)	--
118-B-1_Shallow_6	Boron (17.6)	--
118-B-1_Shallow_7	Boron (36.2) Molybdenum (1.1)	--
118-B-1_Shallow_Focused	Boron (49.0)	Mercury (7.8)

Table 7-6 Remediated Waste Sites Exceeding SSLs and Background for Surface Soils (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances based on comparisons to SSLs and Background	
	Plant/Invertebrate SSL-based HQ	Wildlife SSL-based HQ
	Mercury (145.0)	
118-B-1_Staging pile area_Focused	Mercury (103.0)	Mercury (5.5)
118-B-10_Shallow_Focused	Mercury (2.3)	--
118-B-3_Shallow_Focused	--	Lead (1.2)
118-B-7_Shallow_Focused	Mercury (1.1)	--
118-B-9_Shallow_Focused	Boron (19.4) Mercury (2.3) Zinc (5.0)	Zinc (3.7)
118-C-1_Shallow_3	Molybdenum (2.3) Zinc (1.5)	Zinc (1.1)
118-C-1_Shallow_4	Boron (9.8)	--
118-C-1_Staging Pile Area	Copper (1.2) Selenium (1.5)	Carbon-14 (5.8) Cesium-137 (0.001) Cobalt-60 (0.00008) Europium-152 (0.0001) Total beta radiostrontium (0.004)
118-C-3:3_Shallow_Focused	Mercury (8.0)	--
120-B-1_Shallow_Focused	Boron (16.2) Chromium (682.5) Molybdenum (1.1) Zinc (1.4)	Chromium (7.2) Zinc (1.1)
126-B-3_Shallow	Boron (9.9)	--
126-B-3_Staging pile area_Focused	Zinc (4.4)	Zinc (3.2)
128-B-3_Shallow_2	Boron (12.7) Chromium (91.8) Zinc (2.2)	Lead (1.1) Zinc (1.6)
128-B-3_Shallow_3	Molybdenum (2.4)	--
128-B-3_Staging pile area	Boron (12.1) Mercury (3.7) Zinc (1.6)	Zinc (1.2)

Table 7-6 Remediated Waste Sites Exceeding SSLs and Background for Surface Soils (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances based on comparisons to SSLs and Background	
	Plant/Invertebrate SSL-based HQ	Wildlife SSL-based HQ
128-B-3_Staging pile area_Focused	Boron (35.0) Mercury (1.2)	--
128-C-1_Shallow	Boron (19.6) Selenium (2.5) Silver (1.8) Zinc (1.4)	Zinc (1.0)
128-C-1_Shallow_Focused	Chromium (49.0) Lead (1.2) Mercury (2.0)	Cadmium (1.1) Lead (1.7)
1607-B1_Shallow_Focused	Mercury (2.3) Zinc (1.9)	Zinc (1.4)
1607-B10_Shallow	Chromium (63.0) Mercury (3.8)	--
1607-B2:1_Shallow	Barium (1.2) Boron (39.6) Chromium (47.8) Manganese (2.6)	--
1607-B2:2_Overburden_Focused	Mercury (1.4)	--
1607-B2:2_Shallow	Boron (9.3) Copper (1.0) Mercury (2.4)	--
1607-B7_Shallow	--	Lead (1.2)
1607-B8_Shallow	Lead (3.3) Mercury (1.0)	Lead (4.7)
1607-B9_Shallow	Mercury (1.2)	--
600-233_Shallow_Focused	Selenium (5.8)	Selenium (1.6)

* 90th percentile of Hanford Site background concentration

In the screening evaluation, the soil EPC for each waste site and decision unit (as applicable) was compared to the plant/invertebrate SSL and the wildlife SSL for all COPCs. The HQs for these comparisons are provided in Appendix H, Table H-5. COPCs with HQs equal to or greater than 1.0 were carried forward for further evaluation. COPCs for which appropriate toxicity data were unavailable were not evaluated further, but were retained as uncertainties.

Because the plant/invertebrate and/or wildlife SSL values for 10 COPCs (arsenic, boron, lithium, mercury, manganese, molybdenum, selenium, strontium, thallium, and uranium) were higher than the corresponding PRG values, comparisons of the EPCs for these chemicals with both SSLs and PRGs were reviewed to confirm the EPCs were below both the SSL and PRG. For these 10 chemicals, if an EPC was greater than either the SSL or PRG, the chemical was carried into the background evaluation for that specific waste site decision unit.

7.4.1 Risk Characterization for Radionuclides and Aroclors

Because the dose from radionuclides is additive, the total contributions of radionuclides were calculated using the sum of fractions (SOF) approach. With the SOF method, contributions were considered significant if the EPC was greater than the SSL. The SOF equation is as follows:

$$\text{HI or SOF} = \sum_{j=1}^{n} \text{Exposure}_j / \text{SSL}_j$$

where:

HI	=	hazard index
SOF	=	sum of fractions
Exposure_j	=	exposure concentration for radionuclides
SSL_j	=	soil screening level for radionuclides

For the purposes of this evaluation, the HQs for each radionuclide were summed within each decision unit to equal an SOF. If the SOF was greater than 1, then individual detected radionuclide isotope COPCs were carried forward to the background evaluation. For those COPCs that exceeded one or more SSLs, the EPC was then compared to the background value and summarized in the subsequent table (Appendix H, Table H-7), in Section 7.4.2.

Similarly, for aroclors, HIs were calculated to evaluate additive effects. If the HI for aroclors was greater than 1, then the detected aroclors were identified for further evaluation.

7.4.2 Characterization Relative to Background

Background concentrations for inorganic analytes in soil at the Hanford Site are described in the Non-Rad Soil Background document (DOE/RL-92-24). That document provides the 90th percentile background concentrations for several inorganic analytes. For selected inorganic analytes not included in the Non-Rad Soil Background document (DOE/RL-92-24), the 90th percentile concentration has been obtained from PNNL, as summarized in *Soil Background Data for Interim Use at the Hanford Site* (ECF-HANFORD-11-0038), and from the 100 Area RDR/RAWP (DOE/RL-96-17) for uranium. Background concentrations for radiological analytes in soil at the Hanford Site are described in Rad Soil Background document (DOE/RL-96-12), which provides the 90th percentile concentration of background concentrations for several radiological analytes. Background concentrations were not identified for organic chemicals; therefore, all organic chemicals, with HQs greater than or equal to 1.0 were carried forward. COPC EPCs that were less than the 90th percentile background concentration were excluded from further evaluation. COPCs with EPCs that were not within the range of site background were carried forward for comparison to the PRGs.

7.4.3 Further (Refined) Characterization Relative to PRGs

In the PRG evaluation, the soil EPC for each waste site and decision unit (as applicable) was compared to the plant/invertebrate PRG and the wildlife PRG for all remaining COPCs. COPCs with HQs equal to or greater than 1.0 were retained as COPECs. COPECs were then given further consideration under the SMDP. The methodology used in this step of the risk characterization is provided in Appendix H (*Ecological Risk Evaluation for the 100-BC Source Operable Units* [ECF-100-BC1-11-0014]).

7.4.4 Characterization of Risk through Ingestion of Drinking Water

Freshwater seep drinking ingestion HQs for inorganic chemicals were estimated as the ratio of estimated ingestion doses to TRVs. The TRVs employed were the same as those used to develop the wildlife PRGs used to evaluate soil as presented in *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-00784) and *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311).

$$HQ = Dose/TRV$$

where:

HQ = ecological hazard quotient (unitless)

Dose = drinking water exposure (mg/kg body weight/day)

TRV = toxicological reference value (mg/kg-body weight-day)

For radionuclides, the HQs for evaluating freshwater seep drinking water ingestion were simply a ratio of the measured concentrations in water multiplied by the AUF compared to the BCGs for wildlife. The lowest water BCG of terrestrial or riparian animal receptors were taken from Graded Approach for Radiation Doses to Biota (DOE-STD-1153-2002) or were calculated using the RESRAD BIOTA tool (*RESRAD-BIOTA: A Tool for Implementing a Graded Approach to Biota Dose Evaluation, User's Guide, Version 1* [DOE/EH-0676]) when not available. SOFs were calculated as described above. Also, as with the soil evaluation, the EPC represents the 95 percent UCL of the arithmetic mean concentration of the analyzed constituent.

$$HQ = (EPC*AUF)/BCG$$

where:

HQ = ecological hazard quotient (unitless)

EPC = radionuclide concentration in seep (pCi/L)

AUF = area use factor

BCG = biota concentration guides (pCi/L)

7.4.5 Screening Evaluation Results

The comparisons to plant/invertebrate and wildlife SSLs are provided in Appendix H, Table H-6 for the 100-BC Source OUs. A detailed description of the results of the screening evaluation (i.e., comparison of EPCs with SSLs) in soil is provided below and a summary of exceedances is provided in Table 7-6. The 100-BC Source OU has a total of 81 waste sites evaluated in this ERA. Samples collected greater than 4.6 m (15 ft) bgs (deep and deep focused) were not included in the risk assessment, so four of the 81 sites were eliminated from the risk assessment (100-B-14-3, 100-B-27, 100-C-9-3, 118-C-3-2). Therefore, plant/invertebrate and avian/mammalian SSL HQs for all 75 waste sites are provided in Appendix H, Table H-6. The SSL-based HQs were less than 1.0 for all COPCs in all of the decision units

evaluated at four of the 75 waste sites. These waste sites did not require further evaluation of ecological risk and are provided below:

- 100-B-32
- 118-B-4
- 118-B-6
- 118-C-2

The SSLs, background, and PRGs were not available for nickle-63 (radionuclide) and 25 organic analytes. These COPCs were retained as an uncertainty and are further discussed in Section 7.4.4. The aroclor HIs were less than 1 for all waste sites and all aroclors were eliminated from further evaluation. The EPCs for the inorganic analytes antimony, barium, boron, cadmium, chromium, cobalt, copper, lead, lithium, manganese, mercury, molybdenum, selenium, silver, vanadium, and zinc and the radionuclides carbon-14 and tritium exceeded one or both of the SSLs in 144 waste site/decision units, as presented in Appendix H, Table H-6. Radionuclide SOFs were greater than 1 at four waste sites. These exceedances were based on individual radionuclides, carbon-14 and tritium, in exceedance of their respective SSLs (BCGs). All individual radionuclides for these four waste site decision units were carried forward for additional evaluation. Within the remaining 72 waste sites, EPCs of analytes exceeded the plant/ invertebrate SSLs at each waste site, while fewer analytes exceeded the wildlife SSLs. These waste site decision units were carried forward into the background evaluation.

7.4.6 Results of Background Characterization

Although in exceedance of an SSL, EPCs for many of the COPCs within the remaining waste sites were below the 90th percentile background concentrations, so were eliminated from further evaluation. The comparisons of COPC EPCs to the 90th percentile background for the remaining waste sites are provided in Appendix H, Table H-7. COPCs did not exceed the 90th percentile background concentrations in all of the decision units evaluated at 25 of the remaining 72 waste sites. The 25 waste sites that did not require further evaluation of ecological risks are provided below:

- 100-B Area Sites: 100-B-1, 100-B-16, 100-B-21:2, 100-B-21:3, 100-B-25, 100-B-5, and 100-B-8:2
- 100-C Area Site: 100-C-3
- 116-B Area Sites: 116-B-1, 116-B-12, 116-B-13, 116-B-15, 116-B-2, 116-B-3, 116-B-4, 116-B-6A, and 116-B-6B
- 116-C Area Sites: 116-C-1, 116-C-5, and 116-C-6
- 118-B Area Sites: 118-B-5
- 118-C Area Site: 118-C-4
- 128-B Area Site: 128-B-2
- 1607-B Area Sites: 1607-B11
- 600 Area Site: 600-232

Within the remaining 47 waste sites, 78 decision units had COPC EPCs in exceedance of both an SSL and background. COPC EPCs detected in exceedance of background were carried forward to the PRG evaluation. The inorganic analytes antimony, barium, boron, cadmium, chromium, copper, lead, manganese, mercury, molybdenum, selenium, silver, vanadium, and zinc were detected outside of the

range of background. In addition, the radionuclides carbon-14 and tritium did not have background values, so were carried into the PRG evaluation because of SSL exceedances. A summary of SSL and background evaluation results for the 72 waste sites is provided in Table 7-6.

7.4.7 Results of PRG Characterization

Further evaluation was conducted on those waste sites that were not eliminated in the screening and background evaluations. Risks were evaluated based on the resulting PRG HQs and are provided in Appendix H, Table H-8 and summarized in Table 7-7. The following 16 waste sites did not exceed the plant/invertebrate PRGs or the wildlife PRGs (HQs were less than 1) and were eliminated from further evaluation:

- 100-B Area Sites: 100-B-14:1, 100-B-14:6, 100-B-18, 100B-20, 100-B-23, and 100-B-31
- 100-C Area Site: 100-C-9-1
- 116-B Area Sites: 116-B-5, 116-B-9, and 116-B-10
- 118-C Area Site: 118-C-3:3
- 120-B Area Site: 120-B-1
- 1607 Area Sites: 1607-B2:1, 1607-B8, and 1607-B10
- 600 Area Sites: 600-233

Table 7-7. Remediated Waste Sites Exceeding PRGs for Surface Soils (0 to 4.6 m [0 to 15 ft])

Waste Site/ Decision Unit	Plant/Invertebrate PRG-based HQ	Wildlife PRG-based HQ
100-B-14:1_Overburden_2	--	Carbon-14 (1.4)
100-B-14:2_Overburden_Focused	Mercury (1.6)	--
100-B-14:6_Shallow_Focused	Barium (1.0) Mercury (4.7)	--
100-B-18_Shallow_Focused	Barium (3.6) Boron (1.2) Cadmium (1.3) Mercury (7.3)	Mercury (1.4)
100-B-19_Shallow_5	Mercury (20.3)	Mercury (3.9)
100-B-19_Shallow_Focused	Mercury (57.0) Vanadium (1.0)	Mercury (11.0) Vanadium (2.1)
100-B-20_Shallow_Focused	Mercury (1.1)	--
100-B-22:2_Shallow_Focused	Copper (1.2) Mercury (1.1) Molybdenum (1.0)	--
100-B-23_Shallow_Focused	Mercury (27.3) Zinc (2.1)	Mercury (5.3) Zinc (1.5)
100-B-28_Shallow_Focused	Mercury (2.7) Vanadium (1.2)	Vanadium (2.5)

Table 7-7. Remediated Waste Sites Exceeding PRGs for Surface Soils (0 to 4.6 m [0 to 15 ft])

Waste Site/ Decision Unit	Plant/Invertebrate PRG-based HQ	Wildlife PRG-based HQ
100-B-28_Staging pile area_4	Mercury (15.4)	Mercury (3.0)
100-B-31_Shallow	Molybdenum (2.2)	--
100-C-9:1_Shallow_2	Mercury (6.1)	Mercury (1.2)
100-C-9:2_Shallow_Focused	Copper (1.1) Mercury (2.8)	--
116-B-10_Shallow	Mercury (4.3)	--
116-B-5_Shallow_Focused	Mercury (53.3)	Mercury (10.3) Tritium (1.6)
116-B-9_Shallow	Mercury (1.3)	--
116-C-3_Shallow	--	Carbon-14 (1.3)
116-C-3_Staging pile area_Focused	--	Selenium (1.1)
118-B-1_Overburden_1	Mercury (6.7)	Mercury (1.3)
118-B-1_Shallow_3	Mercury (1.0)	--
118-B-1_Shallow_7	Molybdenum (1.1)	--
118-B-1_Shallow_Focused	Mercury (48.3)	Mercury (9.3)
118-B-1_Staging pile area_Focused	Mercury (34.3)	Mercury (6.6)
118-C-1_Shallow_3	Molybdenum (2.3)	--
118-C-1_Staging Pile Area	Copper (1.0)	Carbon-14 (5.8)
118-C-3:3_Shallow_Focused	Mercury (2.7)	--
120-B-1_Shallow_Focused	Chromium (1.8) Molybdenum (1.1)	Chromium (2.5)
128-B-3_Shallow_3	Molybdenum (2.4)	--
128-B-3_Staging pile area	Mercury (1.2)	--
128-C-1_Shallow	Silver (1.2)	--
1607-B10_Shallow	Mercury (1.3)	--
1607-B2:1_Shallow	Barium (1.1)	--
1607-B8_Shallow	--	Lead (1.1)
600-233_Shallow_Focused	Selenium (1.5)	Selenium (2.1)

The EPCs for the inorganic analytes barium, boron, cadmium, chromium, copper, lead, mercury, molybdenum, selenium, silver, vanadium, and zinc exceeded one or both groups of PRGs (plants/invertebrates, wildlife). Because PRGs are not available for radionuclides, the concentrations of radiological parameters carbon-14 and tritium detected at concentrations exceeding wildlife SSLs were carried forward. These COPCs will be retained as COPECs in one or more of the remaining 35 waste site decision units as follows:

- 100-B-14:1_Overburden_2: Carbon-14
- 100-B-14:2_Overburden_Focused: Mercury
- 100-B-14:6_Shallow_Focused: Barium, and Mercury
- 100-B-18_Shallow_Focused: Barium, Boron, Cadmium, and Mercury
- 100-B-19_Shallow_5: Mercury
- 100-B-19_Shallow_Focused: Mercury and Vanadium
- 100-B-20_Shallow_Focused: Mercury
- 100-B-22:2_Shallow_Focused: Copper, Mercury, and Molybdenum
- 100-B-23_Shallow_Focused: Mercury and Zinc
- 100-B-28_Shallow_Focused : Mercury, and Vanadium
- 100-B-28_Staging pile area-4: Mercury
- 100-B-31_Shallow: Molybdenum
- 100-C-9:1_Shallow_2: Mercury
- 100-C-9:2_Shallow_Focused: Copper, and Mercury
- 116-B-10_Shallow: Mercury
- 116-B-5_Shallow_Focused: Mercury, and Tritium
- 116-B-9_Shallow: Mercury
- 116-C-3_Shallow: Carbon-14
- 116-C-3_Staging pile area_Focused: Selenium
- 118-B-1_Overburden_1: Mercury
- 118-B-1_Shallow_3: Mercury
- 118-B-1_Shallow_7: Molybdenum
- 118-B-1_Shallow_Focused: Mercury
- 118-B-1_Staging pile area_Focused: Mercury
- 118-C-1_Shallow_3: Molybdenum
- 118-C-1_Staging Pile Area: Copper and Carbon-14
- 118-C-3:3_Shallow_Focused: Mercury
- 120-B-1_Shallow_Focused: Chromium and Molybdenum
- 128-B-3_Shallow_3: Molybdenum
- 128-B-3_Staging pile area: Mercury
- 128-C-1_Shallow: Silver
- 1607-B10_Shallow: Mercury
- 1607-B2:1_Shallow: Barium
- 1607-B8_Shallow: Lead
- 600-233_Shallow_Focused: Selenium

7.4.8 Characterization of Drinking Water Ingestion

EPCs from seep water along the 100-BC riparian areas of the Columbia River were evaluated for drinking water intake by birds and mammals representing feeding guilds in the upland and riparian areas of the CRC. The results of the comparisons for nonradionuclides are provided in Appendix H, Table H-9. Under this scenario, exposure from chemicals to all receptors produced HQs of less than 1, indicating no additional risk for wildlife exposure to nonradionuclides from drinking seeps at the 100-BC Area. Further, the results of the evaluation presented in Table 7-7 should be considered acceptable for all of the chemical-Source OU combinations because inclusion of drinking ingestion to the exposure models presented in this chapter (Sections 7.4.1 through 7.4.3) would not have altered the outcomes.

Evaluation of radionuclide doses from wildlife drinking the seep water is included in Appendix H, Table H-10. EPCs for seeps were compared to the lower of BCGs for terrestrial, aquatic, and riparian animals. The total SOF for wildlife drinking seep water from the 100-BC Area was less than 0.01 (Appendix H, Table H-10), indicating there is no additional risk for wildlife exposure to radionuclides from drinking from seeps at the 100-BC Area.

Given the results provided in Appendix H (Tables H-9 and H-10), there is no significant risk to wildlife in the 100-BC Source OUs from drinking freshwater seeps along the Columbia River in the 100-BC riparian area. Further, the results of the evaluation presented in Appendix H should be considered acceptable for all of the chemical-source OU combinations because the inclusion of drinking ingestion in the exposure models presented in this chapter (Sections 7.4.1 through 7.4.3) would not have altered the risk outcomes or conclusions. Inclusion of drinking ingestion in the development of SSLs and PRGs is therefore not warranted.

7.4.9 Uncertainties Assessment

Uncertainties are present in all risk assessments because of the limitations of the available data and the need to make certain assumptions and extrapolations based on incomplete information. In addition, the use of various models (e.g., uptake and food web exposures) carries with it some associated uncertainty as to how well the model reflects actual conditions. Because conservative assumptions were generally used in the exposure and effects assessments, these uncertainties are more likely to result in an overestimation rather than an underestimation of the likelihood and magnitude of risks to ecological receptors. The following uncertainties and limitations associated with the proposed methodology and available data for the ERA are discussed:

- **Data Use**—The quantitative evaluation of chemical concentrations in soils included surface soils from the 0 to 4 m (0 to 15 ft) depth range. Ecology uses a standard point of compliance in soil of 4.6 m (15 ft) for demonstrating protection of ecological receptors (MTCA, "Terrestrial Ecological Evaluation Procedures" [WAC 173-340-7490(4)(b)]). This depth range may over-estimate the depth to which many terrestrial receptors would be exposed. MTCA(WAC 173-340) identifies the biologically active zone in 0 to 1.8 m (0 to 6 ft) (MTCA [WAC 173-340]). Evaluation of data that extends beyond the biologically active zone could either over- or under-estimate risk. For this ERA, the depth from 1.8 to 4.6 m (6 to 15 ft) is also included because human activities could bring materials from that depth to the surface, creating a complete exposure pathway.

  No toxicological data or background were available for some COPCs (8 SVOCs [di-n-butylphthalate, alpha-BHC, carbazole, dibenzofuran, pentachlorophenol, butylbenzylphthalate, hexachloroethane, n-nitrosodiphenylamine], TPH, 11 pesticides [endrin, gamma-BHC, heptachlor, heptachlor epoxide, 2,4,5-T, 2,4,5-TP Silvex, 2,4-D, 2,4-DB, dalapon, dicamba, dinoseb], acetone, nitrogen in nitrate, and nickel-63) or were limited for some COPC/receptor combinations. Therefore, SSLs could not be calculated for all receptors or COPCs. Exclusion of COPCs from SSL development may not

adequately address aggregate risk at a site, although it should be noted that remedial alternatives that are protective of receptors with SSLs may also be protective of receptors lacking sufficient toxicity data. In addition, the absence of SSLs for plants and soil invertebrates can be addressed through performing site-specific bioassays, which are a component of Tier 2.

With respect to TPH, although no SSL or PRG was previously developed for soils at the Hanford Site, published literature is available to provide some perspective. In "Ecotoxicity Test Data for Total Petroleum Hydrocarbons in Soil: Plants and Soil-Dwelling Invertebrates" (Efroymson et al., 2004), the authors compiled a literature review on toxicological effects to plant and invertebrates with the results suggesting invertebrates are more sensitive to some petroleum hydrocarbons than plants. Using lube oil to represent TPH, no effect thresholds ranged from 15 to 1,490 mg/kg in soil and EC20 were found as low as 15 to 149 mg/kg. Conversely, lube oil NOAECs for plants ranged from 969 mg/kg to 12,000 mg/kg. MTCA lists ecological indicator soil concentrations (MTCA (WAC 173-340), Table 749-3) for soil biota for diesel and gasoline range organics at 200 mg/kg and 100 mg/kg, respectively, based on original work published at ORNL (*Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision* [ES/ER/TM-126/R2]). With concentrations as high as 431 mg/kg measured at waste site decision units within the 100-BC OUs, TPH should be considered in the SMDP. These include 100-B-18_Shallow_Focused, 100-B-23_Shallow_Focused, 118-C-1_Staging Pile Area, 128-B-3_Shallow_2, 128-B-3_Shallow_3, 128-B-3_Staging pile area. Three other sites measured TPH but concentrations were below the MTCA values for diesel and gasoline.

Bioavailability and toxicity of metals are functions of many factors including soil pH, with metals (e.g. aluminum, lead, mercury) generally being more bioavailable and toxic at low pHs (*Guidance for Developing Ecological Soil Screening Levels* [OSWER Directive 9285.7-55])). The pH range for soil used to develop plant toxicity values ranges from 3 to 8. (mean = 6.3) (*Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-00784]). The pH range for soil used to develop invertebrate toxicity values ranges from 3.8 to 8.1 (mean = 5.6) (*Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-00784]). The minimum soil pH reported in the RCBRA (DOE/RL-2007-21) in riparian and upland soil was 6.6. Soil pH in the Outer Area of the Central Plateau ranges from 3.6 to 9.9, with 93 percent of observations greater than 6.6. Because the range of pH values in soils associated with plant and soil invertebrate toxicity values within the published literature includes values that are substantially lower than those present throughout most of the Hanford Site, it is likely that the resulting SSLs for plants and soil invertebrates do not accurately represent toxicity. Because metals are more bioavailable at lower pH, the SSLs may overestimate concentrations in Hanford Site soils that would be toxic to plants and soil invertebrates; thus, risk estimates may be overly conservative. Evaluating this potential overestimation of bioavailability was one of the aims of a 2011 Hanford field effort to collect soil with a pH range more reflective of Hanford Site soils. With the exception of four samples collected within the 100-K area, the range of pH values from samples collected for the 2011 study was between 5.8 and 8.7 with all but 5 of 67 samples above the minimum pH of 6.6 identified in previous RCBRA (DOE/RL-2007-21) soil samples. Thus, the PRGs take into consideration the bioavailability of potential contaminants within the Hanford Site soils rather than relying on published data from laboratory studies and other sites, as was done for the SSLs.

- **Wildlife Toxicity Reference Values (TRVs)**—Data on the toxicity of many chemicals to the receptor species were sparse or lacking, requiring the extrapolation of data from other wildlife species or from laboratory studies with nonwildlife species. This is a typical limitation and extrapolation for ERAs and evaluations is common practice because so few wildlife species have been tested directly for most chemicals. The uncertainties associated with toxicity extrapolation were minimized through the selection of the most appropriate test species for which suitable toxicity data were available.

The factors considered in selecting a test species to represent a receptor species included taxonomic relatedness, trophic level, foraging method, and similarity of diet.

A second uncertainty related to the derivation of TRVs applies to metals. Most of the toxicological studies on which the TRVs for metals were based used forms of the metal (such as soluble salts) that do not reflect the bioavailability of metals in soils. This is likely to result in an overestimation of potential risks for these chemicals in soil. A recent study was conducted comparing the toxicity of laboratory-spiked soils versus aged field-collected soils and the predictive ability of the European Union's predicted no effect concentrations for five metals. The study concluded that total metals concentrations in field-collected soils are poor indicators of toxicity ("Toxicity of Trace Metals in Soil as Affected by Soil Type and Aging After Contamination: Using Calibrated Bioavailability Models to Set Ecological Soil Standards" [Smolders et al., 2009]).

- **Chemical Mixtures**—The SSLs employed in this assessment are based on exposure to individual analytes. Information on the ecotoxicological effects of chemical interactions is generally lacking, which required (as is standard for ERAs) that the chemicals be evaluated on a compound-by-compound basis during the comparison to SSLs. This could result in an underestimation of risk (if there are additive or synergistic effects among chemicals) or an overestimation of risks (if there are antagonistic effects among chemicals). Assessment of data in this report resulted in a description of potential exposure risks due to metals, which are typically known to be additive. In this case, effects may be underestimated.

- **Receptor Species Selection**—Reptiles were identified as being part of the food web present at Hanford, but were not evaluated quantitatively even when exposure pathways were complete. A qualitative assessment of potential risk to these taxa can be made by using the results of quantitative evaluation for other fauna with similar diets and assumed similarity in metabolizing COPECs to make inferences. Considering the results of quantitative evaluation of avian receptors can provide some idea as to the potential for risks to these taxa. The uncertainty associated with the lack of toxicological data for reptiles and inferring risk from other fauna could either over- or underestimate risks.

  It was also assumed that reptiles were neither exposed to significantly higher concentrations of chemicals nor were more sensitive to chemicals than the other receptor species evaluated. This assumption was a source of uncertainty in the ERA. In addition, there is some uncertainty associated with the use of specific receptor species to represent larger groups of organisms (e.g., guilds).

- **Food Web Exposure Modeling**—Although much life history data are available for many of the wildlife species found at the Hanford Site, Hanford Site-specific data were unavailable for several specific parameters included in the desktop food web models used to estimate exposure to wildlife. These factors included food ingestion rate, incidental soil ingestion as a percent or as a rate, home range, and dietary composition established as the percent of stomach contents. As a result of this lack of Hanford Site-specific data, exposure parameters were modeled based on either allometric relationships or on data from the same species in other portions of its range. Because diet composition as well as food, water, and soil ingestion rates can differ among individuals and locations, published parameter values may not accurately reflect individuals present at the Hanford Site. Consequently, SSLs may be either overconservative or underconservative. For example, the wildlife EcoSSLs were derived with a model that incorporates prey tissue items that comprise 100 percent of the receptor's diet coming from the site, not accounting for any food obtained in adjacent uncontaminated areas, whereas MTCA (WAC 173-340) values do account for some offsite prey consumption. Therefore, the assumed contributions of ingestion of analytes in prey tissues for the wildlife Eco-SSLs are greater than those used to develop the MTCA (WAC 173-340) values and would be expected to overestimate risk.

Ultimately, there is some uncertainty with both the MTCA and EPA values used as SSLs with respect to site-specificity. The wildlife PRGs employed in this risk assessment are more site-specific than the SSLs because prey concentrations were estimated with Hanford-Site data. However, there is also some uncertainty in those values associated with the percentage of diet obtained from the site. In applying the PRGs, the assumption was that 100 percent of the food ingestion was from the site, which in many cases is an overestimate. This assumption was evaluated on a case-by-case basis to aid the SMDP presented in Section 7.6.

- **Central Tendency Versus Maximum Exposure Concentration Estimates**—As is typical in an ERA, a finite number of samples of environmental media is used to develop the exposure estimates. The maximum measured concentration provides a conservative estimate for immobile biota or those with a limited home range. The most realistic exposure estimates for mobile species with relatively large home ranges and for species populations (even those that are immobile or have limited home ranges) are those based on an estimate of the central tendency of chemical concentrations in each medium to which these receptors are exposed. This is reflected in the wildlife dietary exposure models contained in *Wildlife Exposure Factors Handbook, Volume I* (EPA/600/R-93/187a). It is possible, however, that receptors could spend additional time foraging at a nearby waste site and thus be exposed to analytes from more than one site. Thus, EPC estimates of contaminants in individual waste site media and food sources may not accurately represent contaminant exposure to a receptor ranging into other sites. It is likely, however, that assuming an AUF of 1 will result in a conservative estimate of exposure because it is likely that offsite foraging would be conducted in uncontaminated areas than at other waste sites. Given the mobility of the upper trophic level receptor species used in the ERA, the use of maximum chemical concentrations as EPCs when UCLs were not calculated by ProUCL to estimate the exposure via food webs is very conservative. This conservatism was reduced to more realistic levels when the number of samples collected from a site was adequate in sample size to develop a UCL on the mean.
- **Comparisons to Background Concentrations**—Background concentrations were used to judge whether measured concentrations within waste sites are reflective of site-related activities, background, or a combination. If site chemical concentrations were consistent with these background levels, it was assumed that the concentrations were not site-related. Comparisons to background in this evaluation include the use of the 90th percentile of the background dataset as compared to the EPC. Thus, 10 percent of the background dataset is even higher than the 90th percentile. Concentrations measured above background may be within the distribution of background variability and could represent a false positive risk. The possibility also exists that concentrations below background were indeed site-related, rendering the assumption false. However, the impact of this possibility is minimal because metals and radioisotopes at concentrations consistent with background conditions should exhibit no different ecological effects than those commonly occurring in areas not affected by releases, regardless of their source.
- **Risk Estimates Associated with Remedial Investigation and Limited Field Investigation Soil Data**—In addition to the waste site remediation data (CVP/RSVP), two additional sources of data were considered for use in the ERA. These sources of data include: (1) vadose zone data collected for the RI to fill data gaps associated with the nature and extent of contamination or associated with understanding the fate and transport of contaminants, and (2) LFI data collected in 1992 from the 100-BC OUs. These data were collected for purposes other than fulfilling needs of the risk assessment; as such, they were not used to quantitatively evaluate risks. However, these data were evaluated qualitatively by comparing concentrations of analytes to ecological PRGs to determine whether the results could be useful for risk management decisions.

RI and LFI data are summarized in more detail in Chapter 6, Section 6.1.1. All RI and LFI soil data from the soil borings and wells described in Chapter 6 were compared to the PRGs used in the supplemental ERA. A summary of the soil borings/wells and associated depth intervals for data in the ecological assessment is provided in Appendix H (Table H-11).

Similar to the CVP/RSVP data, soil data from each soil boring, well, or test pit were grouped by depth. Soil data were processed and reduced using the same methods as those described in Section 7.1. Soil samples collected from depth intervals ranging from 0 to 4.6 m (15 ft) bgs were combined and the maximum detected concentration was compared to the Hanford Site background concentration and the lowest available ecological PRG value[7]. Soil samples collected from depth intervals greater than 4.6 m (15 ft) bgs were not evaluated because they extend beyond the 4.6 m (15 ft) bgs standard point of compliance for ecological receptors as defined by MTCA ("Terrestrial Ecological Evaluation Procedures" [WAC 173-340-7490(4)(b)]).

A comparison of maximum detected concentrations to Ecological PRGs from each of these sample locations is provided in Table H-12. A summary of the wells and test pits that report a maximum concentration greater than the ecological PRG is provided in Table 7-8. For the 100-BC Source OU, two LFI sample locations (116-B-5 Crib and 116-B-3 Pluto Crib) report soil concentrations greater than ecological PRGs. These two waste sites have subsequently been remediated under the interim action ROD. As shown in Table 7-8, risk results for these interim remediated waste sites are within acceptable EPA risk thresholds. The results for the remaining LFI soil borings and test pits are within EPA thresholds.

- At 116-B-9 French Drain, a single concentration of aluminum (18,000 mg/kg) that is greater than the ecological PRG value of 3,988 mg/kg and also greater than the 90th percentile background value of 11,800 mg/kg. Lithium (22 mg/kg) is also greater than the ecological PRG value of 2 mg/kg and the 90th percentile Hanford Site background value of 13.3 mg/kg. Both detections greater than ecological PRGs are from the 3.4 to 3.9 m (11 to 13 ft) bgs depth interval. This waste site has been remediated under the interim action ROD reporting concentrations, which are within acceptable EPA thresholds.

- At 118-B-8:1 Fuel Storage Basin (C7847 and C8239), concentrations of mercury, TPH-diesel, and TPH motor oil at concentrations greater than ecological PRG values. Mercury is reported at a concentration (0.31 mg/kg) greater than the ecological PRG value of 0.30 mg/kg and greater than the 90th percentile Hanford Site background value of 0.013 mg/kg at the 3.8 to 4.08 m (12.5 to 13.4 ft) bgs interval. TPH-diesel range and TPH-motor oil are reported at concentrations greater than the ecological PRGs in C7847 and C8239 in the 0 to 0.76 m (0 to 2.5 ft) bgs depth interval. The 118-B-8:1 Fuel Storage Basin is an accepted waste site and remediation has yet not occurred.

[7] The lowest value for each receptor group was used (plant, invertebrate, mammals, birds). PRGs from Tables 7-3 and 7-4 were used and the lowest SSLs from Tables 7-1 and 7-2 were employed as needed.

Table 7-8. Summary of Ecological Risk Comparisons for RI Data, CVP/RSVP Data, and LFI Data

Waste Site	RI Data	Shallow Zone Ecological Risks?	CVP/RSVP Data*	Shallow Zone Ecological Risks?	LFI Data	Shallow Zone Ecological Risks?
Soil Borings Installed to Characterize Nature and Vertical Extent of Contamination Beneath Select Waste Sites						
100-B-5 Trench	199-B4-15 (C7846)	No samples collected from this depth range.	CVP-2003-00014	No individual risks > thresholds	--	--
116-B-14 Trench	C7842	No samples collected from this depth range.	CVP-99-00003	No individual risks > thresholds	199-B3-47	No samples collected from this depth range.
116-B-5 Crib	C7844	No samples collected from this depth range.	WSRF-98-064	No individual risks > thresholds	199-B5-4	Barium (3.05-3.4 m [10-11 ft] bgs) Mercury (2.01-2.10 m [6.6 – 6.9 ft] bgs)
116-B-6B Crib	TP1	No samples collected from this depth range.	CVP-99-00017	No individual risks > thresholds	--	--
116-B-9 French Drain	TP2	Aluminum, Lithium (3.4-3.9 m [11-13 ft] bgs)	WSRF-2004-004	No individual risks > thresholds	--	--
116-C-5 Retention Basin	199-B3-52 (C7843)	No samples collected from this depth range.	CVP-99-00004	No individual risks > thresholds	116-B-11-TP1	No individual risks > thresholds
118-B-6 Burial Ground	C7845	No samples collected from this depth range.	CVP-2006-00002	No individual risks > thresholds	--	--
118-B-8:1 Fuel Storage Basin (B Reactor subsite)	C7847	Mercury (3.8-4.08 m [12.5 – 13.4 ft] bgs) TPH-diesel range (0-0.76 m [0 – 2.5 ft] bgs)	Accepted	--	--	--
	C8239	TPH-diesel range, TPH – motor oil (high boiling point) (0-0.76 m [0 – 2.5 ft] bgs)		--	--	--

Table 7-8. Summary of Ecological Risk Comparisons for RI Data, CVP/RSVP Data, and LFI Data

Waste Site	RI Data	Shallow Zone Ecological Risks?	CVP/RSVP Data*	Shallow Zone Ecological Risks?	LFI Data	Shallow Zone Ecological Risks?
118-B-8:3 Process Sewer (B Reactor subsite)	TP3	No samples collected from this depth range.	Accepted	--	--	--
118-C-3:2 Fuel Storage Basin (C Reactor Subsite)	C7849	No samples collected from this depth range.	CVP-98-00009	--	--	--
Wells Installed to Characterize Nature and Extent of Contamination in Rewetted Zone (not waste site-specific)						
--	199-B5-5 (C7505)	No samples collected from this depth range.	--	--	--	--
--	199-B3-50 (C7506)	No samples collected from this depth range.	--	--	--	--
--	199-B5-6 (C7507)	No samples collected from this depth range.	--	--	--	--
--	199-B8-9 (C7508)	No samples collected from this depth range.	--	--	--	--
--	199-B2-14 (C7665)	No samples collected from this depth range.	--	--	--	--
--	199-B2-15 (C7783)	No samples collected from this depth range.	--	--	--	--
--	199-B2-16 (C7784)	No samples collected from this depth range.	--	--	--	--
--	199-B3-51 (C7785)	No samples collected from this depth range.	--	--	--	--
--	199-B5-8 (C8244)	No samples collected from this depth range.	--	--	--	--
Soil Borings Installed during LFI to Characterize Priority Waste Sites in 100-BC-1 and 100-BC-2						

Table 7-8. Summary of Ecological Risk Comparisons for RI Data, CVP/RSVP Data, and LFI Data

Waste Site	RI Data	Shallow Zone Ecological Risks?	CVP/RSVP Data*	Shallow Zone Ecological Risks?	LFI Data	Shallow Zone Ecological Risks?
116-B-1 Trench	--	--	CVP-99-00012	No individual risks > thresholds	199-B3-48	No samples collected from this depth range.
116-B-2 Fuel Storage Basin Trench	--	--	CVP-99-00015	No individual risks > thresholds	199-B4-10	No individual risks > thresholds
116-B-3 Pluto Crib	--	--	CVP-99-00013	No COPCs reported above background	199-B5-3	Silver (3.4-3.9 m -11-13 ft] bgs)
116-C-1 Liquid Waste Disposal Trench	--	--	CVP-98-00006	No individual risks > thresholds	199-B3-46	No samples collected from this depth range.
116-C-2A Pluto Crib	--	--	CVP-99-00019	No individual risks > thresholds	199-B9-4	No samples collected from this depth range.
Process effluent pipelines south of 116-C-5	--	--	CVP-99-00004	No individual risks > thresholds	199-B5-2	No samples collected from this depth range.
Monitoring Wells Installed for 100-BC-5 OU LFI						
--	--	--	--	--	199-B2-12	No samples collected from this depth range.
--	--	--	--	--	199-B4-8	No samples collected from this depth range.
--	--	--	--	--	199-B4-9	No samples collected from this depth range.
--	--	--	--	--	199-B9-2	No samples collected from this depth range.
--	--	--	--	--	199-B9-3	No samples collected from this depth range.

* Complete reference citations are provided in Chapter 11.

7.5 Assessment of Risks in Riparian, Nearshore Media, and Columbia River

The RCBRA (DOE/RL-2007-21, Volume I) evaluated soil, sediment, and water located in riparian and nearshore areas. The RAGs used in the interim actions addressed risks to human health from direct contact with soil and threats to groundwater and surface water as a result of leaching from soil, but did not directly address risks to ecological receptors, except those protected through compliance with AWQC. The ERA conducted as part of the RCBRA addresses residual contaminant concentrations at remediated waste sites in the upland zones and the transport of contaminants from waste sites to the Columbia River riparian and nearshore zones (Integrated Work Plan [DOE/RL-2008-46]). The CRC (DOE/RL-2010-117) evaluated island soil, sediment, water, and fish tissue located in the Columbia River beyond the nearshore environment. Several investigations conducted on effluent pipelines that discharged to the Columbia River are also summarized.

7.5.1 Summary of Results and Conclusions of RCBRA

The RCBRA evaluated ecological risks at 48 nearshore study sites potentially affected by contamination from Hanford Site sources in comparison to reference sites. Study sites were selected in areas where known contaminated groundwater plumes enter the Columbia River and in areas between the plumes. Twenty-two COPECs were identified for the nearshore environment and sixteen of these (all inorganics) were further identified as contaminants of ecological concern (COECs). The RCBRA concluded that across the Hanford Reach of the Columbia River (i.e. corridor-wide), five COECs (cadmium, chromium, Cr(VI), manganese, and uranium) in the nearshore environment may present an unacceptable level of risk for one or more of the assessment endpoint entities (aquatic plants, aquatic invertebrates, amphibians, fish, and wildlife). These results are based primarily on the comparison of COPEC concentrations to toxicity benchmarks, measures of exposure and effects in biota, or the results of wildlife exposure analyses (RCBRA). The evaluation of these sediment COECs is summarized as follows:

- **Cadmium** was detected in 4 of 5 nearshore sediment samples (Appendix M, Table M-35). However, none of the samples exceeded the lower or upper effects threshold (cleanup standard from *Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho* [Ecology Publication 11-09-54]); thus, cadmium was not carried forward to the FS.

- **Chromium** was detected in 6 of 6 nearshore sediment samples (Appendix M, Table M-37). However, only one sample exceeded the upper effects threshold (cleanup standard from *Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho* [Ecology Publication 11-09-54]) of 88 mg/kg. Riparian soil concentrations were detected at a maximum of only 44 mg/kg and are therefore not the source of the observed sediment measurements. Likewise, total chromium in groundwater is detected below the ecological screening level (ESL) and background, suggesting no potential source partitioning to sediments. Thus, total chromium was not carried forward to the FS.

- **Manganese** was detected in 18 of 18 nearshore sediment samples (Appendix M, Table M-36). Four of the 18 samples exceeded the lower effects threshold (ESL). However, none of the samples exceeded the upper effects threshold (cleanup standard from *Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho* [Ecology Publication 11-09-54]); thus, cadmium was not carried forward to the FS.

The evaluation of these pore water COECs is summarized as follows:

- **Cr(VI)** within the 100-BC Area nearshore filtered samples exceeded the ESL in aquifer tubes (34 of 75 samples) and riparian groundwater wells (25 of 32 samples) (Appendix M, Table M-24). The ESL was also exceeded in both unfiltered pore water samples. Therefore, there is a complete or

significant pathway for observed Cr(VI) concentrations in sediment and water from the 100-BC riparian area, which warrants further discussion in the FS.

- **Manganese** was not detected above the ESL in seep samples of the 100-BC nearshore area (Appendix M, Table M-24). For filtered groundwater, 10 of 53 riparian well samples exceeded the ESL. For filtered aquifer tubes, one of 24 samples exceeded the ESL and none of the 20 unfiltered samples exceeded the ESL. Pore water samples in the 100-BC nearshore area were not filtered but were below the ESL in one of two samples, which does not suggest the 100-BC Area to be the source. Manganese was not detected above the ESL in nearshore surface water samples. Thus, with concentrations in aquifer tubes not consistently exceeding the ESL, it appears that the 100-BC Source OU is not contributing to concentrations of manganese observed in pore water in the Columbia River.

- **Uranium** concentrations within the 100-BC riparian and nearshore aquatic media were below water quality criteria, except for four unfiltered riparian groundwater well samples that were below background (Appendix M, Table M-24). Thus, uranium within the 100-BC Source OUs is not contributing to concentrations of uranium observed in pore water at locations within the Columbia River.

The RCBRA (DOE/RL-2007-21, Volume I) also evaluated ecological risks at 18 representative riparian study sites located adjacent to, or where they may be directly affected by, known contaminated media (i.e., groundwater seeps, soil, and sediment). In addition, data from the 100-B/C Area pilot study and the 100-NR-2 ecological study were evaluated. As with the nearshore environment, 22 COPECs were identified for the riparian environment. The RCBRA identified 9 of the identified 22 COPECs (arsenic, chromium, copper, lead, mercury, selenium, TPH-diesel, vanadium, and zinc) as possibly presenting some level of risk for one or more of the assessment endpoint entities (terrestrial plants, invertebrates, and wildlife) (DOE/RL-2007-21). This is based on soil bioassays, comparison of COPEC concentrations to plant or terrestrial invertebrate benchmarks, or the results of wildlife exposure analyses. However, conclusions in the RCBRA (DOE/RL-2007-21) were that on a River Corridor-wide basis, only six of these COPECs should be considered further (arsenic, chromium, lead, mercury, TPH-diesel, and zinc). A summary of the evaluation of these COECs is provided below.

As shown in Appendix M Table M-31 (plants and invertebrates) and Table M-32 (wildlife), concentrations of arsenic, chromium, lead, mercury, TPH-diesel, and zinc in the 100-BC OUs riparian soils were all below the PRGs presented in Tables 7-4 and 7-5. Thus, none of these soil COECs was carried forward to the FS.

COECs identified within the RCBRA are included in Table 7-9. These COECs were determined for the River Corridor as a whole. Discussion of these COECs with respect specifically to ecological risk within the 100-BC Source OUs is provided in Appendix M of this report and is summarized below.

Table 7-9. Riparian, Nearshore, and Riverine COECs from the RCBRA and CRC

COEC	Receptors	Media	Are 100-BC-1 or 100-BC-2 a Potential Source?	Is 100-BC-5 a Potential Source?
Aluminum [1]	Fish Aquatic Invertebrates Amphibians Aquatic Plants	Pore Water	No	No
Arsenic [2]	Terrestrial Plants	Riparian Soil	No	No
Cadmium [2]	Aquatic Plants and Invertebrates	Sediment	No	No
Chromium [1,2]	Aquatic Plants and Invertebrates and the Bufflehead	Sediment	No	No
Chromium [2]	Terrestrial Plants and Invertebrates	Riparian Soil	No	No
Cr(VI) [1,2]	Fish Aquatic Invertebrates Aquatic Plants	Pore Water	No	Yes
Cr(VI) [1]	Aquatic Plants and Invertebrates	Sediment	No	No
Lead [1]	Fish Aquatic Invertebrates Amphibians Aquatic Plants	Pore Water	No	No
Lead [2]	Terrestrial Plants	Riparian Soil	No	No
Manganese [2]	Aquatic Plants and Invertebrates	Sediment	No	No
Manganese [2]	Aquatic Plants and Invertebrates	Pore Water	No	No
Mercury [2]	Terrestrial Invertebrates	Riparian Soil	No	No
TPH–Diesel [2]	Terrestrial Invertebrates	Riparian Soil	No	No
Uranium [2]	Aquatic Plants and Invertebrates	Groundwater/Pore Water	No	No

Table 7-9. Riparian, Nearshore, and Riverine COECs from the RCBRA and CRC

COEC	Receptors	Media	Are 100-BC-1 or 100-BC-2 a Potential Source?	Is 100-BC-5 a Potential Source?
Zinc [2]	Terrestrial Plants and Invertebrates and Kingbirds	Riparian Soil	No	No

[1] COECs presented in the executive summary of the CRC (DOE/RI-2010-117).
[2] COECs presented in Sections 8.4 and 8.5 of the RCBRA (DOE/RL-2007-21).

7.5.2 Summary of Results and Conclusions of CRC

The CRC (DOE/RL-2010-117) included an ERA that combines both screening and baseline elements. Abiotic media were compared to screening benchmarks for surface water, sediment, and pore water to identify COECs. Soil concentrations were compared to plant and invertebrate benchmarks and desktop food web models were used to evaluate risks to wildlife. A baseline assessment was conducted to assess risk to fish using tissue residue data. The CRC concluded that there were eight COECs within sediment, pore water, island soils, and shoreline sediment (aluminum, chromium, Cr(VI), lead, manganese, nickel, nitrate, selenium, and uranium) of the 100 and 300 Areas. The evaluation included distinct conclusions for the reach adjacent to the100 Area versus those for the reach adjacent to the 100-BC OUs. Aluminum, Cr(VI), and lead were identified for pore water within the 100-BC OUs and chromium and Cr(VI) were identified for sediment within the 100 Areas as a whole, as presented in Table 7-9 (CRC [DOE/RL-2010-117]). Discussion of these COECs with respect specifically to ecological risk within the 100-BC Source OUs is provided in Appendix M. A summary of the evaluation of these COECs is provided below:

- **Aluminum** in pore water concentrations within the 100-BC Area exceeded the ESL in filtered aquifer tubes (5 of 5 samples) and groundwater samples (1 of 40 samples) (Appendix M, Table M-24). The single filtered seep sample did not exceed the ESL. Aluminum was not carried forward to the FS because of the relatively few detections, and lack of a source from groundwater to pore water.

- **Total chromium** was detected in 6 of 6 sediment samples in the 100-BC Area nearshore environment, with one detection above the cleanup level of 88 mg/kg in the same report (Appendix M, Table M-37). Chromium concentrations do not originate from the 100-BC Area riparian soils or nearshore sediment. Total chromium in groundwater is detected below the ESL and background, suggesting no potential source partitioning to sediments. There is no complete or significant pathway for observed total chromium concentrations in sediment from the 100-BC riparian area.

- **Cr(VI)** was detected in 31 of 117 sediment samples in the 100 Area reach of the Columbia River as part of the CRC, with a maximum of 7.38 mg/kg (CRC [DOE/RL-2010-117]). It was also detected in nearshore sediment samples collected for the RCBRA at 0.92 mg/kg at 100-D (1 of 10 detects) (DOE/RL-2007-21) but was not detected in two samples in the 100-BC nearshore area. With no substantial toxicological data available with which to evaluate the bulk sediment measurements, this contaminant was identified as a COEC in both reports. Within the 100-BC Area, nearshore filtered samples exceeded the ESL in aquifer tubes (34 of 75 samples) and groundwater wells (25 of 32 samples) (Appendix M, Table M-24). The ESL was also exceeded in both unfiltered pore water samples. Therefore, there is a complete or significant pathway for observed Cr(VI)

concentrations in pore water from the 100-BC riparian area, which warrants further discussion in the FS.

- **Lead** was detected in filtered groundwater concentrations and seep samples within the 100-BC Area, below the ESL (Appendix M, Table M-24). Pore water samples were not filtered but were below the ESL in one of two samples, which does not suggest the 100-BC Area to be the source. Lead was not carried forward to the FS because of relatively few detections and lack of a source from groundwater to pore water.

7.5.3 100-BC Area River Effluent Pipeline Investigations

During operations, water used in fuel production to cool the reactors was discharged to the Columbia River via effluent pipelines. The release of this cooling water ended when the associated reactors and facilities were shut down. Today, the two inactive 100-BC Area effluent pipelines remain in their original locations in the Columbia River channel. Past characterization efforts obtained samples of the river effluent pipelines from the 100-BC, 100-D, and 100-F areas. Characterization data collected during the river pipeline evaluations were used to evaluate potential risks from contaminants within the pipelines. The RCBRA (DOE/RL-2007-21, Volume I) provided a summary of the previous characterization efforts and risk assessment for these pipelines in Section 8.2.2.

River Discharge Lines Characterization Report (UNI-3262) discussed samples of scale (flakes of mostly rust) from the interior surfaces and enclosed sediment of the effluent pipelines from the 105-C, 105-DR, and 105-F reactors. The pipelines were also visually inspected underwater by a diver, and their positions and physical conditions were assessed. Samples of scale and sediment were analyzed for radionuclides. The major radionuclides detected included cobalt-60, cesium-137, europium-152, europium-154, and europium-155. Radionuclide concentrations were greater in the scale than in the sediment. Direct beta-gamma radiation measurements were also obtained for interior and exterior pipe surfaces. The dose rates measured for direct contact with the interior of the pipe surfaces were less than 1 mrem/hr, and readings on the exterior were below the instrument's detection capability. Because the half lives of all of these radionuclides is less than 30 years, the activity levels have declined by a factor of two to five and are no longer expected to be ecological risk drivers.

In 1994, a comprehensive geophysical survey (*Columbia River Effluent Pipeline Survey* [WHC-SD-EN-TI-278]) located and mapped the reactor effluent pipelines. The study relied mainly on remote sensing geophysical techniques, including navigation and echo sounding, side-scanning radar, sub-bottom profiling, seismic reflection profiling, and GPR. The results indicated that the pipelines have neither broken loose nor moved from their original locations; however, portions of some pipelines are no longer buried.

In 1995, pipe scale and sediment from the interior of the effluent pipelines from the 100-BC and 100-D areas were sampled and physically characterized using a robotic transporter (*100 Area River Effluent Pipelines Characterization Report* [BHI-00538]). Analytical data from these two pipelines were intended to complement the 1984 radionuclide data (*River Discharge Lines Characterization Report* [UNI-3262]) and were expected to represent "worst case" conditions with respect to radiological contamination. This assumption was based on the long years of pipeline service and the volume of effluent known to have been discharged from the 105-B and 105-D/DR reactors.

The analytical results from the 1984 and 1995 effluent pipeline characterization studies at the 105-B, 105-C, 105-D/DR, and 105-F reactors may reasonably be applied to effluent pipelines in 100-K Area, because operations among these reactors were similar. Evaluations of human health and ecological risk have been performed for the river effluent pipelines, as they are today, located on or beneath the river

channel bottom, and for a scenario in which a pipeline section breaks away from the main pipeline and is washed onto the shore of the river. Both the 1996 risk assessment effort (*100 Area River Effluent Pipelines Characterization Report* [BHI-00538]) and the 1998 risk assessment effort (*100 Area River Effluent Pipelines Risk Assessment* [BHI-01141]) relied on data collected from the 1984 and 1995 characterization work. The evaluation of human health and ecological risk performed in 1998 (*100 Area River Effluent Pipelines Risk Assessment* [BHI-01141]) concluded that the concentrations of chromium and mercury in the scale and sediment within the pipelines pose minimal ecological risk, because they have been in contact with river water without dissolving since the reactors were shut down. The 1998 risk evaluation results indicated pipelines present no unacceptable risks and, therefore, there are no remediation requirements under CERCLA. This is supported by the following:

- Minimal deteriorated condition of the pipelines
- Continued decrease of radionuclide concentrations as a result of decay
- Inaccessible location
- Unavailability of significant contaminants to affect human health and the environment

Accordingly, no further action is considered for below-river effluent pipeline waste sites 100-B-8 and 100-C-6 in this RI/FS.

7.5.4 Summary of the Evaluation of Riparian Soils

The RCBRA (DOE/RL-2007-21, Volume I) evaluated ecological risks at representative riparian study sites located adjacent to, or where they may be directly affected by, known contaminated media (groundwater, seeps, soil, or sediment). The RCBRA concluded that six COECs identified for the riparian environment (arsenic, chromium, lead, mercury, zinc, and TPH-diesel) may present an unacceptable level of risk to one or more of the assessment endpoint entities, based on soil bioassays, comparison of COPEC concentrations to plant or terrestrial invertebrate toxicity benchmarks, or the results of wildlife exposure analyses. The CRC (DOE/RL-2010-117) did not identify any risks to terrestrial plants or invertebrates from exposure to island and riparian soils.

Most concentrations detected in riparian soils within the 100-BC OUs fell below ESLs (in this case specifically the SSLs) described previously. Except for aluminum, BEHP, thallium, dieldrin, and vanadium, all other detections were below PRGs within the 100-BC Area (Appendix M, Tables M-31 and M-32). Aluminum, BEHP, thallium, dieldrin, and vanadium are discussed below in Section 7.5.4.3. Those chemicals below PRGs do not warrant further evaluation in the FS.

Unremediated waste sites in the riparian area were not evaluated in this analysis. Because those sites, listed in Table 8-6 in Chapter 8, have similar site histories to the sites currently evaluated, the predicted outcomes are anticipated to be similar as well. Some unremediated waste sites may have exceedances of PRGs, which would provide the basis for remedial action or further evaluation. Additional discussion is provided in Section 7.6.2.

7.5.4.1 Risks to Terrestrial Plants in the Riparian Area

Measurements of all chemicals within the riparian soils of the 100-BC OUs were below plant ESLs (Appendix M, Table M-29 and M-31). Likewise, the CRC (DOE/RL-2010-117) did not identify any risks to terrestrial plants from exposure to island and riparian soils. Therefore, no COPECs in 100-K riparian soils warrant further evaluation in the FS, based on risks to terrestrial plants. This finding is also supported by the results of several biological measures collected as part of the RCBRA (DOE/RL-2007-21), including plant bioassays on Sandberg's bluegrass (*Poa secunda*) and plant tissue testing. Although these lines of evidence carry less weight given their more limited datasets and temporal variability (i.e., they were conducted just once), the results do support the same conclusion. There were no significant

correlations with chemicals and bioassay measures, and there were no significant correlations between soil chemistry and plant tissue measurements.

7.5.4.2 Risks to Terrestrial Invertebrates in the Riparian Area

Ecological risk from exposure to riparian area soils were evaluated using SSLs and PRGs developed for terrestrial exposure. Concentrations of chromium and zinc exceeded RCBRA benchmarks protective of terrestrial invertebrates in the 100-BC Area riparian soil study area (B/C Pilot and 2a) (RCBRA [DOE/RL-2007-21], Tables 5-69 and 5-70). Only thallium had concentrations that exceeded Hanford Site-specific PRGs protective of terrestrial invertebrates (Appendix M, Table M-31); however, Table 5-29 of the RCBRA (DOE/RL-2007-21), indicates that thallium concentrations were below background. The CRC (DOE/RL-2010-117) did not identify any risks to terrestrial invertebrates from exposure to island and riparian soils. Based on this analysis, no COPECs in riparian soil for terrestrial invertebrates warrant further evaluation in the FS based on risks to terrestrial invertebrates.
Terrestrial invertebrate tissue concentrations, which provide an indication of contaminant uptake and bioavailability, were measured at riparian study sites and reference locations and some, but not all, chemicals were detected in terrestrial invertebrates. Statistical differences were found between terrestrial invertebrate tissue concentrations for certain chemicals between riparian study sites and reference sites. However, this line of evidence was ranked low because of the lack of detections in invertebrate tissue for certain riparian chemicals and the possibility of bias as a result of sample collection methods. Statistical differences in tissue concentrations of mercury and zinc in terrestrial invertebrates were noted between River Corridor and reference study sites; this relationship is based on data across the entire River Corridor, and should not be inferred as a relationship that is specific for the 100-BC Area. However, there is insufficient evidence of a correlation for chemicals between tissue concentrations in terrestrial invertebrates and concentrations in soil (RCBRA [DOE/RL-2007-21]).

7.5.4.3 Risk to Wildlife in the Riparian Area

Risk to wildlife in the riparian area was evaluated in the RCBRA using both field measures and desktop food web modeling using similar models to those described in this ERA for SSLs. A separate desktop food web evaluation was included in this ERA using the SSLs and PRGs presented in Tables 7-2 and 7-3. Results of all three of these analyses are described below. The results all three suggest that there is no risk to wildlife in the riparian soils of the 100-BC OUs.

For riparian soils, field ecological measures of the small mammal community were developed as qualitative information on the status of these populations. Estimated dietary contaminant exposures and chemical concentrations in bird or small mammal tissues were compared to ecological effects levels established for dietary ingestion or related to tissue residues. For selected chemicals (cadmium, chromium, lead, selenium, and PCBs), measured tissue concentrations in small mammals trapped in study sites were not greater than reference areas (RCBRA [DOE/RL-2007-21], Volume I, Table 5-48), and were less than available tissue effect levels (RCBRA, page 5-91).
Dietary exposure to terrestrial birds and mammals using wildlife exposure models, estimated for riparian concentrations across the River Corridor, indicated potential exposure higher than LOAEL-based SSL values for copper, selenium, vanadium, and zinc (DOE/RL-2007-21, Section 8.4.1.3). Only zinc was identified as a final COEC for riparian soil exposure to birds and mammals. However, with the exception of zinc, concentrations of these four metals in soil in the 100-BC Area fall within Hanford Site-wide background, and therefore should not warrant further evaluation in the FS. Zinc concentrations in 100-BC Area riparian soil were compared to the Hanford Site-specific PRGs as shown in Table M-32. The results from this comparison show that all zinc concentrations fall below the PRG. Therefore, zinc concentrations in riparian soil do not warrant further evaluation in the FS based on risks to wildlife.
Most concentrations detected in riparian soils within the 100-BC Area fell below SSLs and PRGs. ESLs results showed four chemicals within riparian soils had concentrations above wildlife ESLs within the 100-BC OUs: aluminum, BEHP, dieldrin, and vanadium (Appendix M, Section 4.5 and Table M-32).

However, these analytes were not identified as COECs in the RCBRA (DOE/RL-2007-21), and do not warrant further evaluation in the FS. Aluminum was detected below background and is not bioavailable or considered toxic to wildlife at pH levels above 5.5 like those found in the 100-BC riparian area. Bis(2-ethylhexyl) phthalate concentrations exceeded SSLs in 1 of 9 samples. The SSLs were based on unbound no effect levels in literature-based food chain models (i.e., insufficient site-specific data were available to develop a PRG). Bis(2-ethylhexyl) phthalate is a common lab contaminant that was not identified as a final COEC in the RCBRA (DOE/RL-2007-21) or as a COEC in the CRC (DOE/RL-2010-117); thus, further evaluation is unwarranted. Although the single detection dieldrin is the maximum concentration observed site-wide, the RCBRA broad scale assessment of ecological risks concludes that both CTE and RME exposures are less than the NOAELs and LOAELs for dieldrin and further evaluation is not required (RCBRA [DOE/RL-2007-21], Section 7.3.5.3). The maximum detected concentration of vanadium (58.4 mg/kg) for the 100-BC OUs was less than the site background of 85 mg/kg. Additional discussion is provided in Appendix M, Section 4.5. No additional evaluation is warranted in the FS. Within the RCBRA (DOE/RL-2007-21), information on dietary contaminant exposures was also compared to ecological effects levels for diet to assess risks to birds or mammals potentially exposed to contaminants in nearshore sediments, biota, and water. Only chromium was considered a final COEC. However, the single study site with which this risk was associated is not within the 100-BC Area nearshore environment.

7.5.5 Summary of Evaluation of Nearshore and Columbia River

The results from the evaluation in Appendix M showed that inorganic, organic, and radiological contaminants detected in near-river groundwater samples, collected from the 100-BC-5 OU, are not affecting the aquatic life exposed to pore water, surface water, or sediment in the Columbia River near the 100-BC OU[8]. Numerous lines of evidence were considered as part of the evaluation, which included but were not limited to the comparison of aquatic media (aquifer tube, pore water, spring/seep, and surface water) in the riparian and nearshore areas to ESLs, data quality, temporal significance, and correlations or the lack thereof with chemistry and observed responses in the bioassays and reference data. In general, data quality issues such as presence of contamination in blank samples, or elevated detection limits relative to the criteria in wells not nearest to the river, and the use of unfiltered data (potentially overestimating exposure) indicate data may overestimate risks initially identified through comparisons to aquatic criteria.

Although the biological measures collected do not represent all seasonal conditions and river stage fluctuations, the results of pore water bioassays on aquatic invertebrates and amphibians also suggest little or no correlation between COPEC concentrations and observed responses in the bioassays and the responses were not different from those of upstream references. Benthic invertebrate community structure data also suggest no differences between reference sites and locations adjacent to the Hanford Site. The results from this analysis confirm the results from the evaluation presented in Appendix M, that no COECs are affecting aquatic life exposed to pore water or surface water in the Columbia River near the 100-BC OU.

7.5.5.1 Risk to Fish

No COECs in the RCBRA or in the CRC were identified for surface water exposures to fish. Pore water concentrations at study sites were greater than the water standards or criteria for Cr(VI): RCBRA [DOE/RL-2007-21], Section 8.5.1.4). The CRC (DOE/RL-2010-117) also indicated exceedances of water quality standards or criteria (aluminum, Cr(VI), and lead) in 100-BC Area pore water samples.

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[8] Both filtered and unfiltered water sample results were evaluated in the RCBRA Report (DOE/RL-2007-21). In some cases, the toxicity information or standards/criteria are based on dissolved metals concentrations (filtered samples). Therefore, exposure and the potential for risk from metals contaminants may be overestimated by using the unfiltered (or total metals) concentrations.

However, most other lines of evidence suggest that there is no unacceptable risk to fish in the Columbia River. And as described above in Section 7.5.1 and in Appendix M Section M.4, with the exception of Cr(VI), these chemicals are not found in nearshore groundwater; therefore, there is no source for these COECs from the 100-BC-5 OU.

In general across the River Corridor, fish were smaller (in length and mass) at study sites relative to reference sites. However, many factors either confound or contribute to the size of fish captured, such as fishing pressure or ease of capture of the target size range. Correlation with capture size and chemical concentration or any other factor (e.g., habitat, nutrient availability) was not possible because it was not considered as part of the original study design. There were no strong trends in fish histopathological observations between those collected at study sites and those from reference site locations. No tissue COPECs were correlated with histopathological endpoints associated with adverse effects at study sites. No exceedances of tissue effects levels for nearshore aquatic COPECs were measured in fish tissue. In addition, evidence of greater contaminant uptake in fish from study sites was not apparent for most COPECs and tissues.

For 100-BC OUs, Cr(VI) in 100-BC-5 OU groundwater, which represents a potential source for pore water concentrations that exceed the fish surface water ESL, warrants further evaluation in the FS. Cr(VI) concentrations in multiple nearshore wells and aquifer tubes exceed AWQC, suggesting an ongoing source. Other COPECs detected in pore water above AWQC do not appear to be issues in groundwater or aquifer tubes, suggesting that the 100-BC-5 groundwater OU is not the source of observed elevated concentrations. More detailed discussion of the exceedances for additional chemicals is provided in Appendix M. In general, exceedances of AWQC for other chemicals within various aquatic media (pore water, seeps, aquifer tubes, groundwater, surface water) were either anomalous (i.e., very low frequency), or a result of various laboratory reporting issues.

7.5.5.2 Risks to Aquatic Plants

Potential effects on aquatic plants were evaluated through results of a bioassay in sediment and comparison of sediment and pore water concentrations to SSLs (RCBRA [DOE/RL-2007-21, Volume I], Tables 6-88 through 6-91). Based on the combined pore water and sediment concentrations, the RCBRA identified cadmium, chromium, Cr(VI), manganese, and uranium as COECs warranting further evaluation for potential effects on aquatic plants, as noted in Section 8.5.1.1 (DOE/RL-2007-21). The CRC (DOE/RL-2010-117) identified the final COECs for pore water and sediment within the 100-BC-5 OUs as aluminum, Cr(VI), total chromium, and lead. For the 100-BC Area nearshore sampling sites, antimony and chromium were detected at concentrations greater than the upper threshold sediment biota ESL (Appendix M, Table M-36) and aluminum, Cr(VI), lead, and manganese were greater than the chronic AWQC (Appendix M, Table M-22). Sediment COPECs/COECs are discussed in more detail below, with risks to aquatic invertebrates and in more detail in Appendix M, with a conclusion that observed sediment concentrations are below upper thresholds (cleanup standard from *Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho* [Ecology Publication 11-09-54]) and do not warrant further evaluation.

Pore water COPECs from the 100-BC Area nearshore sampling sites are discussed in more detail in Appendix M, Section 4.2, which concluded that concentrations in the pore water, with the exception of Cr(VI), were not at levels warranting additional evaluation. Of the key plume contaminants in the reach of the Columbia River adjacent to 100-BC OUs, Cr(VI) had concentrations of ecological relevance in the nearshore environment. Only Cr(VI) represents a potential source for concentrations that exceeded water quality criteria at the point of exposure (pore water) warranting further evaluation in the FS.

Laboratory bioassays (i.e., toxicity tests) were conducted with field-collected sediments. Some significant relationships were determined with observed response within aquatic plant toxicity tests in association with confounding factors and some chemicals. Additionally, clear measures of exposure (i.e. accumulation into plants), primarily for inorganic chemicals, were detected in pore water and

sediment. However, of the significant relationships determined, none was with chemicals for which pore water concentrations were greater than aquatic plant benchmarks. Further, no risks to aquatic plants were noted based on toxicity testing. Although the analysis represents only one season of sampling and analysis, the weight of the available data does not suggest risk to aquatic plants.

7.5.5.3 Risks to Aquatic Invertebrates

The primary lines of evidence used to evaluate risks to aquatic invertebrates are field surveys, the results of bioassays, and comparison of sediment and water concentrations to ESLs.

Abiotic Media Concentrations Compared to Literature Values. The final COECs for pore water in the CRC within the 100-BC OUs were identified as aluminum, hexavalent chromium, and lead, as noted in the Executive Summary of the CRC (DOE/Rl-2010-117). Pore water concentrations at study sites across the Hanford Reach were greater than chronic water standards or criteria for three COECs (Cr(VI), manganese, and uranium; RCBRA [DOE/RL-2007-21], Section 8.5.1.1). However, there are significant uncertainties relative to many of the conclusions based on pore water sampling. Further, all of these abiotic measurements represent a single point measurement within a dynamic river system with daily and seasonal fluctuations and flow volumes that can shift the composition of the substrates that were sampled. Exceedances should not be ignored, because they can be indicative of exposure and levels presenting a risk; but because of the uncertainty in the representativeness of the measurements because of the dynamic environment, the exceedances should be considered along with other data that identifies whether there is, in fact, an ongoing source of the measurements. This analysis is presented in Appendix M. The interpretation of pore water results as an indication of adverse effects to aquatic invertebrates is the same as that for aquatic plants, given that the ESLs are protective of both plants and aquatic invertebrates. Cr(VI) in the100-BC-5 groundwater OU, which represents a potential source for pore water concentrations that exceed water quality criteria, warrants further evaluation in the FS.

For the River Corridor as a whole, sediment COECs (cadmium, chromium, and manganese) suggest a potential for adverse effects (RCBRA [DOE/RL-2007-21], Section 8.5.1.2). Likewise, Cr(VI) in sediment was identified as a COEC for the 100-BC-5 Area in the CRC (DOE/RL-2010-117). For sediment samples collected within the 100-BC Area nearshore (Appendix M, Table M-36), concentrations were greater than the upper threshold ESLs for antimony and chromium.

Given the uncertainty with representativeness mentioned above, a more detailed discussion of each of the COECs from the RCBRA (DOE/RL-2007-21), CRC (DOE/RL-2010-1117, Volume I), and 100-BC Area nearshore sediment was presented in Appendix M. Concentrations of most Hanford Reach sediment COECs are either below ESLs (cleanup standard from *Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho* [Ecology Publication 11-09-54]), or below reference in the 100-BC Area nearshore environment (explanations for the exceptions are described in Appendix M). This suggests that sediments upstream from the Hanford Site potentially contribute to concentrations observed in the 100-BC Area nearshore sediments. Further, riparian soils for most of the COECs are lower than upstream sediment and Hanford Site reference soil concentrations, suggesting that the riparian soils in the 100-BC Area are not a source of the observed sediment concentrations for the RCBRA COECs identified. Biological measures such as amphipod bioassays, clam tubes, and community surveys from rock baskets show no clear indication of toxicity or correlation of response with COEC concentrations. Although they do represent only a snapshot in time and do not represent all seasonal conditions and river stage fluctuations, these measures do support the analysis that Hanford Site operations at the 100-BC Area are not adversely affecting aquatic receptors exposed to sediment in the 100-BC Area nearshore environment. Based on these findings, only Cr(VI) in groundwater warrants further evaluation in the FS.

Direct Toxicity Measures. Risks to aquatic macroinvertebrates based on toxicity testing showed some relationships with confounding factors and some COPECs. Histopathology measures of Asiatic clams (*Corbicula fluminea*) differed in study sites compared to reference sites; these measures also showed some negative relationships with COPECs. However, sediment bioassays for the 100-BC Area showed no difference in growth, or higher growth in amphipod (*Hyalella azteca*) relative to reference sites. Likewise, survival and reproduction tests on water fleas in pore water showed no difference at two sites representing the 100-BC Area (2a Aq and 2b Aq), relative to reference sites. Correlation between abiotic media chemistry and any observed differences in measured effects from both bioassays was conducted across the entire Hanford Reach. Mercury was the only COPEC with a significant correlation that showed a potential negative effect with a significant regression; however, mercury was below sediment ESLs at the 100-BC Area study sites. Clams were also monitored for survival. There was a statistical decrease in survival at study sites compared to reference sites, but there was no correlation of clam survival with COPECs. Together these measures do not indicate substrate concentrations were toxic. However, they do represent only a snapshot in time and do not represent all seasonal conditions and river stage fluctuations.

Community Structure Measures. Key community metrics do not suggest that contaminant-related impacts to benthic macroinvertebrates are evident in aquatic study sites as a group, as indicated by the comparison of EPC data from study sites relative to reference sites. Most of the aquatic community measures did not differ between the study sites and reference sites. There were exceptions among the large number of aquatic community measures evaluated, but the agreement among measures was weak and the biological significance to populations is not evident.

Measures of Exposure. Within the RCBRA (DOE/RL-2007-21, Volume I), clear measures of exposure (accumulation), primarily for inorganic COPECs, were detected in water, sediment, and tissues. There were no statistically significant correlations between COPEC concentrations in pore water or sediment with tissues of aquatic organisms, indicating a lack of significant COPEC bioaccumulation. Further, no tissue effect levels for COPECs in invertebrate tissue were exceeded.

Most histopathology measures of clams and mussels showed no significant differences between study sites and reference. Although some exceptions were noted, COPEC concentrations generally did not correlate with differences in histopathology measures.

Weight of Evidence. As stated previously, both the abiotic and biotic measures collected for the RCBRA (DOE/RL-2007-21, Volume I) represent only a snapshot in time and do not represent all seasonal conditions and river stage fluctuations. Abiotic measurements do exceed literature-based screening values for some COPECs, and this line of evidence is generally given the lowest weight given the lack of site-specificity in the literature-based values. Although biological measures give a different perspective than the chemistry, given the limited dataset and the uncertainty with full representation of seasonal measurements, the results of the chemistry cannot be ignored.
Of the key groundwater plume contaminants investigated, only Cr(VI) had concentrations of ecological relevance in the nearshore environment for the 100-BC Area. Cr(VI) in groundwater in the 100-BC-5 OU, which represents a potential ongoing source for pore water concentrations that exceed water quality criteria, warrants further evaluation in the FS. This conclusion is applicable to both aquatic invertebrates and amphibians.

7.5.5.4 Risk to Nearshore Wildlife

The RCBRA evaluated risk to middle trophic-level wildlife including the kingbird, mink, and bufflehead. Risks to wildlife in the nearshore environment are primarily from ingestion of prey consisting of aquatic invertebrates, clams, and fish, and from incidental ingestion of sediment. Only chromium risk to the bufflehead represented a risk warranting further evaluation and the chromium was elevated at just one study site that is not located within the 100-BC Area nearshore environment.

Risk to wildlife in the CRC (DOE/RL-2010-117) focused on exposure to island and riparian soils, and shoreline sediment. Although a handful of chemicals exceeded thresholds based on no-effect levels, only killdeer exposure to lead in shoreline sediments was identified as a final COPEC. The maximum detected concentration was in shoreline sediment in the 100-BC OU, and is below the lowest avian PRG of 156 mg/kg for the killdeer; thus, risk to avian receptors is insignificant and does not warrant further evaluation.

7.5.5.5 Transport Pathways for Cr(VI) from Groundwater to Surface Water

At the 100-BC Area, the groundwater flows toward the Columbia River. During major spring discharge events, river water may enter the banks and the adjacent groundwater system upstream from the Site and move laterally parallel to the river for some distance before discharging back into the river (*Technical Evaluation of the Interaction of Groundwater with the Columbia River at the Department of Energy Hanford Site, 100-D Area* [SGW-39305]). A daily 3 m (9.8 ft) change in river levels superimposed with seasonal changes or alterations of site groundwater flows by remediation efforts likely causes seasonal shifts in the regional groundwater flow system that will consequently impact groundwater-surface water exchange through the hyporheic zone. In addition to the discharge of groundwater to the river through the hyporheic zone, groundwater seasonally discharges in seeps or springs above river stage, principally following seasonal high river stage in early summer. During operations, large volumes of reactor cooling water were discharged to the Columbia River. Under current conditions, the high-volume liquid effluent releases ended when reactor operations ceased in 1971.

Receptors in the riverbed and benthic and hyporheic zones can be exposed to contaminated (1) groundwater, (2) groundwater surface-water mixtures, or (3) surface water. The unconfined aquifer beneath the 100-BC-5 OU discharges to the Columbia River via upwelling through the riverbed, and to a lesser extent, via riverbank springs that appear during periods of low river stage. Sampling locations (e.g., near-river wells, riverbank springs, aquifer tubes, and nearshore river water) used for water quality monitoring near the Columbia River are discussed in the Riparian and Nearshore CSM presented in Appendix M. As is discussed in Chapter 3, springs along the 100-BC Source OU shoreline have been routinely monitored for many years as part of the SESP (2009 Sitewide Environmental Report [PNNL-19455]). Samples of spring water and associated fine-grained sediment collected during the late summer/early fall months have been analyzed for Cr(VI) and other waste effluent indicators. Annual sampling is done when Columbia River flow is at its seasonal low, resulting in the maximum flow of groundwater from the unconfined aquifer to the river. In addition, data were collected near 100-BC Source OUs during the CRC (DOE/RL-2010-117) to address the uncertainty related to the level of contamination entering the Columbia River via upwelling, including the contaminant transport mechanisms. Pore water, surface water, and sediment sampling in the Columbia River was conducted in 2009 and 2010, as outlined in the Columbia River RI Work Plan (DOE/RL-2008-11).

Based on the available information, there is a pathway for migration of concentrations of Cr(VI) in 100-BC-5 OU near-river groundwater to shoreline pore water. In addition, there is evidence (based on conductivity measurements) of pore water entry into Columbia River surface water. However, surface water samples collected in the vicinity of the 100-BC Area have not produced any detectable levels of Cr(VI). The flux of Cr(VI) in groundwater is apparently too small to produce significant Cr(VI) impacts related to Hanford Site operation in Columbia River surface water.

7.5.6 Conclusions

Table 7-9 presents the 12 COECs identified by RCBRA (DOE/RL-2007-21, Volume I) and in the CRC in the riparian and nearshore media. Except for Cr(VI) in groundwater, there are no potential sources for the COECs that are unrelated to the Hanford Site. These sources are summarized in the RCBRA and the CRC. For each COEC, RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2010-117) abiotic

media data (soil, sediment, groundwater, pore water, aquifer tubes, seeps, and surface water) from reference areas, upstream sources, and onsite riparian and nearshore areas were presented and discussed in Appendix M to establish the likelihood that the 100-BC Source OUs were sources of the COECs identified. Only Cr(VI) from the 100-BC-5 Area groundwater OU was considered a source in the 100-BC nearshore and riparian area.

7.6 Risk Conclusions and Scientific Management Decision Point

One or more COPCs from the RCBRA were identified and evaluated within 81 of the 100-BC Source OU waste sites that have been reclassified as "interim closed" or "no action." RCBRA COPCs were evaluated in this ERA for each decision unit (e.g., overburden, shallow-focused, shallow, staging pile area) at each waste site by comparing the EPCs to the plant/invertebrate SSL, the wildlife SSL, background, the plants/invertebrates PRG, and wildlife PRG values. Within 100-BC Source OUs, 26 waste sites were retained for additional consideration in this SMDP based on concentrations of 15 COPECs (antimony, barium, boron, cadmium, carbon-14, chromium, copper, lead, manganese, mercury, molybdenum, selenium, tritium, vanadium, and zinc).

At the SMDP, the results of the ERA were considered in the context of other factors (e.g., spatial coverage, data, chemical specifics, receptors at risk, and confidence in PRGs) to support recommendations on the COECs to be brought forward to the risk manager and considered for the FS. This included agreement on the assessment endpoints, representative receptors, and complete exposure pathways that correspond to those COECs. The final recommendation for the SMDP is a conclusion that there were no potential risks to ecological receptors in the upland waste sites and source OUs warranting further evaluation in the FS. As part of the assessment of contributions to ecological risks identified in the riparian and nearshore environments of the Columbia River (RCBRA [DOE/RL-2007-21]) and the main channel, far shore, and island environment of the Columbia River in the CRC (DOE/RL-2010-117), Cr(VI) in the 100-BC-5 groundwater OU is recommended for further evaluation in the FS.

7.6.1 Scientific Management Decision Point Considerations

Within the process for conducting ecological risk assessments at CERCLA sites, several decision points occur at which risk managers, risk assessors, and other stakeholders must agree on a path forward with respect to ecological risk associated with a site. Typical variations include the following risk assessment outcomes:

- No unacceptable potential risks to ecological receptors (e.g., risks are sufficiently low and below risk-based thresholds such as SSLs or PRGs)
- Potential for risks to ecological receptors, but the risks do not warrant the evaluation of remedial alternatives in the FS because of a number of considerations[9]
- Potential for risks to ecological receptors, but there is uncertainty in one or more component of the ecological risk assessment that warrants the evaluation of remedial alternatives in the FS
- Need to evaluate remedial alternatives in the FS based on the protection of another receptor or exposure pathway (e.g., human health) that would address any potential ecological risks
- Potential for risk to ecological receptors warranting evaluation of remedial alternatives in the FS

[9] For example, a wildlife risk for a specific contaminant was driven by an estimated exposure to a badger but the size of the site is 20 m^2, representing a minimal portion of the total required foraging area for a badger and the site does not represent a preferential feeding area.

With the various risk assessment outcomes listed above, agreement is needed on the following elements to assist in the evaluation of remedial alternatives in the FS: the COCs, the assessment endpoints, the exposure pathways, and the risk questions. To confidently achieve one of the risk assessment outcomes, a number of factors and supporting information were considered in the conclusion of the risk assessment to assist risk management decisions. These outcomes were considered within the context of other exposure pathways and receptors evaluated at the same site. Factors that were considered to interpret the results of the risk characterization and determine whether the site requires evaluation of remedial alternatives in the FS included the following:

- Spatial characteristics of the remediated waste site (area and excavation depth of the remediated waste site)
- Proximity and size of nearby unremediated waste sites and unimpacted habitat
- Number and location of samples collected at the site
- Data quality (presence of qualifiers, adequacy of detection limits)
- Frequency that risk-based thresholds are exceeded and the location(s) of those exceedances
- Chemical-specific properties of each COC (e.g., does it have the potential to biomagnify in the food web or is it persistent in the environment)
- Identification of specific receptors that have the potential for adverse health effects (feeding guild [plants, insects, or omnivorous, herbivorous, insectivorous, or carnivorous wildlife], proportion of receptors affected, likelihood of population- or community-level effects, home range of the receptors at risk relative to the area exceeding risk-based thresholds)
- Recalculation of the EPC based on the home range of the receptor or to estimate the residual risk after the removal action has been implemented
- Evaluation of PRG (i.e., level of confidence, basis, relation to other PRGs such as those for human health or groundwater protection)

As shown in Table 7-10, 26 waste sites within the 100-BC OU were reported with concentrations of COPECs greater than their respective PRGs. During development of the risk assessment, the factors above were evaluated and resulted in a recommendation, as part of the SMDP, that no waste sites be carried forward into the FS for evaluation of remedial alternatives. The decisions for 100-BC OUs were based on a subset of the factors described above, including the following:

- The depth of samples[10] exceeding thresholds relative to the 4.6 m (15 ft) bgs standard point of compliance for ecological receptors defined by MTCA (WAC 173-340)
- The number and frequency of exceedances of the risk thresholds (PRGs)
- The magnitude of exceedance relative to the risk thresholds (the HQ)
- The confidence in the ecological risk thresholds defining the exceedances

[10] For the purposes of the ERA, it was assumed that soil up to 4.6 m (15 ft) bgs is accessible to ecological receptors because these soils can be brought to the surface by human activities, thereby becoming biologically accessible. In some cases, the database indicated soils were collected from a shallow depth, but further review conducted for the SMDP showed that soils were collected below 4.6 m (15 ft).

- The quality of the sample data defining the exceedances
- The location of the samples exceeding thresholds, sample frequency, and proximity of other exceedances
- The area of exceedance relative to home range of receptor exceeding and relative to area of unimpacted nearby habitat

As indicated in Table 7-10, consideration of the factors listed above resulted in the conclusion of no unacceptable risks to terrestrial wildlife or plants and invertebrates exposed to vadose zone soils and a recommendation of no further action for any of the waste sites within the 100-BC or 100-BC-5 Source OUs based on ecological risk. For unremediated waste sites, remedial actions will consider the PRGs based on ecological risk through the SMDP process laid out here. More detail in applying that process to unremediated sites is provided in Sections 7.6.2 and 7.6.3.

7.6.2 Recommendations for Evaluating Wildlife in Future Assessments at Unremediated Waste Sites

Data and process knowledge indicate ecological PRGs will be exceeded at unremediated waste sites. Those exceedances will be evaluated through the ERA process, including consideration of such factors as waste site size and wildlife home ranges within a scientific management decision point, to determine a basis for action. PRGs will be presented in the Proposed Plans for protection of wildlife receptors. The PRGs will achieve protection of the populations of wildlife species constituting the food web found at the Hanford Site (Figure 7-1), including a range of feeding guilds. The receptor species selected for quantitative development of PRGs are intended to be representative of the species within those feeding guilds.

As discussed in the technical support documents for ecological values in soil for wildlife (*Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-00784]; *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-01311]), the values used to calculate PRGs are based on the assumption that the size of the waste site inhabited by a receptor is the same size as the area used by the animal; e.g., its home range, breeding range, or feeding/foraging range. In other words, the PRGs assume that a wildlife receptor is exposed 100 percent of the time to the contaminants in a waste site at uniform concentrations equal to the EPC. This ratio of the area of contamination to the home range is known as an Area Use Factor (AUF). An AUF = 1.0 is another way of stating the assumption that the contaminated area and home range are identical. An AUF of 1.0 means that an animal is exposed to site contaminants 100 percent of the time, depending on the home range of the animal in relation to the size of the waste site, assuming that the AUF = 1.0 in development of SSLs or PRGs may considerably overstate ecological risks. However, several wildlife receptors, particularly the carnivorous mammals and most birds, have home ranges much larger than most of the waste sites; therefore, applying PRGs for those receptors to most waste sites would overstate ecological risks.

The home ranges for the wildlife receptors used for PRG development are shown in Appendix H, Table H-5. In considering the home range data available for each species, recognition must be given to the fact that these ranges are reduced during breeding season. On the other hand, food sources in an arid environmental such as Hanford may be more scarce than what is reflected in the studies available, some of which were not conducted in similar habitats. Although many biological studies have been conducted at Hanford, studies specifically on home range or population density are not available for all species or guilds being evaluated.

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
100-B-14:1	Overburden_2	Carbon-14	44	60,700	Not Exceeded	32	Moderate. Semi-site-specific value calculated for a specific Hanford wildlife species (badger) using RESRAD BIOTA Version 1.5 model (DOE/EH 0676, 2004) but with literature inputs, because Hanford Site-specific data were not available for all parameters. Consideration of the size of waste sites relative to the home range of wildlife receptors was not considered.	88	Length = 1,390 m (4,560 ft)	Not Applicable	6	<1 to 664	<0.03 to 21	--	No. Overburden soils from this site currently reside at a depth greater than 4.6 m (15 ft) bgs: direct contact within point of compliance is incomplete.
100-B-14:2	Overburden Focused	Mercury	0.47	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Not Exceeded	8	Length = 1,286 m (4,219 ft)	Not Applicable	1	<0.02 to 0.47	<0.06 to 1.4	--	No. EPC only slightly greater than plant PRG with only 1 of 8 samples along a linear feature exceeding the low confidence plant PRG. No soil concentrations greater than lowest wildlife PRG for biomagnifying compound. The size of the waste site is small and the likelihood of effects is low. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).

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Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
100-B-14:6	Shallow Focused	Barium	364	358	Moderate to High – RCBRA NOEC for invertebrates. Confidence in PRG is high with respect to a lack of toxicity at this concentration but low in that the PRG is set at the highest concentration samples; thus, PRG could be higher.	1,690	Not Exceeded	2	Length = 455 m (1,493 ft)	2.4 m (8 ft)	1	74 to 364	0.21 to 1.0	--	No. EPC slightly greater than invertebrate PRG. An elevated concentration at a point site does not suggest exposure is sufficient to cause an adverse effect to the invertebrate community. The area of the waste site is insignificant given availability and size of nearby suitable habitat without contamination outside of the 100-BC Source OU.
100-B-14:6	Shallow Focused	Mercury	1.4	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified (Kabata-Pendias and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Not Exceeded	2	Length = 455 m (1,493 ft)	2.4 m (8 ft)	1	<0.02 to 1.4	<0.06 to 4.2	--	No. One of 2 samples along a linear feature exceeding the low confidence plant PRG. No soil concentrations greater than lowest wildlife PRG for biomagnifying compound. The size of the waste site is small and the likelihood of effects is low. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).
100-B-18—184-B Powerhouse Debris Pile	Shallow Focused	Barium	1,300	358	Moderate to High – RCBRA NOEC for invertebrates. Confidence in PRG is high with respect to a lack of toxicity at this concentration but low in that the PRG is set at the highest concentration samples; thus, PRG could be higher.	1,690	Not Exceeded	11	505 m^2 (5,436 ft^2)	0.30 m (1.0 ft)	1	54 to 1,300	0.15 to 3.6	--	No. Only one of 11 samples within a small site (0.12 ac/0.05 ha) slightly exceeded the invertebrate (358 mg/kg) and plant (500 mg/kg) PRGs. An elevated concentration at a point site does not suggest exposure is sufficient to cause an adverse effect to the invertebrate or plant communities. The area of the waste site is insignificant given availability and size of nearby suitable habitat without contamination outside of the 100-BC Source OU. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
															habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).
100-B-18—184-B Powerhouse Debris Pile	Shallow Focused	Boron	34	28.6	Moderate to High – RCBRA NOEC for invertebrates. Confidence in PRG is high with respect to a lack of toxicity at this concentration but low in that the PRG is set at the highest concentration samples; thus, PRG could be higher.	91	Not Exceeded	11	505 m^2 (5,436 ft^2)	0.30 m (1.0 ft)	1	1.2 to 34	0.04 to 1.1	--	No. Only one of 11 samples within a small site slightly exceeded the invertebrate (28.6 mg/kg) and plant (29.6 mg/kg) PRGs, which are a NOEC. An elevated concentration at a point site does not suggest exposure is sufficient to cause an adverse effect to the invertebrate or plant communities. The area of the waste site is insignificant given availability and size of nearby suitable habitat without contamination outside of the 100-BC Source OU. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).
100-B-18–184-B Powerhouse Debris Pile	Shallow Focused	Cadmium	13	10	High – Hanford Site-specific NOEC for plants. Confidence in PRG is high with respect to a lack of toxicity at this concentration but low in that the PRG is set at the highest concentration samples; thus, PRG could be higher.	29	Not Exceeded	11	505 m^2 (5,436 ft^2)	0.30 m (1.0 ft)	1	<0.05 to 13	<0.01 to 3.3	--	No. Only one of 11 samples within a small site slightly exceeded the invertebrate PRGs, a NOEC. An elevated concentration at a point site does not suggest exposure is sufficient to cause an adverse effect to the invertebrate community. No soil concentrations greater than lowest wildlife PRG for biomagnifying compound. The area of the waste site is insignificant given availability and size of nearby suitable habitat without contamination outside of the 100-BC Source OU containing invertebrates.

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
100-B-18—184-B Powerhouse Debris Pile	Shallow Focused	Mercury	2.2	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Moderate-High. Deer mouse Hanford Site-specific value modeled with Hanford Site-specific prey tissue data using a combination of regression models and BAFs.	11	505 m^2 (5,436 ft^2)	0.30 m (1.0 ft)	6/11	<0.02 to 2.2	<0.06 to 6.7/<0.01 to 1.4	--	No. The size of the waste site is very small at 262 m^2 (5,436 ft^2). The home range of the deer mouse is 2 times greater (890 m^2/9,670 ft^2; Bowers and Smith, 1979). Employing an AUF would result in a hazard quotient below 1 and just one of 11 samples exceeds the wildlife PRG. Effects to plants are uncertain given the low confidence in the PRG. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).
100-B-18—184-B Powerhouse Debris Pile	Shallow Focused	TPH	222	15 to 1490	Low - Values in Table 749-3 100 mg/kg for gasoline and 200 mg/kg for diesel based on values published in ES/ER/TM-126/R2. The same author has also reported that NOECs for lube oil range from 15-1,490 mg/kg (Efroymson et al., 2004). All of these values are from a secondary source and may not reflect Hanford Site conditions.	NA	NA	2 1 sample and a duplicate both consisting of 25 random aliquots.	505 m^2 (5,436 ft^2)	0.30 m (1.0 ft)	2	165 to 222	NA	--	No. Investigation area insignificant (0.05 ha/ 0.12 ac) given availability and size of nearby suitable habitat without contamination. The waste site with the nearest proximity is over 153 m (500 ft) away. The exact form of the petroleum compounds measured at the site is unknown. Also, the suitability of toxicity values for the Hanford Site has not been fully assessed. The area of the waste site is insignificant given availability and size of nearby suitable habitat without contamination outside of the 100-BC Source OU containing invertebrates.

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
100-B-19—100-BC Area Stained Soil Sites and 100-BC Area Chemical Contaminated Surface Soil Areas	Shallow_5	Mercury	6.1	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Moderate-High. Deer mouse Hanford Site-specific value modeled with Hanford Site-specific prey tissue data using a combination of regression models and BAFs.	10	262 m^2 (2,820 ft^2)	0.91 m (3 ft)	3/1	<0.01 to 6.1	<0.03 to 18/<0.01 to 3.8	--	No. The size of the waste site is very small at 262 m^2 (2,820 ft^2). The home range of the deer mouse is three times greater (890 m^2/9,670 ft^2; Bowers and Smith, 1979). Employing an AUF would result in a hazard quotient around 1 and just 1 of 10 samples exceeds the wildlife PRG. Effects to plants are uncertain given the low confidence in the PRG. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).
100-B-19→100-BC Area Stained Soil Sites and 100-BC Area Chemical Contaminated Surface Soil Areas	Shallow Focused	Mercury	17	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Moderate-High. Deer mouse Hanford Site-specific value modeled with Hanford Site-specific prey tissue data using a combination of regression models and BAFs.	7	262 m^2 (2,820 ft^2)	0.91 m (3 ft)	5/4	<0.01 to 17	<0.03 to 52/<0.01 to 11	--	No. Mercury concentration at single point location was removed when export water line was installed. The size of the waste site is very small at 262 m^2 (2,820 ft^2). The home range of the deer mouse is three times greater (890 m^2/9,670 ft^2; Bowers and Smith, 1979). Employing an AUF to the residual exposure concentration would result in a hazard quotient around 1. Effects to plants are uncertain given the low confidence in the PRG. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
100-B-19—100-BC Area Stained Soil Sites and 100-BC Area Chemical Contaminated Surface Soil Areas	Shallow Focused	Vanadium	91	89	High – Hanford Site-specific NOEC for plants. Confidence in PRG is high with respect to a lack of toxicity at this concentration but low in that the PRG is set at the highest concentration samples; thus, PRG could be higher.	43	Moderate. Killdeer Hanford site-specific value modeled with Hanford Site-specific prey tissue data using BAFs.	7	262 m^2 (2,820 ft^2)	0.91 m (3ft)	1/7	44 to 91	0.52 to 1.1/1.0 to 2.1	--	No. All concentrations within range of naturally occurring vanadium concentrations. No known sources of vanadium. Vanadium concentrations exceed the killdeer PRG and two samples exceed that for the California quail. The size of site is small (262 m^2/2,820 ft^2). The home range of the killdeer is significantly greater (80,128 m^2/862,488 ft^2; Mace, 1971 in NISC, 1996) and that for the quail is even greater (CWHR, 2012). Employing an AUF would result in a hazard quotient well below 1.
100-B-20	Shallow Focused	Mercury	0.33	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Not Exceeded	5	191.4 m^2 (2,060 ft^2)	0.30 m (1.0 ft)	1	<0.014 to 0.327	<0.05 to 1.1	--	No. EPC only slightly greater than plant PRG and only 1 of 5 samples exceeded the low confidence plant PRG. No soil concentrations greater than lowest wildlife PRG for biomagnifying compound. The size of the waste site is small and the likelihood of effects is low. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).
100-B-22:2—100-B Water Treatment Facilities	Shallow Focused	Copper	67	58	High–Invertebrate Hanford Site-specific NOEC from Ecology Publication 11-03-006. Confidence in PRG is high with respect to a lack of toxicity at this concentration but low in that the PRG is set at the highest concentration samples; thus, PRG could be higher.	213	Not Exceeded	11	19,740 m^2 (212,500 ft^2)	0.15 to 0.30 m (0.5 to 1.0 ft)	1	15 to 67	0.30 to 1.3	--	No. Only 1 of 11 samples exceeded the invertebrate PRG, which is a NOEC. An elevated concentration at a point site does not suggest exposure is sufficient to cause an adverse effect to the invertebrate community. No soil concentrations greater than lowest wildlife PRG for biomagnifying compound. The area of the waste site is insignificant given availability and size of nearby suitable habitat without contamination outside of the 100-BC Source OU containing invertebrates.

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
100-B-22:2—100-B Water Treatment Facilities	Shallow Focused	Mercury	0.32	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Not Exceeded	11	19,735 m^2 (212,425 ft^2)	0.6 m to 2.4 m (2 ft to 8 ft)	1	0.02 to 0.3	0.03 to 1.1	--	No. EPC only slightly greater than plant PRG and only 1 of 11 samples exceeded the low confidence plant PRG. No soil concentrations greater than lowest wildlife PRG for biomagnifying compound. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).
100-B-22:2—100-B Water Treatment Facilities	Shallow Focused	Molybdenum	2	2	Low – Plant ORNL Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. Neuman et al., 1987 reported that phytotoxicty of molybdenum has never been reported in the literature.	5.7	Not Exceeded	11	19,735 m^2 (212,425 ft^2)	0.6 m to 2.4 m (2 ft to 8 ft)	1	0.3 to 1.9	0.145 to 1.0	All but one detected sample was also identified in the associated blank (B qualifier)	No. One sample and the EPC are just at the high confidence PRG, which is a NOEC.

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Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
100-B-23—100-BC Area Surface Debris	Shallow Focused	Mercury	8.2	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Moderate-High. Deer mouse Hanford Site-specific value modeled with Hanford Site-specific prey tissue data using a combination of regression models and BAFs.	4	~100 m^2 (1,076 ft^2)	0.30 m (1.0 ft)	2/1	<0.01 to 8.2	<0.03 to 25/<0.01 to 5.1		No. The size of the waste site is very small at 100 m^2 (1,076 ft^2). The home range of the deer mouse is nine times greater (890 m^2/9,670 ft^2; Bowers and Smith, 1979). Employing an AUF would result in a hazard quotient well below 1. Effects to plants are uncertain given the low confidence in the PRG. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).
100-B-23—100-BC Area Surface Debris	Shallow Focused	Zinc	1,310	621	Moderate-High RCBRA NOEC for invertebrates. Confidence in PRG is high with respect to a lack of toxicity at this concentration but low in that the PRG is set at the highest concentration samples; thus, PRG could be higher.	856	High. Killdeer Hanford Site-specific value modeled with Hanford Site-specific prey tissue data using a regression model.	4	~100 m^2 (1,076 ft^2)	0.30 m (1.0 ft)	1/1	34 to 1,310	0.09 to 3.3/0.04 to 1.5	--	No. The Zinc EPC exceeded the killdeer PRG and that for the red-tailed hawk and badger. The size of site is small (100 m^2/1,076 ft^2). The home range of the killdeer is significantly greater (80,128 m^2/862,488 ft^2; Mace, 1971 in NISC, 1996) and that for the red-tailed hawk (CWHR, 2012) and badger (Kurta, 1995; Long, 1999) are even greater. Employing an AUF would result in a hazard quotient well below 1.
100-B-23—100-BC Area Surface Debris	Shallow Focused	TPH	173	15 to 1490	Low - Values in Table 749-3 100 mg/kg for gasoline and 200 mg/kg for diesel based on values published in ES/ER/TM-126/R2. The same author has also reported that NOECs for lube oil range from 15-1490 mg/kg (Efroymson et al., 2004). All of these values are from a secondary source and	NA	NA	35	~100 m^2 (1,076 ft^2)	0.30 m (1.0 ft)	0	133 (U) - 154 (U)	NA	--	No. Twenty-eight samples (13 samples collected from an air filter, 12 samples collected from an oil filter, and 3 samples collected from other debris) did not represent surface soil and were not included in the evaluation. The remaining 7 samples were collected from soil; however, TPH was not detected in any of these samples.

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
					may not reflect Hanford Site conditions.										
100-B-28—183-C Headhouse to the 183-B Pumphouse Sodium Dichromate Transfer Pipeline	Shallow Focused	Mercury	0.8	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Not Exceeded	6	Length = 631 m (2,070 ft)	0.30 m (1.0 ft)	1	<0.02 to 0.80	<0.06 to 2.4	--	No. Short linear feature with minimal exceedance of low confidence plant PRG in just 1 of 6 samples. No soil concentrations greater than lowest wildlife PRG for biomagnifying compound. The size of the waste site is small and the likelihood of effects to plants is low. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).
100-B-28—183-C Headhouse to the 183-B Pumphouse Sodium Dichromate Transfer Pipeline	Shallow Focused	Vanadium	106	89	High – Hanford Site-specific NOEC for plants. Confidence in PRG is high with respect to a lack of toxicity at this concentration but low in that the PRG is set at the highest concentration samples; thus, PRG could be higher.	43	Moderate. Killdeer Hanford Site-specific value modeled with Hanford Site-specific prey tissue data using BAFs.	6	Length = 631 m (2,070 ft)	0.30 m (1.0 ft)	1/6	53 to 106	0.62 to 1.3/1.2 to 2.5	--	No. All concentrations within range of naturally occurring vanadium concentrations. No known sources of vanadium. Vanadium concentrations exceed the killdeer PRG and that for the California quail. The size of site is small (631 m /2,070 ft). The home range of the killdeer is significantly greater (80,128 m^2/862,488 ft^2; Mace, 1971 in NISC, 1996) and that for the quail even greater (CWHR, 2012). Employing an AUF would result in a hazard quotient well below 1.

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
100-B-28—183-C Headhouse to the 183-B Pumphouse Sodium Dichromate Transfer Pipeline	Staging pile area_4	Mercury	4.6	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Moderate-High. Deer mouse Hanford Site-specific value modeled with Hanford Site-specific prey tissue data using a combination of regression models and BAFs.	12	Length = 631 m (2,070 ft)	Not Applicable	2/1	<0.02 to 18.5	<0.06 to 56/<0.01 to 12	--	No. This short linear feature was well-sampled (12 total samples). One sample was high at 18.5 mg/kg. The rest were nondetect save one detection in the range of the low confidence plant PRG. Unless there was an attractive nuisance leading wildlife to the location of the high detection, exposure would NOT result in a risk to small mammals at the population level. Adverse effects to plants are also unlikely. If effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).
100-B-31—Garnet Sand Located at the 183-C Clearwell Pads	Shallow	Molybdenum	4.5	2	Low – Plant ORNL – Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. Neuman et al., 1987 reported that phytotoxicty of molybdenum has never been reported in the literature.	5.7	Not Exceeded	21	16,281 m^2 (53,400 ft^2)	0.30 m (1.0 ft)	7	0.43 to 8.5	0.22 to 2.2	--	No. EPC slightly greater than low confidence plant PRG. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
100-C-9:1—Main Process Sewer Collection Line	Shallow_2	Mercury	1.8	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Moderate-High. Deer mouse Hanford Site-specific value modeled with Hanford Site-specific prey tissue data using a combination of regression models and BAFs.	22	Length = 2,871 m (9,420 ft)	4.6 m (15 ft)	7/4	<0.01 to 8.8	<0.03 to 27/<0.01 to 5.5	--	No. Soil samples collected from a depth greater than 4.6 m (15 ft) bgs: direct contact within point of compliance is incomplete. Samples collected much deeper than the burrowing depth of small mammals at Hanford (1 m [3.3 ft] for pocket mouse [Cline et al., 1980]) or other similar sites (0.5 m [1.6 ft] for deer mouse at Idaho National Engineering Laboratory [Reynolds and Laundre, 1988]).
100-C-9:2—Sanitary Sewers	Shallow Focused	Copper	66	58	High–Invertebrate Hanford Site-specific NOEC from Ecology Publication 11-03-006. Confidence in PRG is high with respect to a lack of toxicity at this concentration but low in that the PRG is set at the highest concentration samples; thus, PRG could be higher.	213	Not Exceeded	13	Length = 459 m (1,506 ft)	2.0 to 9.0 m (6.6 to 29.5 ft)	1	14 to 66	0.28 to 1.3	--	No. Only 1 of 13 samples exceed the invertebrate PRG. No soil concentrations greater than lowest wildlife PRG for biomagnifying compound. Most samples collected from depths greater than 4.6 m (15 ft) bgs; direct contact within point of compliance is incomplete. The maximum observed depth of invertebrates reported at the Hanford Site was 2.7 m (8.9 ft; PNNL-2774). The area of the waste site is insignificant given availability and size of nearby suitable habitat without contamination outside of the 100-BC Source OU containing invertebrates.

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
100-C-9:2—Sanitary Sewers	Shallow Focused	Mercury	0.85	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Not Exceeded	13	Length = 459 m (1,506 ft)	2.0 to 9.0 m (6.6 to 29.5 ft)	3	<0.01 to 0.85	<0.03 to 2.6	--	No. EPC slightly greater than the low confidence plant PRG for those samples less than 2.7 m (8.9 ft). No soil concentrations greater than lowest wildlife PRG for biomagnifying compound. Most samples collected from depths greater than 4.6 m (15 ft) bgs where direct contact within point of compliance is incomplete. The size of the waste site (narrow linear feature) is small and the likelihood of effects is low. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).
116-B-10—Dry Well Quench Tank	Shallow	Mercury	1.3	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Not Exceeded	4	4 m^2 (13 ft)		1	0.07 to 1.3	0.21 to 3.9	--	No. EPC only slightly greater than plant PRG and only 1 of 4 samples exceeded the low confidence plant PRG. No soil concentrations greater than lowest wildlife PRG for biomagnifying compound. The size of the waste site is small and the likelihood of effects is low. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
116-B-5—Crib	Shallow Focused	Mercury	16	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Moderate-High. Deer mouse Hanford Site-specific value modeled with Hanford Site-specific prey tissue data using a combination of regression models and BAFs.	45	58 m^2 (624 ft^2)	4.9 m (16 ft)	9/7	<0.01 to 16	<0.03 to 48/<0.01 to 10	--	No. Soil samples collected from a depth greater than 4.6 m (15 ft) bgs: direct contact within point of compliance is incomplete. No soil concentrations greater than lowest wildlife PRG for biomagnifying compound. The area of the waste site is insignificant given availability and size of nearby suitable habitat without contamination outside of the 100-BC Source OU.
116-B-5—Crib	Shallow Focused	Tritium	680	1,680,000	Not Exceeded	420	Moderate. Semi-site-specific value calculated for a specific Hanford wildlife species (badger) using RESRAD BIOTA Version 1.5 model (DOE/EH 0676, 2004) but with literature inputs, because Hanford Site-specific data were not available for all parameters. Consideration of the size of waste sites relative to the home range of wildlife receptors was not considered.	6	58 m^2 (624 ft^2)	4.9 m (16 ft)	2	<50 to 680	0.12 to 1.6	--	No. Soil samples collected from a depth greater than 4.6 m (15 ft) bgs: direct contact within point of compliance is incomplete. The area of the waste site is insignificant given availability and size of nearby suitable habitat without contamination outside of the 100-BC Source OU.

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Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
116-B-9—French Drain	Shallow	Mercury	0.39	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Not Exceeded	4	Length = 4 m (13 ft) Area = 2.3 m^2 (25 ft^2)	2.4 m (8.0 ft)	1	0.17 to 0.39	0.52 to 1.2	--	No. EPC only slightly greater than plant PRG and only 1 of 4 samples exceeded the low confidence plant PRG. No soil concentrations greater than lowest wildlife PRG for biomagnifying compound. The size of the waste site is small and the likelihood of effects is low. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).
116-C-3—105C Chemical Waste Tanks	Shallow	Carbon-14	42	60,700	Not Exceeded	32	Moderate. Semi-site-specific value calculated for a specific Hanford wildlife species (badger) using RESRAD BIOTA Version 1.5 model (DOE/EH 0676, 2004) but with literature inputs, because Hanford Site-specific data were not available for all parameters. Consideration of the size of waste sites relative to the home range of wildlife receptors was not considered.	10	Length = 11 m (36 ft)	8.5 m (28 ft)	1	<0.31 to 42	<0.01 to 1.3	--	No. Only 1 of 10 samples exceeded the PRG. Soil samples collected from a depth greater than 4.6 m (15 ft) bgs: direct contact within point of compliance is incomplete. Size of site is insignificant given that area use factors were not incorporated into the PRG.

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
116-C-3—105C Chemical Waste Tanks	Staging pile area focused	Selenium	1.6	2	High – Plant Hanford Site-specific NOEC. Confidence in PRG is high with respect to a lack of toxicity at this concentration but low in that the PRG is set at the highest concentration samples; thus, PRG could be higher.	1.4	Moderate-High. Deer Mouse Hanford Site-specific value modeled with Hanford Site-specific prey tissue data using a combination of regression models and BAFs.	3	Length = 11 m (36 ft) Area = 149 m^2 (1,604 ft^2)	Not Applicable	3	1.6 to 1.8	1.3 to 1.5/1.1 to 1.3	--	No. Low confidence in analytical method. Detected concentrations and MDLs are reported within the same range as the PRG values. The size of the waste site is very small at 149 m^2 (1,604 ft^2). The home range of the deer mouse is eight times greater (890 m^2/9,670 ft^2; Bowers and Smith, 1979). Employing an AUF would result in a hazard quotient well below 1.
118-B-1—105B Solid Waste Burial Ground	Overburden_1	Mercury	2	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Moderate-High. Deer mouse Hanford Site-specific value modeled with Hanford Site-specific prey tissue data using a combination of regression models and BAFs.	2	37,442 m^2 (403,000 ft^2)	Not Applicable	1	<0.02 to 2.0	<0.06 to 6.1/<0.01 to 1.3	--	No. Overburden soils from this waste site currently reside at a depth greater than 4.6 m (15 ft) bgs: direct contact within point of compliance is incomplete. Further, samples were collected 3 m (10 ft) below ground, much deeper than the burrowing depth of small mammals at Hanford (1 m [3.3 ft] for pocket mouse [Cline et al., 1980]) or other similar sites (0.5 m [1.6 ft] for deer mouse at Idaho National Engineering Laboratory [Reynolds and Laundre, 1988]). If adverse effects to plants did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).
118-B-1—105B Solid Waste Burial Ground	Shallow_7	Molybdenum	2.1	2	Low–Plant ORNL Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. Neuman et al., 1987 reported that phytotoxicty of molybdenum has never been reported in the literature.	5.7	Not Exceeded	3	37,442 m^2 (403,000 ft^2)	10 m (33 ft)	1	<0.80 to 2.1	0.40 to 1.1	--	No. Soil samples collected from a depth greater than 4.6 m (15 ft) bgs: direct contact within point of compliance is incomplete. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
118-B-1—105B Solid Waste Burial Ground	Shallow_3	Mercury	0.3	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Not Exceeded	6	37,442 m^2 (403,000 ft^2)	Not Applicable	2	<0.01 to 13.4	<0.033 to 44	Maximum concentration identified in associated blank (B qualifier)	No. One sample was measured at the same level as the low confidence plant PRG. One sample was measured higher than the plant, wildlife, and invertebrate PRG (12.5 mg/kg) but was also found in the blank. The EPC was only just at the plant PRG: adverse effects to plants are not likely. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).
118-B-1—105B Solid Waste Burial Ground	Shallow Focused	Mercury	15	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Moderate-High. Deer mouse Hanford Site-specific value modeled with Hanford Site-specific prey tissue data using a combination of regression models and BAFs.	7	37,442 m^2 (403,000 ft^2)	10 m (33 ft)	4/3	<0.02 to 15	<0.06 to45/<0.01 to 9.4	--	No. Soil samples collected from a depth greater than 4.6 m (15 ft) bgs: direct contact within point of compliance is incomplete.

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
118-B-1—105B Solid Waste Burial Ground	Staging pile area focused	Mercury	10	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Moderate-High. Deer mouse Hanford Site-specific value modeled with Hanford Site-specific prey tissue data using a combination of regression models and BAFs.	2	Not Applicable	Not Applicable	1	0.06 to 10	0.18 to 30/0.04 to 6.3	--	No. This area was backfilled inside the excavated site and is currently at depths greater than 4.6 m (15 ft). Direct contact within point of compliance is incomplete. Further, samples were collected 3 m (10 ft) below ground, much deeper than the burrowing depth of small mammals at Hanford (1 m [3.3 ft] for pocket mouse [Cline et al., 1980]) or other similar sites (0.5 m [1.6 ft] for deer mouse at Idaho National Engineering Laboratory [Reynolds and Laundre, 1988]).
118-C-1—105C Solid Waste Burial Ground	Shallow_3	Molybdenum	4.5	2	Low–Plant ORNL Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. Neuman et al., 1987 reported that phytotoxicty of molybdenum has never been reported in the literature.	5.7	Not Exceeded	4	18,019 m^2 (194,000 ft^2)	5.2 m (17 ft)	1	<0.8 to 4.5	<0.40 to 2.3	--	No. Soil samples collected from a depth greater than 4.6 m (15 ft) bgs; direct contact within point of compliance is incomplete. The area of the waste site is insignificant given availability and size of nearby suitable habitat without contamination outside of the 100-BC Source OU.

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
118-C-1—105C Solid Waste Burial Ground	Staging pile area	Carbon-14	182	60,700	Not Exceeded	32	Moderate. Semi-site-specific value calculated for a specific Hanford wildlife species (badger) using RESRAD BIOTA Version 1.5 model (DOE/EH 0676, 2004) but with literature inputs, because Hanford Site-specific data were not available for all parameters. Consideration of the size of waste sites relative to the home range of wildlife receptors was not considered.	16	18,019 m^2 (194,000 ft^2)	Not Applicable	1	<0.4 to 182	<0.01 to 5.7	--	No. Soil samples collected from a depth greater than 4.6 m (15 ft) bgs: direct contact within point of compliance is incomplete.
118-C-1—105C Solid Waste Burial Ground	Staging pile area	Copper	58	58	High–Invertebrate Hanford Site-specific NOEC from Ecology Publication 11-03-006. Confidence in PRG is high with respect to a lack of toxicity at this concentration but low in that the PRG is set at the highest concentration samples; thus, PRG could be higher.	213	Not Exceeded	16	18,019 m^2 (194,000 ft^2)	Not Applicable	1	13 to 144	0.26 to 2.9	--	No. Only one of 16 samples is equal to the invertebrate PRG, which is a NOEC. The EPC is at this NOEC, thus there is no indication of an adverse effect. Soil samples were collected from a depth greater than 4.6 m (15 ft) bgs: direct contact within point of compliance is incomplete. The maximum observed depth of invertebrates reported at the Hanford Site was 2.7 m (8.9 ft; PNNL-2774).
118-C-1—105C Solid Waste Burial Ground	Staging pile area	TPH	146	15 to 1490	Low - Values in Table 749-3 100 mg/kg for gasoline and 200 mg/kg for diesel based on values published in ES/ER/TM-126/R2. The same author has also reported that NOECs for lube oil range form 15-1490 mg/kg (Efroymson et al., 2004). All of these	NA	NA	16	18,019 m^2 (194,000 ft^2)	Not Applicable	16	<133 to 146	NA	UC, or C	No. Samples were either nondetect at 133 mg/kg or detected with a C flag at 143 mg/kg. Soil samples were collected from a depth greater than 4.6 m (15 ft) bgs: direct contact within point of compliance is incomplete. The maximum observed depth of invertebrates reported at the Hanford Site was 2.7 m (8.9 ft; PNNL-2774).

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
					values are from a secondary source and may not reflect Hanford Site conditions.										
118-C-3:3—105-C French Drains	Shallow Focused	Mercury	0.8	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Not Exceeded	4	2.6 m^2 (28 ft^2)	4.6 m (15 ft)	1	<0.01 to 0.8	<0.03 to 2.4	--	No. Soil samples collected from a depth greater than 4.6 m (15 ft) bgs: direct contact within point of compliance is incomplete. The area of the waste site is insignificant given availability and size of nearby suitable habitat without contamination outside of the 100-BC Source OU.
120-B-1—105B Battery Acid Sump	Shallow Focused	Chromium	273	149	Moderate to High – RCBRA NOEC for invertebrates. Confidence in PRG is high with respect to a lack of toxicity at this concentration but low in that the PRG is set at the highest concentration samples; thus, PRG could be higher.	109	Moderate. Killdeer Hanford Site-specific value modeled with Hanford Site-specific prey tissue data using BAFs.	6	6.5 m^2 (70 ft^2)	3.0 m (10 ft)	1/4	19 to 273	0.45 to 6.5/0.17 to 2.5	--	No. Sampling locations with concentrations greater than wildlife PRG are immediately adjacent to the 100-B Reactor wall. The size of site is small (6.5 m^2/70 ft^2). The home range of the killdeer is significantly greater (80,128 m^2/862,488 ft^2; Mace, 1971 in NISC, 1996). Employing an AUF would result in a hazard quotient well below 1. Further, samples were collected 3 m (10 ft) below ground, much deeper than the burrowing depth of small mammals at Hanford (1 m [3.3 ft] for pocket mouse [Cline et al., 1980]) or other similar sites (0.5 m [1.6 ft] for deer mouse at Idaho National Engineering Laboratory [Reynolds and Laundre, 1988]). The maximum observed depth of invertebrates reported at the Hanford Site was 2.7 m (8.9 ft; PNNL-2774); thus, exposure to invertebrates is also incomplete. The area of the waste site

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
															is insignificant given availability and size of nearby suitable habitat without contamination outside of the 100-BC Source OU.
120-B-1—105B Battery Acid Sump	Shallow Focused	Molybdenum	2.1	2	Low–Plant ORNL Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. Neuman et al., 1987 reported that phytotoxicty of molybdenum has never been reported in the literature.	5.7	Not Exceeded	6	6.5 m^2 (70 ft^2)	3.0 m (10 ft)	3	<0.92 to 2.3	<0.46 to 1.2		No. EPC slightly greater than low confidence plant PRG. The size of the site is insignificant. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).
128-B-3—Burn Pit Site	Shallow_2	TPH	431	15 to 1490	Low - Values in Table 749-3 100 mg/kg for gasoline and 200 mg/kg for diesel based on values published in ES/ER/TM-126/R2. The same author has also reported that NOECs for lube oil range from 15-1490 mg/kg (Efroymson et al., 2004). All of these values are from a secondary source and may not reflect Hanford Site conditions.	NA	NA	10	17,047 m^2 (183,500 ft^2)		3	<133 to 431	NA	--	No. Three detects of 11 samples. The exact form of the petroleum compounds measured at the site is unknown, but no exceedances of PRGs were noted for individual PAH chemicals measured in the Shallow 1 and Shallow 3 decision units. Also, the suitability of toxicity values for the Hanford Site has not been fully assessed. The area of the waste site is insignificant given availability and size of nearby suitable habitat without contamination outside of the 100-BC Source OU containing invertebrates.

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
128-B-3—Burn Pit Site	Shallow_3	Molybdenum	4.7	2	Low–Plant ORNL Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. Neuman et al., 1987 reported that phytotoxicty of molybdenum has never been reported in the literature.	5.7	Not Exceeded	17	17,047 m^2 (183,500 ft^2)	0.3 m (1.0 ft)	1	<0.83 to 4.7	<0.42 to 2.4	--	No. EPC slightly greater than low confidence plant PRG. The maximum observed depth of invertebrates reported at the Hanford Site was 2.7 m (8.9 ft; PNNL-2774). Exposure pathways to contaminated soils are incomplete for those receptors for which a risk was identified.
128-B-3—Burn Pit Site	Shallow_3	TPH	258	15 to 1490	Low - Values in Table 749-3 100 mg/kg for gasoline and 200 mg/kg for diesel based on values published in ES/ER/TM-126/R2. The same author has also reported that NOECs for lube oil range from 15-1490 mg/kg (Efroymson et al., 2004). All of these values are from a secondary source and may not reflect Hanford Site conditions.	NA	NA	17	17,047 m^2 (183,500 ft^2)	0.3 m (1.0 ft)	1	<133 to 258	NA	--	No. Just one detection in 17 samples. The exact form of the petroleum compounds measured at the site is unknown and the suitability of toxicity values for the Hanford Site has not been fully assessed. The area of the waste site is insignificant given availability and size of nearby suitable habitat without contamination outside of the 100-BC Source OU containing invertebrates.

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
128-B-3—Burn Pit Site	Staging pile area	Mercury	0.37	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Not Exceeded	10	17,047 m^2 (183,500 ft^2)	Not Applicable	2	<0.01 to 0.46	<0.03 to 1.4	--	No. EPC and 2 of 10 samples only slightly greater than the low confidence plant PRG. No soil concentrations greater than lowest wildlife PRG for biomagnifying compound. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).
128-B-3—Burn Pit Site	Staging pile area	TPH	179	15 to 1490	Low - Values in Table 749-3 100 mg/kg for gasoline and 200 mg/kg for diesel based on values published in ES/ER/TM-126/R2. The same author has also reported that NOECs for lube oil range from 15-1490 mg/kg (Efroymson et al., 2004). All of these values are from a secondary source and may not reflect Hanford Site conditions.	NA	NA	10	17,047 m^2 (183,500 ft^2)	Not Applicable	2	<133 to 179	NA	--	No. Detected in 2 of 10 samples. The exact form of the petroleum compounds measured at the site is unknown and the suitability of toxicity values for the Hanford Site has not been fully assessed. The area of the waste site is insignificant given availability and size of nearby suitable habitat without contamination outside of the 100-BC Source OU containing invertebrates.

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
128-C-1—Burn Pit Site	Shallow	Silver	3.7	3	High – Invertebrate Hanford Site-specific NOEC. Confidence in PRG is high with respect to a lack of toxicity at this concentration but low in that the PRG is set at the highest concentration samples; thus, PRG could be higher.	98	Not Exceeded	14	15,372m^2 (165,462 ft^2)	4.0 m (13 ft)	1	0.04 to 6.6	0.01 to 1.2	Maximum concentration identified in associated blank (C qualifier)	No. The EPC was slightly greater than the invertebrate PRG, which is a NOEC. Only 1 of 14 samples exceeded the NOEC; thus, there is no indication of an adverse effect to the invertebrate community. Concentrations were not above any other PRG. The area of the waste site is insignificant given availability and size of nearby suitable habitat without contamination outside of the 100-BC Source OU.
1607-B10—Septic Tank System	Shallow	Mercury	0.38	0.3	Low - ORNL Value - Given low confidence by the authors because of limited number of studies available in the published literature and no primary literature available for effects on plants. The effect reported at 0.3 mg/kg was unspecified ([No Suggestions] and Pendias, 1984). The other available study described by ORNL (Panda et al., 1992) reported a NOEC for growth of 34.9 mg/kg.	1.6	Not Exceeded	4	59 m^2 (635 ft^2)	2.5 m (8.2ft)	1	0.14 to 0.38	0.42 to 1.2	--	No. EPC only slightly greater than plant PRG and only 1 of 4 samples exceeded the low confidence plant PRG. No soil concentrations greater than lowest wildlife PRG for biomagnifying compound. The size of the waste site is small and the likelihood of effects is low. If adverse effects did occur, habitat fragmentation in the 100-BC Source OU would not be likely given the current level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see section 7.6.2).
1607-B2:1—Septic Tank	Shallow	Barium	387	358	Moderate to High – RCBRA NOEC for invertebrates. Confidence in PRG is high with respect to a lack of toxicity at this concentration but low in that the PRG is set at the highest concentration samples; thus, PRG could be higher.	1,690	Not Exceeded	11	3,457 m^2 (37,210 ft^2)	0.30 m (1 ft)	1	89 to 642	0.25 to 1.8	--	No. The EPC was slightly greater than the invertebrate PRG, which is a NOEC. Only 1 of 14 samples exceeded the NOEC; thus, there is no indication of an adverse effect to the invertebrate community. Concentrations were not above any other PRG. The area of the waste site is insignificant given availability and size of nearby suitable habitat without contamination outside of the 100-BC Source OU.

Table 7-10. Summary of Factors Considered for Scientific Decision Management Process

Waste Site and Waste Site Description	Decision Unit	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Confidence and Basis	Avian/ Mammal PRG (mg/kg or pCi/g)	Confidence and Basis	Number of Sampling Locations	Area or Length of Waste Site	Depth of Samples (bgs)	Number of Results that Exceed PRG	Range of Concentrations (mg/kg or pCi/g)	Range of Hazard Quotient	Data Quality	Carry Waste Site into FS for Remedy Evaluation?
1607-B8—Septic Tank System	Shallow	Lead	166	1700	Not Exceeded	156	High. Killdeer Hanford Site-specific value modeled with Hanford Site-specific prey tissue data using a regression model.	4	7 m^2 (75 ft^2)	2.5 m (8.2ft)	1	12 to 166	0.10 to 1.3	--	No. One of 4 samples in a significantly small site (7 m^2/75ft ^{2}) was slightly greater than the killdeer PRG and no other PRG. The home range of the killdeer (>196,916 km^2/76,000 m^2) is significantly greater than the acreage of the site thus employing an AUF would yield a HQ below 1 and risk at this site is acceptable.
600-233—Vertical Pipe Near 100-B Electrical Laydown Area	Shallow Focused	Selenium	3	2	High – Plant Hanford Site-Specific NOEC Confidence in PRG is high with respect to a lack of toxicity at this concentration but low in that the PRG is set at the highest concentration samples thus PRG could be higher.	1.4	Moderate-High. Deer Mouse Hanford Site-specific value modeled with Hanford Site-specific prey tissue data using a combination of regression models and BAFs.	2	Length = 160 m (525 ft)	1.5 m (5 ft)	1	<2.7 to 3.0	<2.3 to 2.5/<1.9 to 2.1	"C" flags	No. There is low confidence in analytical method. Detected concentrations and MDLs are reported within the same range as the PRG values. Selenium was detected in blanks of maximum concentrations samples. The area of the waste site is insignificant given availability and size of nearby suitable habitat without contamination outside of the 100-BC Source OU.

Sources: Ecology Publication 11-03-006, *Ecological Soil Screening Levels for Arsenic and Lead in the Tacoma Smelter Plume Footprint and Hanford Site Old Orchards Ecology.*

Efroymson et al., 2004, "Ecotoxicity Test Data for Total Petroleum Hydrocarbons in Soil: Plants and Soil-Dwelling Invertebrates."

ES/ER/TM-126/R2, *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision.*

Panda et al., 1992, "Monitoring and Assessment of Mercury Pollution in the Vicinity of a Chlorakali Plant. II. Plant-Availability, Tissue-Concentration and Genotoxicity of Mercury from Agricultural Soil Contaminated with Solid Waste Assessed in Barley (*Hordeum vulgare* L.)."

Notes: Analytical results flagged with a "C" qualifier indicate that analyte was detected in both the sample and the associated QC blank.

MTCA = model toxics control act

ORNL = Oak Ridge National Laboratory

POC = point of compliance

Completion of remedial actions as part of the cleanup verification process that is based on ecological PRGs will incorporate a SMDP on a case-by-case basis to determine that the action is protective of ecological receptors. The SMDP approach and its use in remediation decision making would be presented in detail in the RDR/RAWP. Further, in cases where verification samples exceed the PRGs and these PRGs represent the limiting value (i.e., the wildlife PRGs are lower than all other applicable PRGs), then a risk management decision should be made such as the SMDP described in Section 7.6.1. Particular attention should be given to the number of samples exceeding the PRGs, the spatial area represented by the samples, and the depth at which samples exceed the PRGs. Other key factors that would be considered in the SMDP process would include:

- Size of the waste site relative to home range of wildlife receptors (e.g., developing and applying an AUF in the comparison of an EPC to the PRGs)
- Estimation of exposure using a central tendency estimate such as the 95 percent UCL
- Size of the waste site relative to area of adjacent uncontaminated habitat
- Nature and extent of residual contamination following remediation
- Potential presence of exposure pathways following remediation
- The number and frequency of exceedances of the risk thresholds (PRGs)
- The location of the samples exceeding thresholds, sample frequency, and proximity of other exceedances

PRGs are typically based on a concentration that may elicit adverse effects (i.e., reduce survival, growth, or reproduction), as observed in the low number of individuals exposed to chemicals in laboratory toxicity tests. For some chemicals, this is based on toxicity tests reporting a 20 percent effect level (e.g., mortality observed in 20 percent or more tested organisms or growth reduced by 20 percent). For other chemicals, this is the lowest concentration tested with undefined adverse effects. In considering the results of verification data for future remedial actions relative to the PRGs, consideration must be given to the origins of the toxicity data upon which the exceeded PRGs are based. This should be considered in the context of the risk management goal (protection of populations of wildlife), the selected assessment endpoint (reproduction, survival, and growth), and specific life history data for the selected wildlife receptors selected to represent the end points (e.g., home range, population density).

7.6.3 Recommendations for Evaluating Plants and Invertebrates in Future Assessments at Unremediated Waste Sites

PRGs for terrestrial plants and invertebrates have been established for the Hanford Site (*Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site* [ECF-HANFORD-11-0158]), and have been a useful tool in screening waste sites for potential adverse impacts to these communities. However, the use of these PRGs in selecting final remediation goals in the feasibility study or the proposed plan should be considered on a site-specific basis except for waste sites where listed protected species have been identified (i.e., federal or state listed and protected threatened or endangered species). This recommendation is based on the following lines of evidence: no significant adverse toxicological effects observed at the highest available concentrations tested in site-specific bioassays; historical and ongoing biological surveys demonstrating no significant differences from control areas; and the limited likelihood of habitat fragmentation as a result of areas with elevated contaminants in soil. The plant and invertebrate PRGs can serve to help identify where remedial actions have been effective. However, in cases where verification samples exceed these PRGs and these

PRGs represent the limiting value (that is, the plant or invertebrate PRG is lower than all other applicable PRGs), then a risk management decision should be made such as the SMDP described in Section 7.6.1. Particular attention should be given to the number of samples exceeding the PRGs, the spatial area represented by the samples, and the depth at which samples exceed the PRGs.

Plant and invertebrate bioassays have been conducted at the Hanford Site on both plant and invertebrate species by DOE (RCBRA [DOE/RL-2007-21, Volume 1]; Central Plateau Ecological Risk Assessment Data Package Report [DOE/RL-2007-50]; Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site [ECF-HANFORD-11-0158]); and Ecology (Ecological Soil Screening Levels for Arsenic and Lead in the Tacoma Smelter Plume Footprint and Hanford Site Old Orchards Ecology [Ecology Publication 11-03-006]). Results of these studies have not shown any significant adverse effects that can be clearly attributed to soil chemistry that has resulted as part of past operations or practices at Hanford. Scatter plots of the effects versus chemical concentrations show no clear patterns and statistical tests have shown no correlation between effects and soil chemistry. As a result, the highest concentrations established have served as NOECs with no upper bounds, which have been established as PRGs. Some sensitive species may demonstrate adverse effects to some degree at concentrations exceeding these NOECs. However, the risk management goal from the *DQO Summary Report for the 100 Area and 300 Area Component of the RCBRA* (BHI-01757) was the maintenance of diversity and abundance of flora and fauna at the community or population level. As noted in Appendix A to *Generic Ecological Assessment Endpoints (GEAEs) for Ecological Risk Assessment* (EPA/630/P-02/004F), EPA's principles for ecological risk assessment and risk management at Superfund sites state, "Superfund's goal is to reduce ecological risks to levels that will result in the recovery and maintenance of healthy local populations and communities of biota." Comparing waste site chemical concentrations to LOECs could help identify potential community level risks to plants and invertebrates and would adequately achieve the risk management goal. However, establishing a concentration gradient with site-specific weathered soils (as opposed to spiked laboratory tests with more highly bioavailable forms of chemicals) capable of producing a LOEC has proven to be problematic. The concentrations have not been at levels high enough to demonstrate significant toxicity to native species (most of the plant tests have all been on native blue grass [Poa secunda], nematodes [Caenorhabditis elegans], and springtails [Folsomia candida]). Moreover, the chemicals present in the soil (mostly inorganic constituents and metals) are not known to be significant bioaccumulators. This points to the fact that existing concentrations at the Hanford Site may not be toxic to plants and invertebrates.

Numerous studies measuring the diversity and abundance and many other parameters have been part of biological surveys conducted at the Hanford Site. Among these are the SESP that has been conducted by PNNL for over 20 years. The RCBRA (DOE/RL-2007-21 Volume 1) also included biological surveys for cryptogam, plants, invertebrates, and small mammals. These studies have included observations at both contaminated and uncontaminated sites across the Hanford Site. Overall, these studies document a complex and thriving ecosystem and show no clear distinction in measures at waste sites versus those at control sites. However, it should be noted that only a portion of the areas studied include previously contaminated or remediated areas. Thus, there is no certainty that the same conclusion could be drawn from the remaining waste sites that have not yet been addressed.

At some sites, if significant effects to the plant community occur, a negative impact could be habitat fragmentation from reduced function of the plants or complete loss of the community. Habitat fragmentation is the discontinuity in spatial distribution of resources and conditions that affect occupancy, reproduction, or survival in a particular species ("What is Habitat Fragmentation?" [Franklin et al., 2002]). However, this is not likely to occur at the Hanford Site if waste sites are left unremediated. In their current conditions, waste sites have a range of no to partial plant cover that supports a community

of invertebrates such as ants and beetles, small burrowing mammals, birds, and carnivorous wildlife. The soil contains a seed bank from both plants existing at the site and the surrounding plants outside the waste site. The surrounding shrub-steppe and grassland habitats would act as habitat refugia that ultimately would buffer the waste sites from extreme variation in the overall environmental condition and continue to support the ecosystem.

7.6.4 Evaluation of Sediment in Future Assessments and at Unremediated Waste Sites Below the Ordinary High Water Mark

Waste sites extending below the ordinary high water mark of the Columbia River should be assessed as an aquatic environment and as such should be evaluated for the protection of aquatic organisms described in the conceptual model in Appendix M. The evaluation of surface sediment data for any future assessments will be against the freshwater sediment ESLs presented in Table M-4 of Appendix M. These values are from a number of sources and are intended for screening measured concentrations for potential adverse effects to aquatic organisms exposed to sediments. However, not all of the ESLs presented are specifically designed to be used as cleanup levels for evaluating remedial actions. The primary source of freshwater sediment PRGs are the cleanup screening levels (CSLs) published in *Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho* (Ecology Publication 11-09-054). These values were specifically selected as thresholds for freshwater sediments in Washington, Oregon, and Idaho through the evaluation of field-collected toxicological data. The CRC (DOE/RL-2010-117) presented sediment LOECs for nine chemicals (acetone, alpha-BHC, chromium, dichlorodiphenyldichloroethane, heptachlor epoxide, phosphorous, silver, toluene, and TPH diesel) but values from *Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho* (Ecology Publication 11-09-054) were only available for four of these chemicals. Values for other chemicals rely on various other sources and methods. These LOECs could be used as PRGs, such as the heptachlor epoxide value from "Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems" (MacDonald et al., 2000), but others such as those derived through equilibrium partitioning might require additional consideration. Recommended freshwater sediment PRGs are presented in Table 7-11. As with the soil investigations described above, future assessments should include SMDP considerations (Section 7.6.2).

Table 7-11. Freshwater Sediment PRGs

Chemical	PRG	Source and Notes
Conventional Pollutants (mg/kg)		
Ammonia	300	Ecology Publication 11-09-054
Total sulfides	61	Ecology Publication 11-09-054
Metals (mg/kg)		
Antimony[b]	12	Ecology Publication 11-09-054
Arsenic	120	Ecology Publication 11-09-054
Cadmium	5.4	Ecology Publication 11-09-054
Chromium	88	Ecology Publication 11-09-054
Copper	1,200	Ecology Publication 11-09-054
Lead	> 1,300	Ecology Publication 11-09-054

Table 7-11. Freshwater Sediment PRGs

Chemical	PRG	Source and Notes
Mercury	0.8	Ecology Publication 11-09-054
Nickel	110	Ecology Publication 11-09-054
Selenium	> 20	Ecology Publication 11-09-054
Silver	1.7	Ecology Publication 11-09-054
Zinc	> 4,200	Ecology Publication 11-09-054
Organic Chemicals (µg/kg)		
4-Methylphenol	2,000	Ecology Publication 11-09-054
Acetone	141	Calculated by EpP w foc = 0.007, Koc = 1.981, LOEC of 10 mg/L from Ewell et al., 1986; 96-hour LC50 of 100 mg/L for Daphnia magna; UF of 10 applied for LC50 - LOEC conversion
Alpha-BHC	240	Calculated by EpP w foc = 0.007, Koc = 3,380, LOEC from Canton et al., 1975; EC50 for reproduction of 0.100 mg/L for Daphnia, test duration 25 days. UF of 10 applied for EC50 - LOEC use. Likely conservative value; other values in Ecotox higher
Benzoic acid	3,800	Ecology Publication 11-09-054
beta-Hexachlorocyclohexane	11	Ecology Publication 11-09-054
bis(2-Ethylhexyl)phthalate	22,000	Ecology Publication 11-09-054
Carbazole	1100	Ecology Publication 11-09-054
Dibenzofuran	680	Ecology Publication 11-09-054
Dibutyltin	130,000	Ecology Publication 11-09-054
Dieldrin	9.3	Ecology Publication 11-09-054
Di-n-butyl phthalate	1,000	Ecology Publication 11-09-054
Di-n-octyl phthalate	> 1,100	Ecology Publication 11-09-054
Heptachlor epoxide	16	Consensus-based probable effects concentration (PEC) from MacDonald et al., 2000
Monobutyltin	> 4,800	Ecology Publication 11-09-054
Pentachlorophenol	> 1,200	Ecology Publication 11-09-054
Phenol	210	Ecology Publication 11-09-054
Phosphorous	2,000,000	Severe Effects Level (SEL) from Persuad et al., 1993
Tetrabutyltin	> 97	Ecology Publication 11-09-054
Toluene	5,220	Calculated by EpP w foc = 0.007, Koc[a] = 268, LOEC of 2.74 mg/L from Moles et al., 1981. Statistically significant reduction in growth

Table 7-11. Freshwater Sediment PRGs

Chemical	PRG	Source and Notes
		in coho salmon fry after 40-day exposure
Total DDDs	860	Ecology Publication 11-09-054
Total DDEs	33	Ecology Publication 11-09-054
Total DDTs	8,100	Ecology Publication 11-09-054
Total PAHs	30,000	Ecology Publication 11-09-054
Total PCB Aroclors	2,500	Ecology Publication 11-09-054
Tributyltin	320	Ecology Publication 11-09-054
Bulk Petroleum Hydrocarbons (mg/kg)		
TPH-Diesel	510	Ecology Publication 11-09-054
TPH-Residual	4,400	Ecology Publication 11-09-054

Table 7-11. Freshwater Sediment PRGs

Chemical	PRG	Source and Notes

Notes:

> "Greater than" value indicates that the toxic level is unknown, but above the concentration shown.

EqP = equilibrium partitioning

foc = fraction of organic carbon

LC50 = concentration estimated to be lethal to fifty percent of test organisms

Koc = octonal water partitioning coefficient

UF = uncertainty factor

EC50 = concentration at which fifty percent of test organisms are estimated to show an adverse effect

1. Acetone: 96-hour LC50 of 100 mg/L for Daphnia magna; UF of 10 applied for LC50 - LOEC conversion. Value supported by other studies. Lowest value over NOEC of 1.5 mg/l after UF applied. Ecotox reference 11951.

2. Alpha-BHC: EC50 for reproduction of 0.100 mg/L to Daphnia, test duration 25 days. UF of 10 applied for EC50 - LOEL use. Likely conservative value; other values in Ecotox higher. Ecotox Ref. 952, Test 11031.

3. Toluene: Statistically significant reduction in growth in coho salmon fry at 2.74 mg/L after 40-day exposure. Ecotox Ref. 15191, Test 67003.

Koc sources:

a. EPI, 2011, Estimation Program Interface Suite Version 4.10.

b. ORNL, 2010, Risk Assessment Information System.

Sources:

Canton et al., 1975, "Toxicity, Accumulation and Elimination Studies of α-hexachlorocyclohexane (α-HCH) with Freshwater Organisms of Different Trophic Levels."

Ecology Publication 11-09-054, *Development of Benthic SQVs for Freshwater Sediment in Washington, Oregon, and Idaho.*

Ewell et al., 1986, "Simultaneous Evaluation of the Acute Effects of Chemicals on Seven Aquatic Species."

MacDonald et al., 2000, "Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems."

Moles et al., 1981, "Reduced Growth of Coho Salmon Fry Exposed to Two Petroleum Components, Toluene and Naphthalene, in Fresh Water."

Persuad et al., 1993, "Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario."

8 Identification and Screening of Technologies

This chapter begins the feasibility study of the RI/FS. The RI defined the problem, and the FS evaluates solutions to remedy the problem. The FS consists of three phases: screening of remedial technologies, development of remedial alternatives, and detailed analysis of selected alternatives. Remedial technologies are assembled into alternatives that address contamination on a media- or source-specific basis. Technologies are evaluated in this chapter to determine their effectiveness to remove the contaminants (described in Chapter 4) or interrupt the exposure pathway (described in Chapters 6 and 7).

Chapter 8 presents the following:

- RAOs, ARARs, PRGs (Section 8.1)
- General response actions (GRAs) Section 8.2)
- Identification and screening of remedial technologies and associated process options to clean up the contamination (Section 8.3)

Chapter 9 assembles the alternatives and Chapter 10 provides a detailed analysis of the alternatives to address contaminated media at 100-BC.

Highlights

- RAOs are identified for soil, groundwater, and surface water.
- PRGs are the numerical representation of the RAOs and are established for each contaminant, receptor, and exposure pathway.
- Of the 140 sites in 100-BC, 10 are recommended for evaluation in the FS. A range of general response actions to meet RAOs is identified for waste sites and contaminated groundwater.
- Process options and technologies under these response actions were evaluated for relative effectiveness, implementability, and cost.
- Response actions retained for waste sites include no action, institutional controls, RTD, void-fill grouting, and surface barriers.
- Response actions retained for groundwater include no action, MNA, pump-and-treat, ion exchange, groundwater flushing, and institutional controls.

8.1 Remedial Action Objectives

RAOs are general descriptions of what the remedial action is expected to accomplish (that is, medium-specific or site-specific goals for protecting human health and the environment). They are defined as specifically as possible to address the following concerns:

- Media of interest (contaminated soil or groundwater)
- Types of contaminants (radionuclides and chemical constituents)
- Potential receptors (humans, flora, and fauna)
- Exposure pathways (external radiation, direct contact, or ingestion)

Contaminant concentrations that may remain in the environmental media once the remedial action is complete.

The RAOs provide a basis for evaluating the capability of a specific remedial alternative to achieve compliance with potential ARARs and/or an intended level of risk protection for human health and the environment in accordance with the NCP "Remedial Investigation/Feasibility Study and Selection of Remedy" (40 CFR 300.430(e)(2)(i)), and CERCLA RI/FS Guidance (EPA/540/G-89/004). RAOs for the 100-BC source and groundwater OUs are presented in Section 8.1.4. Background information used in developing the RAOs is presented in Sections 8.1.1 through 8.1.3.

8.1.1 Contaminants of Concern

The evaluations of remedial actions for specific waste sites relies upon a comprehensive review of all available data for each site; including, field data if available, radiological surveys, process history,

analogous site information, personal interviews, engineering drawings and as-builts, and any other available information. Based on the evaluations conducted in Chapters 5, 6, and 7, the following analytes were identified as COCs in soil for these previously remediated waste sites: carbon-14, cesium-137, cobalt-60, europium-152, europium-154, nickel-63, strontium-90, and tritium. For yet-to-be-remediated waste sites, additional nonradionuclide COPCs are identified and listed in Table 8-1.

Because of the comprehensive review conducted during the development of the RI/FS, the characteristics of each site are sufficiently defined for the purpose of alternative development and comparison in the FS. During implementation of remedial actions, should field conditions vary from those presented in the FS and indicate a need to re-evaluate the efficacy of the selected remedial action, the appropriate remedy modification will be used, consistent with CERCLA guidance. Additional information on these waste sites is presented in Section 8.2.1. As discussed in Section 4.2.2.1, waste sites collocated within historical orchard lands will be remediated as needed to meet the cleanup levels prescribed in the applicable ROD. Contamination associated with historical orchard lands will not be remediated beyond the waste site footprint.

Based on the evaluations conducted in Chapters 5, 6, and 7, the following analytes were identified as COCs in groundwater: Cr(VI), strontium-90, and tritium. The COCs and COPC s for vadose zone soil and groundwater are presented in Table 8-1.

Table 8-1. Summary of Soil and Groundwater COCs and COPCs

Radionuclides (Soil)		Nonradionuclides (Soil)	
Carbon-14	Europium-154	Cr(VI)*	Polycyclic Aromatic Hydrocarbons
Cesium-137	Nickel-63	Lead	
Cobalt-60	Strontium-90*	Mercury	
Europium-152	Tritium*	Total Chromium	
Radionuclides (Groundwater)		**Nonradionuclides (Groundwater)**	
Strontium-90		Cr(VI)	
Tritium			

*Identified as a COC in a previously remediated waste site.

8.1.2 Potential Applicable or Relevant and Appropriate Requirements

Substantive standards of promulgated regulations pertaining to CERCLA response actions are identified through the ARAR identification process, which is based on CERCLA Section 121(d) and EPA guidance (CERCLA RI/FS Guidance [EPA/540/G-89/004]; *CERCLA Compliance with Other Laws Manual: Interim Final* [EPA/540/G-89/006]; and *CERCLA Compliance with Other Laws Manual: Part II* [EPA/540/G-89/009]). Section 121(d) requires, with exceptions, that any promulgated substantive ARAR standard, requirement, criterion, or limitation under any federal environmental law, or any more stringent state requirement pursuant to a state environmental statute, or facility siting laws, be met (or a waiver justified) for any hazardous substance, pollutant, or contaminant that will remain onsite after completion of remedial action. Additionally, NCP "Remedial Design/Remedial Action, Operation and Maintenance" (40 CFR 300.435(b)(2)) requires that ARARs be attained (unless waived) during the remedial action. Identifying ARARs is part of the 100-BC FS process.

Vadose zone soil (including waste sites) and groundwater in 100-BC will be remediated under a CERCLA decision document. Any remedial action(s) implemented will be required to meet ARARs. In many cases, the ARARs form the basis for the PRGs to which contaminants must be remediated to protect HHE. ARARs also define or restrict how specific requirements of a remedial alternative can be implemented based on the nature of the activity or the location of the site.

8.1.2.1 The ARARs Evaluation Process

The ARARs evaluation prepared for this RI/FS was conducted in accordance with the NCP "Remedial Investigation/Feasibility Study and Selection of Remedy" (40 CFR 300.430(f)(1)(ii)(B)(2)).

A distinction and clarification related to ARARs involves onsite and offsite actions. Onsite actions are defined to be "the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action" (NCP [40 CFR 300]). Onsite actions must comply with ARARs, but need only comply with the substantive parts of those requirements. Offsite actions must comply with both the substantive and administrative requirements. For onsite activities, a requirement under federal and state environmental laws may be either applicable or relevant and appropriate, but not both.

The identification of ARARs is a two-step process. First, it must be determined if the law or regulation is applicable. If not applicable, it must be determined if the law or regulation is both relevant and appropriate. The terms "applicable" and "relevant and appropriate" are defined in NCP "Definitions" (40 CFR 300.5) as follows.

"Applicable requirements" are those substantive standards that specifically address the situation at a CERCLA site. The requirements would legally apply to remedial actions in the absence of CERCLA authority. All jurisdictional prerequisites of the requirement must be met in order for the requirement to be applicable, including specific application to federal agencies (e.g., through a waiver of federal sovereign immunity).

"Relevant and appropriate" requirements mean those environmental requirements such as cleanup standards that address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site (NCP "General" [40 CFR 300.400(g)(2)]). A requirement that is relevant and appropriate may not meet one or more jurisdictional prerequisites for applicability but still make sense at the site, given the circumstances of the site and the release.

In evaluating the relevance and appropriateness of a requirement, the eight comparison factors in NCP "General" (40 CFR 300.400(g)(2)) are considered:

1. The purposes of the requirement and the CERCLA action
2. The medium regulated or affected by the requirement and the medium contaminated or affected at the CERCLA site
3. The substances regulated by the requirement and the substances found at the CERCLA site
4. The actions or activities regulated by the requirement and the remedial action contemplated at the CERCLA site
5. Any variances, waivers, or exemptions of the requirement and their availability for the circumstances at the CERCLA site
6. The type of place regulated and the type of place affected by the release or CERCLA action

7. The type and size of structure or facility regulated and the type and size of structure or facility affected by the release or contemplated by the CERCLA action

8. Any consideration of use or potential use of affected resources in the requirement and the use or potential use of the affected resource at the CERCLA site

To be considered (TBC) materials and information includes, for example, nonpromulgated advisories, criteria, proposed standards, or guidance issued by federal or state governments that is not legally binding and does not have the status as ARARs. In some circumstances, TBCs may be considered along with ARARs in determining the remedial action necessary for protection of human health and the environment. Some TBC information can complement ARARs in determining protectiveness at a site or implementation of certain actions. For example, because soil cleanup standards do not exist for all contaminants, screening levels that are TBCs may be helpful in defining suitable RAGs.

Section 161 of the *Atomic Energy Act of 1954* (AEA), as amended, provides DOE the authority to establish Orders containing instructions and operational requirements considered to be important to protect human health and the environment from nuclear material, source material, and byproduct materials. While the requirements of DOE Orders must be met, they are not ARARs and are independent of the TBC and ARARs identification process at the Hanford Site.

Potential ARARs for 100-BC are examined to determine whether they fall into one of three categories: chemical-specific, location-specific, or action-specific requirements. These categories are defined as follows:

- Chemical-specific requirements are usually health- or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of public and worker safety levels and site cleanup levels.

- Location-specific requirements are restrictions placed on the concentration of dangerous substances or the conduct of activities solely because they occur in special geographic areas.

- Action-specific requirements are usually technology- or activity-based requirements or limitations triggered by remedial actions performed at the site.

8.1.2.2 Waivers from ARARs

The CERCLA lead agency delegated authority under Section 121 may waive ARARs, with EPA's concurrence, and select a remedial action that does not attain the same level of cleanup as that identified by the ARARs. In Superfund Implementation (Executive Order 12580), the President delegated Section 121 authority to DOE for cleanup of DOE facilities. Section 121 of SARA identifies the following six circumstances in which DOE may waive ARARs for onsite remedial actions:

- The remedial action selected is only a part of a total remedial action (such as an interim action), and the final remedy will attain the ARAR upon its completion.

- Compliance with the ARAR will result in a greater risk to human health and the environment than alternative options.

- Compliance with the ARAR is technically impracticable from an engineering perspective.

- An alternative remedial action will attain an equivalent standard of performance using another method or approach.

- The ARAR is a state requirement that the state has not consistently applied (or demonstrated the intent to apply consistently) in similar circumstances.

ARAR waivers can be in the ROD, or if post-ROD information shows an ARAR cannot be met because it is technically impracticable from an engineering perspective, but remedy will still be protective, an ARAR waiver can be granted through a ROD modification after a proposed plan and public comment period. For groundwater, Technical impracticability (TI) waivers only apply to that portion of the groundwater contaminant plume for which restoration to ARARs is determined to be technically impracticable.

8.1.2.3 Potential ARARs Identified for 100-BC

Table 8-2 presents potential federal and Washington State ARARs. When the final remedy selection is documented in the ROD, all federal and state ARARs, with which the final remedy must comply, are also finalized. Key potential ARARs are identified in following text.

Potential Chemical-Specific ARARs. The chemical-specific ARARs that may affect remediation of 100-BC OU are the elements of the *Washington State Administrative Code* regulations that implement the MTCA (WAC 173-340). Within this branch of the *Washington Administrative Code*, there are detailed regulations with developing standards for remedial actions involving soil cleanup (MTCA "Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) and groundwater cleanup standards (MTCA "Groundwater Cleanup Standards" [WAC 173-340-720]). These standards are in the form of risk-based concentrations that help establish soil and groundwater cleanup standards for nonradioactive contaminants. Following is a list of additional Washington State and federal regulations:

- Substantive portions of MTCA "Selection of Cleanup Actions" [WAC 173-340-360] and MTCA "Overview of Cleanup Standards" [WAC 173-340-700] through MTCA "Site-Specific Terrestrial Ecological Evaluation Procedures" [WAC 173-340-7493]). Nonzero MCL goals and MCLs promulgated under the SDWA, "National Primary Drinking Water Regulations" (40 CFR 141), and/or by the state of Washington ("Group A Public Water Supplies" [WAC 246-290])

- The AWQC developed under the *Clean Water Act of 1977* (CWA) (Section 304) and/or promulgated by the state of Washington ("Water Quality Standards for Groundwaters of the State of Washington" [WAC 173-200] and "Water Quality Standards for Surface Waters of the State of Washington" [WAC 173-201A])

- The *Toxic Substances Control Act of 1976* (TSCA) (implemented via "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions" [40 CFR 761])

- "National Primary and Secondary Ambient Air Quality Standards" (40 CFR 50)

- "National Emissions Standards for Hazardous Air Pollutants" (40 CFR 61)

Potential Location-Specific ARARs. Potential location-specific ARARs that have been identified for the 100-BC OUs include those that protect cultural, historic, and Native American sites and artifacts under the *Native American Graves Protection and Repatriation Act of 1990* and *Archaeological and Historic Preservation Act of 1974*. Other identified ARARs are those that protect listed endangered and threatened species or their critical habitat under the *Endangered Species Act of 1973*. The *Migratory Bird Treaty Act of 1918* has been identified as substantive standards for DOE compliance in executive orders and a *Memorandum of Understanding Between the United States Department of Energy and the United States Fish and Wildlife Service Regarding Implementation of Executive Order 13186, "Responsibilities of Federal Agencies to Protect Migratory Birds,"* (DOE and USFWS, 2006). The act is pertinent for CERCLA response actions when there is a potential to affect protected bird species adversely.

Potential Action-Specific ARARs. Action-specific ARARs that could be pertinent to possible remediation activities at 100-BC relate to waste management activities, solid and dangerous waste regulations (for management of characterization and remediation waste, and performance standards for waste left in place), and radioactive waste management under AEA regulations. The other major category of action-specific ARARs concern standards for controlling emissions to the environment. When a CERCLA remedial action involves the construction or modification of drinking water systems, the SDWA is an ARAR, while such onsite work is exempt from SDWA permit requirements.

8.1.2.4 Waste Management Standards

Remedial action alternatives proposed in Chapter 9 of this FS have the potential to generate a variety of waste streams that contain both radioactive and chemical constituents. It is anticipated that most of the waste will be designated as low level. However, quantities of dangerous or mixed waste, PCB-contaminated waste, and asbestos and asbestos-containing material could be generated. The majority of the waste will be in a solid form.

The identification, storage, treatment, and disposal of hazardous waste and the hazardous component of mixed waste generated during the remedial action would be subject to the substantive provisions of RCRA. In the state of Washington, RCRA is implemented through "Dangerous Waste Regulations" (WAC 173-303), which is an EPA authorized state RCRA program. The substantive portions of the dangerous waste standards for generation and storage would apply to the management of any dangerous or mixed waste generated during this remedial action. Treatment standards for dangerous or mixed waste that is subject to RCRA land disposal restrictions are specified in "Dangerous Waste Regulations," "Land Disposal Restrictions" (WAC 173-303-140), which incorporates "Land Disposal Restrictions" (40 CFR 268) by reference. Radioactive waste is managed by DOE under the authority of the AEA. EPA has regulatory authority over release of radioactive waste in context of a CERCLA action.

The TSCA and regulations in "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions" (40 CFR 761) generally govern the management and disposal of PCB waste. The TSCA regulations contain specific provisions for PCB waste, including PCB waste that contains a radioactive component. The PCBs also are considered underlying hazardous constituents under RCRA and, thus, could be subject to "Dangerous Waste Regulations" (WAC 173-303) and "Land Disposal Restrictions" (40 CFR 268) requirements.

Removal and disposal of asbestos and asbestos-containing material are regulated under the *Clean Air Act of 1990* and National Emission Standards for Hazardous Air Pollutants (NESHAP), "National Emission Standard for Asbestos" (40 CFR 61, Subpart M). These regulations provide for special precautions to prevent environmental releases or exposure to personnel of airborne emissions of asbestos fibers during remedial actions.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-BC

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
Groundwater					
***Safe Drinking Water Act of 1974* (Public Law 93-523, as amended; 42 USC 300f, et seq.); "National Primary Drinking Water Regulations" (40 CFR 141)**					
"Maximum Contaminant Levels for Organic Contaminants" (40 CFR 141.61) "Maximum Contaminant Level Goals for Organic Contaminants" (40 CFR 141.50)	Chemical	Establishes MCLs and nonzero MCLGs as criteria for groundwater and surface water that are or may be used for drinking water. The standards/goals are designed to protect human health from adverse effects of organic contaminants in drinking water.	Groundwater in 100-BC contains contaminants that may require remediation; although groundwater is not currently used for drinking water, it is a potential drinking water source and it discharges into the Columbia River (which is used for drinking water).	ARAR	Groundwater remediation and management activities (such as groundwater treatment, discharge of treated groundwater, in situ remediation of groundwater, monitored natural attenuation [MNA], etc.).
"Maximum Contaminant Levels for Inorganic Contaminants" (40 CFR 141.62) "Maximum Contaminant Level Goals for Inorganic Contaminants" (40 CFR 141.51)	Chemical	Establishes MCLs and nonzero MCLGs as criteria for groundwater and surface water that are or may be used for drinking water. The standards/goals are designed to protect human health from adverse effects of inorganic contaminants in drinking water.	Groundwater in 100-BC contains contaminants that may require remediation. It is not currently used for drinking water but is a potential drinking water source (it discharges into the Columbia River, which is used for drinking water).	ARAR	Groundwater remediation and management (such as discharge of treated groundwater, in situ remediation of groundwater, MNA, etc.).
"Maximum Contaminant Levels for Radionuclides" (40 CFR 141.66)	Chemical	Establishes MCLs as criteria for groundwater and surface water that are or may be used for drinking water. The standards are designed to protect human health from adverse effects radionuclides in drinking water.	Groundwater in 100-BC contains contaminants that may require remediation. It is not currently used for drinking water but is a potential drinking water source (it discharges into the Columbia River, which is used for drinking water).	ARAR	Groundwater remediation and management (such as discharge of treated groundwater, in situ remediation of groundwater, MNA, etc.).
"Water Pollution Control" (RCW 90.48, as amended); "Underground Injection Control Program" (WAC 173-218)					
"UIC Well Classification Including Allowed and Prohibited Wells" (WAC 173-218-040)	Action	Establishes criteria and standards for an underground injection control program.	Groundwater in 100-BC contains contaminants that may require remediation; treated groundwater may be discharged through underground injection wells.	ARAR	Groundwater remedial activities involve underground injection.
"Hazardous Waste Cleanup – Model Toxics Control Act" (RCW 70.105D, as amended); "Model Toxics Control Act—Cleanup" (WAC 173-340)					
"Groundwater Cleanup Standards" (WAC 173-340-720) "Method B Cleanup Levels for Potable Groundwater" (WAC 73-340-720(4)(b)(i-iii)(A)&(B)) "Adjustments to Cleanup Levels" (WAC 173-340-720(7))	Chemical	Groundwater cleanup levels are based on estimates of the highest beneficial use and the reasonable maximum exposure expected to occur under both current and potential future site use conditions. Method B equations (720-1 and 720-2) to calculate groundwater cleanup levels for noncarcinogens and carcinogens, respectively, only if "sufficiently protective, health-based criteria or standards have not been established under applicable state and federal laws." Groundwater cleanup levels are established at concentrations that do not directly or indirectly cause violations of surface water, sediments, soil, or air cleanup standards.	Groundwater in 100-BC contains contaminants that require remediation. It is not currently used for drinking water but is a potential drinking water source (it discharges into the Columbia River, which is used for drinking water).	ARAR	Groundwater remediation and management (e.g., discharge of treated groundwater, in situ remediation of groundwater, MNA).
"Water Well Construction" (RCW 18.104, as amended); "Minimum Standards for Construction and Maintenance of Wells" (WAC 173-160)					
"How Shall Each Water Well Be Planned and Constructed?" (WAC 173-160-161)	Action	Identifies well planning and construction requirements.	Groundwater monitoring and treatment wells and borings occur in 100-BC.	ARAR	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.
"What Are the Requirements for the Location of the Well Site and Access to the Well?" (WAC 173-160-171)	Action	Identifies the requirements for locating a well.	Groundwater monitoring and treatment wells and borings occur in 100-BC.	ARAR	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-BC

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
"What Are the Requirements for Preserving the Natural Barriers to Ground Water Movement Between Aquifers?" (WAC 173-160-181)	Action	Identifies the requirements for preserving natural barriers to groundwater movement between aquifers.	Groundwater monitoring and treatment wells and borings occur in 100-BC.	ARAR	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.
"What Are the Minimum Standards for Resource Protection Wells and Geotechnical Soil Borings?" (WAC 173-160-400)	Action	Identifies the minimum standards for resource protection wells and geotechnical soil borings.	Groundwater monitoring and treatment wells and borings occur in 100-BC.	ARAR	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.
"What Are the General Construction Requirements for Resource Protection Wells?" (WAC 173-160-420)	Action	Identifies the general construction requirements for resource protection wells.	Groundwater monitoring and treatment wells and borings occur in 100-BC.	ARAR	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.
"What Are the Minimum Casing Standards?" (WAC 173-160-430)	Action	Identifies the minimum casing standards.	Groundwater monitoring and treatment wells and borings occur in 100-BC.	ARAR	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.
"What Are the Equipment Cleaning Standards?" (WAC 173-160-440)	Action	Identifies the equipment cleaning standards.	Groundwater monitoring and treatment wells and borings occur in 100-BC.	ARAR	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.
"What Are the Well Sealing Requirements?" (WAC 173-160-450)	Action	Identifies the well sealing requirements.	Groundwater monitoring and treatment wells and borings occur in 100-BC.	ARAR	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.
"What Is the Decommissioning Process for Resource Protection Wells?" (WAC 173-160-460)	Action	Identifies the decommissioning process for resource protection wells.	Groundwater monitoring and treatment wells and borings occur in 100-BC.	ARAR	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.
Radionuclide ARAR Dose Compliance Concentrations for Superfund Sites					
"Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination" (Luftig and Weinstock, 1997, OSWER Directive 9200.4-18) "Distribution of OSWER Radiation Risk Assessment Q & A's Final Guidance" (Luftig and Page, 1999, OSWER Directive 9200.4-31P)	Chemical	This memorandum presents clarification for establishing protective cleanup levels in media for radioactive contamination at CERCLA sites. EPA has determined that the dose limits established by the NRC in, "Radiological Criteria for License Termination" (62 FR 39058) (25 mrem/yr, which is equivalent to 5×10^{-4} increase lifetime risk), will not provide a protective basis for establishing PRGs under CERCLA. A dose of 15 mrem/yr effective dose (approximately equivalent to 3×10^{-4} increase in lifetime risk) is preferred as the maximum dose limit for humans. In the final guidance, EPA further clarifies that 15 mrem/yr is not a presumptive cleanup level under CERCLA. Rather, site decision makers should continue to use the CERCLA risk range when ARARs are not used to set cleanup levels. This is for several reasons, as using dose-based guidance would result in unnecessary inconsistency regarding how radiological and nonradiological (chemical) contaminants are addressed at CERCLA sites.	Groundwater in 100-BC contains radioactive contaminants that if not remediated, could pose unacceptable risk to human health.	TBC	Development of groundwater cleanup levels.
Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites (OSWER Directive 9200.4-17P)	Action	Provides the framework and appropriateness for using MNA as a remedy component for organic and inorganic contaminants.	Groundwater in 100-BC contains contaminants that require remediation. The use of MNA as a remedy may be appropriate.	TBC	Groundwater remediation activities including MNA.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-BC

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
Surface Water					
***Clean Water Act of 1972* (Public Law 107-303, as amended; 33 USC 1251, et seq.), Section 303c; "Water Quality Standards" (40 CFR 131)**					
"Toxics Criteria for Those States Not Complying with Clean Water Act Section 303(c)(2)(B)" (40 CFR 131.36(b)(1))	Chemical	Establishes numeric water quality criteria for the protection of human health and aquatic organisms. Toxic criteria for the protection of aquatic life is provided in the water quality criteria regulations "Toxics Criteria for Those States Not Complying with Clean Water Act Section 303(c)(2)(B)" (40 CFR 131.36(b)(1)), "EPA's Section 304(a), Criteria for Priority Toxic Pollutants," supersede criteria adopted by the state, except where the state criteria are more stringent than the federal criteria.	Groundwater in 100-BC contains contaminants that require remediation and discharges into the Columbia River.	ARAR	Groundwater remediation activities that impact surface water (e.g., discharge of treated groundwater, in situ remediation of groundwater, and MNA).
"Hazardous Waste Cleanup -- Model Toxics Control Act" (RCW 70.105D, as amended); "Model Toxics Control Act—Cleanup" (WAC 173-340)					
"Surface Water Cleanup Standards" (WAC 173-340-730)	Chemical	Surface water cleanup levels are based on estimates of the highest beneficial use and the reasonable maximum exposure expected to occur under both current and potential future site use conditions.	Groundwater in 100-BC contains contaminants that require remediation and discharges into the Columbia River. The Columbia River is a current and future source of drinking water.	ARAR	Groundwater remediation activities that impact surface water (e.g., discharge of treated groundwater, in situ remediation of groundwater, and MNA).
"Water Pollution Control" (RCW 90.48, as amended); "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A)					
"Toxic Substances" (WAC 173-201A-240(3))	Chemical	Establishes water quality standards for surface waters of the state of Washington consistent with public health and public enjoyment of the waters and the propagation and protection of fish, shellfish, and wildlife.	Groundwater in 100-BC contains contaminants that require remediation and discharges into the Columbia River. The Columbia River is a current and future source of drinking water. The use designations for the Columbia River include aquatic life use (spawning and rearing), primary contact recreation, water supply (drinking, irrigation, and agriculture), and miscellaneous uses (wildlife habitat, harvesting, commerce, boating, and aesthetics).	ARAR	Groundwater, remediation activities that impact surface water (e.g., discharge of treated groundwater, in situ remediation of groundwater, and MNA).
Soil and Vadose Zone					
"Hazardous Waste Cleanup -- Model Toxics Control Act" (RCW 70.105D, as amended); "Model Toxics Control Act—Cleanup" (WAC 173-340)					
"Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740(3))	Chemical	Establishes soil cleanup levels where residential land use represents the reasonable maximum exposure under both current and future site use conditions. Cleanup standards require specification of the following: • Hazardous substance concentrations that protect human health and the environment (cleanup levels). • Location of the site where cleanup levels must be attained ("points of compliance"). • Other regulatory requirements that apply to the cleanup action because of the type of action or location of the site. These requirements are generally established in conjunction with the selection of a specific cleanup action.	Soil in 100-BC contains contaminants that require remediation. The requirements corresponding to Method B soil cleanup levels may be used to calculate cleanup levels based on an unrestricted land use, which is more conservative than the conservation/mining land use assigned to this area.	ARAR	Soil cleanup actions where concentration of hazardous substances in the soil exceeds Method B cleanup levels using "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740(3)(b) and (c)).

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-BC

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
"Deriving Soil Concentrations for Groundwater Protection" (WAC 173-340-747(3) through (8))	Chemical	Establishes soil concentrations that will not cause contamination of groundwater at levels that exceed the groundwater cleanup levels established under "Groundwater Cleanup Standards" (WAC 173-340-720). Provides an overview of the methods for deriving these soil concentrations to meet relevant criteria. Certain methods are tailored for particular types of hazardous substances or sites and certain methods are more complex than others and/or require the use of site-specific data.	Soil in 100-BC contains contaminants that require remediation. The requirements corresponding to soil cleanup levels may be used to calculate cleanup levels to ensure protection of groundwater. Although groundwater is not currently used for drinking water, it is a potential drinking water source and discharges into the Columbia River (which is used for drinking water).	ARAR	Soil cleanup actions where concentration of hazardous substances in the soil exceeds soil concentration for protection of groundwater. As allowed, "Deriving Soil Concentrations for Groundwater Protection" (WAC 173-340-747(8)), Alternative fate and transport models, one of the seven allowable methods under "Deriving Soil Concentrations for Groundwater Protection" (WAC 173-340-747) will be used to determine appropriate cleanup levels.
Guidance for Developing Ecological Soil Screening Levels (OSWER Directive 9285.7-55)	Chemical	Provides a set of risk-based soil screening levels (Eco-SSLs) for several soil contaminants that are of ecological concern for terrestrial plants and animals at hazardous waste sites. Also describes the process used to derive these levels and provides guidance for their use.	Soil in 100-BC contains contaminants that require remediation. Comparison to SSLs may be appropriate for defining potential COPCs or to default to an Eco-SSL for COPCs that lacks corresponding published state cleanup criteria.	TBC	Soil cleanup actions to protect Ecological Receptors.
"Terrestrial Ecological Evaluation Procedures" (WAC 173-340-7490) "Site-Specific Terrestrial Ecological Evaluation Procedures" (WAC 173-340-7493) "Priority Contaminants of Ecological Concern" (WAC 173-340-7494)	Chemical	Defines goals and procedures for determining whether a release of hazardous substances to soil may pose a threat to the terrestrial environment. Characterizes existing or potential threats to terrestrial plants or animals exposed to hazardous substances in soil, and establishes site-specific cleanup standards for the protection of terrestrial plants and animals. "Priority Contaminants of Ecological Concern" (WAC 173-340-7494) provides for numeric concentrations of hazardous substances determined to persist, bioaccumulate, or be highly toxic to terrestrial ecological receptors.	Soil in 100-BC contains contaminants that require evaluation to determine if ecological exposures have the potential to cause significant adverse effects.	TBC	Soil remediation activities including containment, RTD, and MNA. After using the generic screening levels available in Table 749-3, site-specific terrestrial ecological cleanup levels have been developed using "Site-Specific Terrestrial Ecological Evaluation Procedures" (WAC 173-340-7493).
Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites (OSWER Directive 9200.4-17P)	Action	Provides the framework and appropriateness for using MNA as a remedy component for organic and inorganic contaminants.	Soil in 100-BC contains contaminants that require remediation. The use of MNA as a remedy may be appropriate.	TBC	Soil remediation activities including MNA.
Air					
"Washington Clean Air Act" (RCW 70.94); "General Regulations for Air Pollution Sources" (WAC 173-400)					
"General Regulations for Air Pollution Sources" (WAC 173-400)	Action	Defines methods of control to be employed to minimize the release of air contaminants associated with fugitive emissions resulting from materials handling, construction, demolition, or other operations. Emissions are to be minimized through application of best available control technology.	Soil and/or groundwater remedial actions implemented in 100-BC have the potential to emit emissions subject to these standards, because soil and groundwater hazardous contaminants detected in 100-BC include covered hazardous air pollutants.	ARAR	Actions performed at 100-BC that result in the emission of hazardous air pollutants, including decontamination, demolition, and excavation activities implemented during a remedial action that have the potential to emit visible, particulate, fugitive, and hazardous air emissions and odors.
"General Standards for Maximum Emissions" (WAC 173-400-040)	Action	All sources and emissions units are required to meet the general emission standards unless a specific source standard is available. General standards apply to visible emissions, particulate fallout, fugitive emissions, odors, emission detrimental to health and property, sulfur dioxide, and fugitive dust.	Soil and /or groundwater remedial actions implemented in 100-BC have the potential to emit emissions subject to these standards, because hazardous contaminants detected in 100-BC include covered regulated hazardous air pollutants.	ARAR	Remedial actions that have the potential to release hazardous air emissions.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-BC

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
"Emission Standards for Sources Emitting Hazardous Air Pollutants" (WAC 173-400-075)	Action	Establishes national emission standards for hazardous air pollutants. Adopts, by reference, "National Emission Standards for Hazardous Air Pollutants" (40 CFR 61) and appendices.	Soil and/or groundwater hazardous contaminants detected in 100-BC include covered regulated hazardous air pollutants.	ARAR	Actions performed at 100-BC that could result in the emission of hazardous air pollutants, including decontamination, demolition, and excavation activities implemented during the remedial action that have the potential to emit visible, particulate, fugitive, and hazardous air emissions and odors.
"Washington Clean Air Act" (RCW 70.94, as amended); "Controls for New Sources of Toxic Air Pollutants" (WAC 173-460)					
"Purpose" (WAC 173-460-010) "Applicability" (WAC 173-460-030) "Control Technology Requirements" (WAC 173-460-060) "Ambient Impact Requirement" (WAC 173-460-070) "First Tier Review" (WAC 173-460-080) "Table of ASIL, SQER and de Minimis Emission Values" (WAC 173-460-150)	Action	Establishes control of new sources emitting toxic air pollutants to prevent air pollution, reduce emissions to the extent reasonably possible, and maintain such levels of air quality as will protect human health and safety. Toxic air pollutants include carcinogens and noncarcinogens listed in "Table of ASIL, SQER and de Minimis Emission Values" (WAC 173-460-150). Three major requirements of this regulation are implementation of best available control technology for toxics, quantification of toxic air pollutant emissions, and demonstration of health and safety protection	Hazardous contaminants detected in soil and/or groundwater in 100-BC include constituents that would constitute toxic air pollutants if released to the air.	ARAR	Groundwater and soil remediation activities such as 100-BC treatment systems that have the potential to emit hazardous air emissions and that would be considered a new source.
"Washington Clean Air Act" (RCW 70.94, as amended); "Ambient Air Quality Standards and Emission Limits for Radionuclides" (WAC 173-480)					
"Ambient Standard" (WAC 173-480-040)	Action	Defines the maximum allowable level for radionuclides in the ambient air, which shall not cause a maximum accumulated dose equivalent of 25 mrem/yr to the whole body or 75 mrem/yr to any critical organ. However, ambient air standard under National Emissions Standards for Hazardous Air Pollutants (NESHAP) "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities" (40 CFR 61, Subpart H) and "National Emission Standards for Radionuclide Emissions from Federal Facilities Other Than Nuclear Regulatory Commission Licensees and Not Covered by Subpart H" (40 CFR 61, Subpart I) are not to exceed amounts that result in an effective dose equivalent of 10 mrem/yr to any member of the public.	Hazardous contaminants detected in soil and groundwater in 100-BC include radionuclides that could be emitted to ambient air during remedial actions.	ARAR	Investigative and remediation activities (such as excavation, RTD, demolition, ventilation, vacuuming/exhaust) that have the potential to emit radionuclides above maximum acceptable levels.
"General Standards for Maximum Permissible Emissions" (WAC 173-480-050)	Action	At a minimum, all emission units shall make every reasonable effort to maintain radioactive materials in effluents to unrestricted areas; control equipment of sites operating under ALARA shall be defined as reasonably available control technology and as low as reasonably achievable control technology.	The potential for fugitive and diffuse emissions resulting from demolition and excavation and related activities will require efforts to minimize those emissions.	ARAR	Investigative and remediation activities (such as excavation, RTD, demolition, ventilation, and vacuuming/exhaust) that have the potential to emit radionuclides above maximum acceptable levels.
"Emission Monitoring and Compliance Procedures" (WAC 173-480-070)	Action	Requires that radionuclide emissions shall be determined by calculating the dose to members of the public using Department of Health-approved sampling procedures at the point of maximum annual air concentration in an unrestricted area where any member of the public may be.	Hazardous contaminants detected in soil and groundwater in 100-BC include radionuclides that could be emitted to unrestricted areas during remedial actions.	ARAR	Investigative and remediation activities (e.g., excavation, RTD, demolition, ventilation, and vacuuming/exhaust) that have the potential to emit radionuclides to unrestricted areas above maximum acceptable levels.
"Emission Standards for New and Modified Emission Units" (WAC 173-480-060)	Action	Requires that construction, installation, or establishment of a new air emission control units use best available radionuclide control technology.	Hazardous contaminants detected in soil and groundwater in 100-BC include radionuclides that could be emitted from air emission control units during remedial actions.	ARAR	Investigative and remediation activities (e.g., excavation, RTD, demolition, ventilation, and vacuuming/exhaust) that require air pollution control equipment and have the potential to emit radionuclides.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-BC

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
"Nuclear Energy and Radiation" (RCW 70.98, as amended); "Radiation Protection—Air Emissions" (WAC 246-247)					
"National Standards. Adopted by Reference for Sources of Radionuclide Emissions" (WAC 246-247-035(1)(a)(ii)) [adopts by reference "Prohibited Activities"{40 CFR 61.05}])	Action	Identifies prohibition of any owner or operator of any stationary source subject to a national emission standard for hazardous air pollutants from constructing or operating the new or existing source in violation of any such standard.	Substantive requirements of this standard are applicable because the remedial actions in 100-BC may be subject to NESHAP's Air Pollutant Standards and resultant requirements have the potential to be detected in, and potentially emitted from, structures, components, debris, soil, or groundwater involved in the remedial action.	ARAR	Investigative and remedial activities.
"National Standards Adopted by Reference for Sources of Radionuclide Emissions" (WAC 246-247-035 (1)(a)(i) [adopts by reference "Compliance with Standards and Maintenance Requirements" {40 CFR 61.12}])	Action	Requires the owner or operator of each stationary source of hazardous air pollutants subject to a national emission standard for a hazardous air pollutant to determine compliance with numerical emission limits in accordance with emission tests established in NESHAP "Emission Tests and Waiver of Emission Tests" (40 CFR 61.13) or as otherwise specified in an individual subpart. Compliance with design, equipment, work practice, or operational standards shall be determined as specified in the individual subpart. Also, maintain and operate the source, including associated equipment for air pollution control, in a manner consistent with good air pollution control practice for minimizing emissions.	Hazardous contaminants that would be subject to NESHAP's Air Pollutant Standards and resultant requirements have the potential to be detected in, and potentially emitted from, structures, components, debris, soil, or groundwater involved in the remedial actions in 100-BC. Associated design, equipment, work practice, or equipment for air pollution control may also be maintained and operated.	ARAR	Investigative and remedial actions involve stationary sources that provide a potential to emit regulated hazardous air pollutants (e.g., vapor extraction systems, decontamination stations, deactivation, demolition, or waste removal or storage activities). Associated design, equipment, work practice, or air emissions controls may be maintained and operated.
"National Standards Adopted by Reference for Sources of Radionuclide Emissions" (WAC 246-247-035 (1)(a) (i) [adopts by reference "Monitoring Requirements" {40 CFR 61.14}])	Action	Requires the owner or operator to maintain and operate each monitoring system as specified in the applicable subpart, and in a manner consistent with good air pollution control practice for minimizing emissions. Approvals of alternatives to any monitoring requirements or procedures are obtained from the regulatory agency.	Hazardous contaminants that would be subject to NESHAP's Air Pollutant Standards and resultant requirements have the potential to be detected in, and emitted from, structures, components, debris, soil, or groundwater involved in the remedial actions in 100-BC. The hazardous contaminants will be monitored as identified under each applicable NESHAP subpart.	ARAR	Investigative and remedial soil, air, and groundwater monitoring systems, and decontamination and stabilization of contaminated structures, treatment of sludge, and operation of exhausters and vacuums, that produce airborne emissions of hazardous pollutants to unrestricted areas.
"National Standards Adopted by Reference for Sources of Radionuclide Emissions" (WAC 246-247-035 (1)(a)(ii) [adopts by reference "Standard" (40 CFR 61.92)])	Chemical	Establishes emission standards for radionuclides equivalent to NESHAP "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities" (40 CFR 61, Subpart H), by reference. U.S. DOE Hanford Site radionuclide airborne emissions shall be controlled so as not to exceed amounts that would cause an exposure to any member of the public of greater than 10 mrem/yr effective dose equivalent.	Hazardous radionuclide contaminants that would be subject to NESHAP; Radionuclide Air Pollutant Standards and resultant requirements have the potential to be detected in, and emitted from, structures, components, debris, soil or groundwater involved in the remedial actions in 100-BC.	ARAR	Investigative and remedial soil, air, groundwater monitoring systems and decontamination and stabilization of contaminated structures, treatment of sludge, and operation of exhausters and vacuums, that produce airborne emissions of hazardous radionuclide pollutants to unrestricted areas.
"National Standards Adopted by Reference for Sources of Radionuclide Emissions" [WAC 246-247-035 (1)(a)(ii) [adopts by reference "Emission Monitoring and Test Procedures" {40 CFR 61.93}])	Action	Specifies that radionuclide emissions shall be determined and effective dose equivalent values to members of the public calculated to determine compliance with the 10 mrem/yr effective dose equivalent standard. Radionuclide emissions shall be collected and measured using approved methods. A quality assurance program shall be conducted that meets the performance requirements described in Appendix B, Method 114. Measurement by methods specified in the paragraph (b) shall be made at all release points that have the potential to discharge radionuclides to the air in quantities that cause an effective dose equivalent in excess of 1 percent of the 10 mrem/yr standard. For other release points that have a potential to release radionuclides into the air, periodic confirmatory measurements shall be made to verify the low emissions.	Hazardous radionuclide contaminants that would be subject to NESHAP Radionuclide Air Pollutant Standards and resultant requirements have the potential to be detected in, and emitted from, structures, components, debris, soil, or groundwater involved in the remedial actions in 100-BC. The hazardous contaminants will be monitored as identified under each applicable NESHAP subpart.	ARAR	Investigative and remedial soil, air, and groundwater monitoring systems, and decontamination and stabilization of contaminated structures, treatment of sludge, and operation of exhausters and vacuums, that produce airborne emissions of hazardous radionuclide pollutants to unrestricted areas.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-BC

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
"General Standards" (WAC 246-247-040(3)) "General Standards" (WAC 246-247-040(4))	Action	Requires that emissions be controlled to ensure ALARA-based and Best Available Controls standards are not exceeded	Hazardous contaminants that would be subject to radionuclide air emission standards and resultant requirements have the potential to be detected in, and emitted from, structures, components, debris, soil, or groundwater involved in the remedial actions in 100-BC.	ARAR	Investigative and remedial soil, air, and groundwater monitoring systems, and decontamination and stabilization of contaminated structures, treatment of sludge, and operation of exhausters and vacuums, that produce airborne emissions of hazardous radionuclide pollutants to unrestricted areas.
"Monitoring, Testing and Quality Assurance" (WAC 246-247-075)	Action	Establishes the monitoring, testing, and quality assurance requirements for radioactive air emissions. Emissions from nonpoint and fugitive sources of airborne radioactive material will be measured. Measurement techniques may include but are not limited to sampling, calculation, smears, or other reasonable method for identifying emissions as determined by the lead agency.	Hazardous contaminants in 100-BC waste sites that would be subject to radionuclide air emission standards and resultant requirements have the potential to be detected in, and emitted from, structures, components, debris, soil, or groundwater involved in the remedial actions.	ARAR	Investigative and remedial soil, air, and groundwater monitoring systems, and decontamination and stabilization of contaminated structures, treatment of sludge, and operation of exhausters and vacuums, that produce airborne emissions of hazardous radionuclide pollutants to unrestricted areas.
***Clean Air Act of 1990* and amendments; "National Emission Standard for Asbestos" (40 CFR 61, Subpart M),**					
"Applicability" (40 CFR 61.140) "Standard for Demolition and Renovation" (40 CFR 61.145)	Action	Defines regulated ACM and regulated removal and handling requirements. Specifies sampling, inspection, handling, and disposal requirements for regulated sources having the potential to emit asbestos. Specifically, no visible emissions are allowed during handling, packaging, and transport of ACM.	Encountering ACM on pipelines or buried asbestos within the 100-BC Area is possible during the during remediation activities.	ARAR	Site investigation and remediation activities that include demolition and/or renovation and associated handling, packaging, and transportation of ACM, including IDW management and disposal.
"Standard for Waste Disposal for Manufacturing, Fabricating, Demolition, Renovation, and Spraying Operations" (40 CFR 61.150)	Action	Identifies requirements for the removal and disposal of asbestos from demolition and renovation activities.	Encountering ACM on pipelines or buried asbestos within the 100-BC Area is possible during the during remediation activities.	ARAR	Site investigation and remediation activities that include demolition and/or renovation and associated handling, packaging, and transportation of ACM including IDW management and disposal.
Solid Waste					
***Toxic Substances Control Act of 1976* (Public Law 107-377, as amended; 15 USC 2605, et seq.); "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions" (40 CFR 761)**					
"Applicability," "PCB Waste" (40 CFR 761.50(b)1, 2, 3, 4 and 7) "Applicability," "Storage for Disposal" (40 CFR 761.50(c))	Action	Establishes general PCB disposal requirements for the storage and disposal of PCB wastes including liquid PCB wastes, PCB items, PCB remediation waste, PCB bulk product wastes, and PCB/radioactive wastes at concentrations greater than 50 ppm.	PCB wastes may be encountered and or generated during the remediation of 100-BC.	ARAR	Soil excavation and remediation, equipment and debris handling and disposal, and investigation-derived waste (IDW) management and disposal.
"Disposal Requirements," "PCB Liquids" (40 CFR 761.60(a)) "Disposal Requirements," "PCB Articles" (40 CFR 761.60(b)) "Disposal Requirements," "PCB Containers" (40 CFR 761.60(c))	Action	Establishes requirements applicable to the handling and disposal of PCB liquids, PCB articles, and PCB containers.	PCB liquids, articles, and/or containers may be encountered and or generated during the remedial actions for 100-BC.	ARAR	Equipment and debris handling, storage, and disposal; IDW management and disposal.
"PCB Remediation Waste" (40 CFR 761.61)	Action	Provides cleanup and disposal options for PCB remediation waste, including soil, based on the concentration at which the PCBs are found.	PCB remediation wastes may be encountered and or generated during the remedial actions for 100-BC.	ARAR	Soil remediation, RTD, and IDW management and disposal.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-BC

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
"Hazardous Waste Management Act of 1976" (RCW 70.105, as amended); "Dangerous Waste Regulations" (WAC 173-303)					
"Identifying Solid Waste" (WAC 173-303-016) "Recycling Processes Involving Solid Waste" (WAC 173-303-017)	Action	Establishes criteria for solid and recycled solid waste.	Solid waste and/or recycled solid waste may be generated during 100-BC remedial actions.	ARAR	Investigative and remediation activities.
"Designation of Dangerous Waste" (WAC 173-303-070)	Action	Establishes the method for determining if a solid waste is a dangerous waste (or an extremely hazardous waste).	Dangerous/hazardous waste may be generated during 100-BC remedial actions.	ARAR	Investigative and remediation (including waste treatment) activities that generate waste (such as drums, barrels, tanks, containers, bulk waste, debris, and contaminated soil).
"Conditional Exclusion of Special Wastes" (WAC 173-303-073)	Action	Establishes the conditional exclusion and the management requirements of special waste, as defined in WAC 173-303-040, "Definitions."	Special waste may be generated during 100-BC remedial actions.	ARAR	FS remediation activities (disposal, storage, recycling, and onsite treatment) that manage special waste consistent with the requirements of the *Washington Administrative Code.*
"Requirements for Universal Waste" (WAC 173-303-077)	Action	Identifies waste exempted from regulation under "Land Disposal Restrictions" (WAC 173-303-140) and "Requirements for Generators of Dangerous Waste" (WAC 173-303-170) through "Reserved" (173-303-9907) (excluding WAC 173-303-960, "Special Powers and Authorities of the Department"). These wastes are subject to regulation under WAC 173-303-573, "Standards for Universal Waste Management."	Universal waste may be generated during the 100-BC remedial actions.	ARAR	FS remediation activities (disposal, storage, recycling, and onsite treatment) that manage universal waste consistent with the requirements of the *Washington Administrative Code.*
"Recycled, Reclaimed, and Recovered Wastes" (WAC 173-303-120) "Recycled, Reclaimed, and Recovered Wastes" (WAC 173-303-120(3)) "Recycled, Reclaimed, and Recovered Wastes" (WAC 173-303-120(5))	Action	Defines the requirements for the recycling of materials that are solid and dangerous waste. Specifically, "Recycled, Reclaimed, and Recovered Wastes" (WAC 173-303-120(3)) provides for the management of certain recyclable materials, including spent refrigerants, antifreeze, and lead acid batteries. "Recycled, Reclaimed, and Recovered Wastes" (WAC 173-303-120(5)) provides for the recycling of used oil.	Recycled, reclaimed, and recovered waste may be generated during 100-BC remedial actions.	ARAR	FS remediation recycling activities consistent with the requirements of the *Washington Administrative Code* and are not otherwise subject to CERCLA as hazardous substances.
"Land Disposal Restrictions" (WAC 173-303-140)	Action	Establishes treatment requirements and disposal prohibitions for land disposal of dangerous waste and incorporates by reference ("Land Disposal Restrictions" [WAC 173-303-140(2)(a)] the federal land disposal restrictions of "Land Disposal Restrictions" [40 CFR 268], that are applicable to solid waste that is designated as dangerous or mixed waste in accordance with "Designation of Dangerous Waste" (WAC 173-303-070(3)).	Onsite land disposal may be a selected remedy for 100-BC dangerous waste and debris.	ARAR	Investigative and remediation wastes destined for onsite land disposal.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-BC

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
"Requirements for Generators of Dangerous Waste" (WAC 173-303-170)	Action	Establishes the requirements for dangerous waste generators. "Requirements for Generators of Dangerous Waste" (WAC 173-303-170(3)) includes the substantive provisions of "Accumulating Dangerous Waste On-Site"(WAC 173-303-200), by reference. "Accumulating Dangerous Waste On-Site" (WAC 173-303-200) further includes certain substantive standards from "Use and Management of Containers" (WAC 173-303-630) and "Tank Systems" (WAC 173-303-640), by reference. Specifically, the substantive standards for management of dangerous/mixed waste are applicable to the management of dangerous waste that will be generated during the remedial action.	Dangerous waste may be generated from the remedial actions in 100-BC.	ARAR	IDW and remediation wastes (contaminated soil and groundwater, personnel protective gear, treatment chemicals, etc.).
"Accumulating Dangerous Waste On-Site" (WAC 173-303-200)	Action	Establishes the requirements for accumulating waste onsite. WAC 173-303-200 further includes certain substantive standards from WAC 173-303-630 and -640 by reference.	Dangerous waste may be generated from the remedial actions in 100-BC.	ARAR	Management of dangerous waste during remedial and investigative actions.
"Requirements" (WAC 173-303-64620(4))	Action	Establishes the standards for implementing corrective action for releases of dangerous waste and constituents under the HWMA. Corrective action is implemented by requiring corrective action follow certain sections of "Model Toxics Control Act—Cleanup" (WAC 173-340) and "Requirements" (WAC 173-303-64620(4)).	Corrective action applies to all releases of dangerous waste and dangerous constituents during Hanford Site operations as stated in "Requirements" (WAC 173-303-64620(1)). CERCLA may be the authority being used to clean up the release; the cleanup must be "consistent with" corrective action. The substantive portions of "Model Toxics Control Act—Cleanup" (WAC 173-340) establish minimum requirements for HWMA corrective action.	ARAR	Corrective action applies to environmental media at the Hanford Site where dangerous waste and dangerous constituents have been placed whether intentional or unintentional, during Hanford Site operations.
"Solid Waste Management—Reduction and Recycling" (RCW 70.95, as amended); "Solid Waste Handling Standards" (WAC 173-350)					
"Owner Responsibilities for Solid Waste" (WAC 173-350-025) "Performance Standards" (WAC 173-350-040) "On Site Storage, Collection and Transportation Standards" (WAC 173-350-300) "Remedial Action" (WAC 173-350-900)	Action	Establishes minimum functional performance standards for the proper handling and disposal of solid waste. Requirements for the proper handling of solid waste materials originating from residences, commercial, agricultural, and industrial operations and other sources and identifies those functions necessary to ensure effective solid waste handling programs at both the state and local level.	Solid, nondangerous waste will be generated during the implementation of 100-BC remedial actions.	ARAR	Investigative and remedial actions that generate solid, nondangerous waste.
Historical and Archeological Resources					
***National Historic Preservation Act of 1966* (Public Law 89-665, as amended, 16 USC 470, et seq.)**					
"Protection of Historic Properties" (36 CFR 800)	Location	Legislation intended to preserve historical and archaeological sites in the United States. Requires federal agencies to consider the impacts of their undertaking on cultural properties through identification, evaluation, mitigation processes, and consultation with interested parties.	Cultural and historic sites have been identified within 100-BC.	ARAR	Investigation and remediation activities that occur in areas near cultural or historic sites.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-BC

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
***Protection and Enhancement of the Cultural Environment* (Executive Order 11593)**					
"National Historic Landmarks Program" (36 CFR 65) "National Register of Historic Places" (36 CFR 60)	Location	Requires federal agencies to consider the impacts of their undertaking on cultural properties through identification, evaluation, mitigation processes, and consultation with interested parties.	Cultural and historic sites have been identified within 100-BC.	ARAR	Investigation and remediation activities that occur in areas near cultural or historic sites.
***Native American Graves Protection and Repatriation Act of 1990* (Public Law 101-601, as amended, 25 USC 3001, et seq.); "Native American Graves Protection and Repatriation Regulations" (43 CFR 10)**					
"Native American Graves Protection and Repatriation Regulations" (43 CFR 10)	Location	Establishes federal agency responsibility for discovery of human remains, associated and unassociated funerary objects, sacred objects, and items of cultural patrimony. Requires Native American Tribal consultation in the event of discovery.	Native American archaeological, cultural, and historic sites have been identified within 100-BC. Native American remains and associated objects may be present.	ARAR	Investigations and remedial activities that affect Native American archaeological, cultural, and historic sites that contain associated remains and objects.
***Archaeological and Historic Preservation Act of 1974* (Public Law 93-291, as amended; 16 USC 469a-1 through 469a-2(d))**					
"Applicant Requirements" 16 USC 469a-1 through 469a-2(d)	Location	Requires that remedial actions do not cause the loss of any archaeological or historic data. This act mandates preservation of the data; it does not require protection of the actual waste site or facility.	Archaeological and historic sites have been identified within 100-BC.	ARAR	Investigation and remediation activities that occur in areas near archeological or historic sites.
Natural and Ecological Resources					
***Floodplain Management* (Executive Order 11988)**					
"Compliance with Floodplain and Wetland Environmental Review Requirements" (10 CFR 1022)	Location	Take action to avoid adverse effects, minimize potential harm, and restore and preserve natural and beneficial values of the floodplain.	Some of the waste sites within 100-BC subject to remediation are located within the Columbia River floodplain.	ARAR	Remedial actions will occur in the floodplain.
***Endangered Species Act of 1973* (Public Law 93-205, as amended; 7 USC Section 136; 16 USC, Ch. 1531, et seq.)**					
"Interagency Cooperation—Endangered Species Act of 1973, as Amended" (50 CFR 402)	Location	Prohibits actions by federal agencies that are likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of habitat critical to them. Mitigation measures must be applied to actions that occur within critical habitats or surrounding buffer zones of listed species, in order to protect the resource.	Federal endangered and/or threatened species including fish, plants, and animals are found within 100-BC.	ARAR	Remediation actions and investigation activities that occur within critical habitats or designated buffer zones of federal listed species.
***Migratory Bird Treaty Act of 1918* (16 USC 703-712; Ch. 128; July 13, 1918; 40 Stat. 755), as amended**					
Migratory Bird Treaty Act of 1918 (16 USC 703-712)	Location	Protects all migratory bird species and prevents "take" of protected migratory birds, their young, or their eggs.	Migratory birds occur in 100-BC.	ARAR	Remedial actions that require mitigation measures to deter nesting by migratory birds on, around, or within remedial action site and methods to identify and protect occupied birds' nests.
***Bald Eagle Protection Act of 1940* (RCW 77.12.655), "Powers and Duties," "Habitat Buffer Zone for Bald Eagles—Rules;" "Permanent Regulations," "Bald Eagle Protection Rules" (WAC 232-12-292)**					
"Permanent Regulations," "Bald Eagle Protection Rules" (WAC 232-12-292)	Location	Protects eagle habitat to maintain eagle populations so the species is not classified as threatened, endangered, or sensitive in Washington State.	Bald eagles nest, feed, and overwinter along the shores of the Columbia River in 100-BC.	ARAR	Investigative and remediation activities that impact bald eagle habitat.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-BC

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
			***Fish and Wildlife Conservation Act of 1980*, "Nongame Act" (Public Law 96-366, as amended; 16 USC 2901-2911)**		
"Rules Implementing the Fish and Wildlife Conservation Act of 1980" (50 CFR 83)	Location	Preserve and promote conservation of nongame fish and wildlife and their habitats.	Non-wildlife and their habitats may occur in 100-BC.	ARAR	Remedial action that impact nongame fish, and wildlife and/or their habitats.
			Land Use and Exposure Scenarios		
Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement (DOE/EIS-0222-F; *Supplement Analysis: Hanford Comprehensive Land-Use Plan Environmental Impact Statement* [DOE/EIS-0222-SA-01])	Location	Establishes the future land use projections for the Hanford Site which includes 100-BC.	Land use, as stated in the Hanford Comprehensive Land Use Plan, is conservation/mining for land outside either (1) the Hanford Reach National Monument or (2) the River Corridor, which includes 100-BC.	TBC	

Sources: Complete reference citations are provided in Chapter 11.

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Waste generated through the CERCLA remedial actions and designated as low-level waste that meets the ERDF acceptance criteria (*Environmental Restoration Disposal Facility Waste Acceptance Criteria* [WCH-191]) is planned to be disposed at ERDF, which is engineered to meet appropriate performance standards. ERDF is considered onsite for management and/or disposal of waste from remedial actions that may be proposed in this document.[1]

Waste designated as dangerous or mixed waste would be treated as appropriate to meet land disposal restrictions and ERDF acceptance criteria, and disposed of at ERDF. The ERDF is an engineered facility that provides a high degree of protection to HHE and meets RCRA minimum technical requirements for landfills, including standards for a double liner, a leachate collection system, leak detection, monitoring, and final cover. Construction and operation of ERDF was authorized using a separate CERCLA ROD (*Declaration of the Interim Record of Decision for the Environmental Restoration Disposal Facility* [hereinafter called ERDF ROD (EPA/ROD/R10-95/100)]; *Record of Decision Amendment: U.S. Department of Energy Environmental Restoration Disposal Facility Hanford Site – 200 Area Benton County, Washington* [EPA/AMD/R10-02/030]). *Explanation of Significant Differences: USDOE Environmental Restoration Disposal Facility, Hanford Site, Benton County, Washington* (hereinafter called ERDF ESD [EPA/ESD/R10-96/145]) modified the ERDF ROD (EPA/ROD/R10-95/100) to clarify the eligibility of waste generated during cleanup of the Hanford Site. Per the ERDF ESD (EPA/ESD/R10-96/145), the ERDF is eligible for disposal of any low-level waste, mixed waste, and hazardous/dangerous waste generated as a result of cleanup actions (e.g., remedial/removal action waste and investigation-derived waste), provided the waste meets ERDF *Washington Administrative Code* requirements and appropriate CERCLA decision documents are in place.

Some of the aqueous waste designated as low-level waste, dangerous, or mixed waste would be transported to the Effluent Treatment Facility (ETF) for treatment and disposal. The ETF is a RCRA-permitted facility authorized to treat aqueous waste streams generated on the Hanford Site and dispose of these streams at a designated state-approved land disposal facility in accordance with applicable requirements.

Waste designated as PCB remediation waste likely would be disposed at ERDF, depending on whether it meets the waste acceptance criteria. The PCB waste that does not meet ERDF waste acceptance criteria would be retained at a PCB storage area that meets the requirements for TSCA storage. The PCB waste would be transported for future disposal at an appropriate disposal facility. Asbestos and asbestos-containing material would be removed, packaged as appropriate, and disposed of at the ERDF.

8.1.2.5 Standards Controlling Emissions to the Environment

Remedial action alternatives proposed in Chapter 9 of this FS have the potential to generate airborne emissions of both radioactive and criteria/toxic pollutants. Implementation of these activities and associated air monitoring will be discussed in the RD/RAWP for 100-BC.

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[1] CERCLA Section 104(d)(4), "where two or more noncontiguous facilities are reasonably related on the basis of geography, or on the basis of the threat or potential threat to the public health or welfare or the environment, the President may, at his discretion, treat these facilities as one." The preamble to the NCP (40 CFR 300) clarifies the stated EPA interpretation that when noncontiguous facilities are reasonably close to one another, and waste at these sites are compatible for a selected treatment or disposal approach, CERCLA Section 104(d)(4) allows the lead agency to treat these related facilities as one for response purposes. This allows the lead agency to manage waste transferred between such noncontiguous facilities without having to obtain a permit. The ERDF is considered to be onsite for response purposes under this remedial/removal/removal action. It should be noted that the scope of work covered in this remedial/removal/removal action is for a facility and waste contaminated with hazardous substances. Materials encountered during implementation of the selected remedial/removal/removal action that are not contaminated with hazardous substances will be dispositioned by the DOE.

8.1.2.6 Radiological Air Emissions

The federal *Clean Air Act of 1990* (CAA) and the "Washington Clean Air Act" (RCW 70.94) requires regulation of radioactive air pollutants. The state implementing regulation "Ambient Air Quality Standards and Emission Limits for Radionuclides" (WAC 173-480) sets standards that are as stringent or more stringent than the federal CAA including the federal implementing regulation, "National Emission Standard for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities" (NESHAP) (40 CFR 61, Subpart H). EPA's partial delegation of the Subparts A and H authority to the state of Washington includes all substantive emissions monitoring, abatement, and reporting aspects of the federal regulation. These state standards protect the public by conservatively establishing exposure standards applicable to the maximally exposed public individual. Members of the public can travel on the Columbia River through the Hanford Reach, but they cannot "abide or reside" there.

"Ambient Air Quality Standards and Emission Limits for Radionuclides" (WAC 173-480) limits emissions of radionuclides to the ambient air by requirement that emissions of radionuclides in the air shall not cause a maximum effective dose equivalent of more than 10 mrem/yr to the whole body to any member of the public. Under the state implementing regulations, "Radiation Protection—Air Emissions" "Definitions" (WAC 246-247-030(15)) defines the member of the public (real or hypothetical) who abides or resides in an unrestricted area, and may receive the highest total effective dose equivalent from the emission unit(s) under consideration, taking into account all exposure pathways affected by the radioactive air emissions. In addition, by its adoption of the federal standard at NESHAP "Standard" (40 CFR 61.92), the state limits radionuclide airborne emissions from the DOE Hanford Site (i.e., facility) to not exceed amounts that would cause an exposure to any member of the public of greater than 10 mrem/yr effective dose equivalent. The state implementing regulation "Radiation Protection—Air Emissions" (WAC 246-247), which adopts the "Ambient Air Quality Standards and Emission Limits for Radionuclides" (WAC 173-480) standards and the NESHAP "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities" (40 CFR 61, Subpart H), requires verification of compliance with the 10 mrem/yr standard and would be applicable to the remedial action.

"Radiation Protection—Air Emissions" (WAC 246-247) further addresses sources emitting radioactive airborne emissions by requiring monitoring of such sources. Such monitoring requires physical measurement (that is, sampling) of the effluent or ambient air. The substantive provisions of "Radiation Protection—Air Emissions" (WAC 246-247) that require monitoring of radioactive airborne emissions would be applicable to remedial actions subject to these standards.

The above state implementing regulations further address control of radioactive airborne emissions where economically and technologically feasible ("Radiation Protection – Air Emissions," "General Standards" [WAC 246-247-040(3) and (4)]). To address the substantive aspect of these requirements, best or reasonably achieved control technology could be addressed by ensuring that applicable emission control technologies (those successfully operated in similar applications) would be used when economically and technologically feasible (that is, based on cost/benefit). Controls will be administered as appropriate using the best methods from among those that are reasonable and effective.

8.1.2.7 Criteria/Toxic Air Emissions

Under "General Regulations for Air Pollution Sources" (WAC 173-400) and "Controls for New Sources of Toxic Air Pollutants" (WAC 173-460) requirements are established for the regulation of emissions of criteria/toxic air pollutants. The primary nonradioactive emissions resulting from remedial actions will be fugitive particulate matter. In accordance with "General Regulations for Air Pollution Sources," "General Standards for Maximum Emissions" (WAC 173-400-040), reasonable precautions must be taken to

(1) prevent the release of air contaminants associated with fugitive emissions resulting from excavation, materials handling, or other operations and (2) prevent fugitive dust from becoming airborne from fugitive sources of emissions. The use of treatment technologies that would result in emissions of toxic air pollutants that would be subject to the substantive applicable requirements of "Controls for New Sources of Toxic Air Pollutants" (WAC 173-460) are not anticipated to be a part of remedial actions selected for 100-BC.

If treatment of some waste encountered during the remedial action is required to meet ERDF waste acceptance criteria, the type of treatment anticipated would consist of solidification/stabilization techniques such as macroencapsulation or grouting and "Controls for New Sources of Toxic Air Pollutants" (WAC 173-460) would not be considered an ARAR. If more aggressive treatment is required that would result in the emission of regulated air pollutants, the substantive requirements of "General Regulations for Air Pollution Sources," "Requirements for New Sources in Attainment or Unclassifiable Areas" (WAC 173-400-113(2)) and "Controls for New Sources of Toxic Air Pollutants," "Control Technology Requirements" (WAC 173-460-060) would be evaluated to determine potential applicability.

Emissions to the air will be minimized during implementation of remedial actions through use of standard industry practices such as the application of water sprays and fixatives. These techniques are considered reasonable precautions to control fugitive emissions as required by regulatory standards.

8.1.2.8 100-BC Groundwater Beneficial Use

CERCLA and the NCP (40 CFR 300) establish separate requirements for a groundwater remedy: to be protective of HHE, and to meet ARARs. This is a concept of central importance to the development of the groundwater remedy for the 100-BC-5 OU. These separate requirements are further clarified in a memorandum ("Clarification of the Role of Applicable, or Relevant and Appropriate Requirements in Establishing Preliminary Remediation Goals under CERCLA" [Fields, 1997]).

The requirement to achieve threshold protectiveness and ARAR-based requirements is established by the NCP (40 CFR 300). The NCP (40 CFR 300) also establishes the requirement to return useable groundwater to beneficial use within a reasonable time frame. EPA generally defers to state agency definitions of useable groundwater provided under the various comprehensive state groundwater protection programs, administered by the states across the United States, and a state's determination of groundwater usability at CERCLA sites (*Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites* [EPA/540/G-88/003]). The state of Washington defines groundwater as potable in MTCA "Groundwater Cleanup Standards" (WAC 173-340-720(2)), unless the exclusion criteria in MTCA "Groundwater Cleanup Standards" (WAC 173-340-720(2)(a) through (c)) can be demonstrated (for example, insufficient yield or natural constituents that make it unsuitable as a drinking water source). The groundwater within the100-BC-5 OU does not meet the exclusion criteria; therefore, it is classified as potable and must be restored to beneficial use wherever practicable and within a time frame that is reasonably consistent with NCP (40 CFR 300) requirements. The state of Washington has further determined that the highest beneficial use for potable groundwater at most of the cleanup sites within the state, including the Hanford Site, is as a potential source of domestic drinking water (MTCA "Groundwater Cleanup Standards" [WAC 173-340-720(1)(a)]).

Groundwater within the 100-BC-5 OU is currently contaminated, and withdrawal is prohibited because of institutional controls placed on it by DOE. Under current site-use conditions, no groundwater wells are available for public consumption specific to 100-BC. Further, groundwater within this OU is not anticipated to become a future source of drinking water until cleanup criteria are met and groundwater is restored. However, groundwater was evaluated for drinking water use to support the determination of the basis for action and to support the development of PRGs for evaluating remedial alternatives in the FS.

8.1.2.9 100-BC Surface Water Beneficial Use

Surface water beneficial use is considered because groundwater within the 100-BC-5 OU currently discharges to the Columbia River through upwelling and seeps. "Water Quality Standards for Surface Waters of the State of Washington," "Use Designations—Fresh Waters" (WAC 173-201A-600) and "Water Quality Standards for Surface Waters of the State of Washington," "Table 602—Use Designations for Fresh Waters by Water Resource Inventory Area (WRIA)" (WAC 173-201A-602) identify the beneficial use (or designated uses) for rivers and streams of Washington State. Designated uses for waters of Washington State can include public water supply; protection for fish, shellfish, and wildlife; and recreational, agricultural, industrial, navigational, and aesthetic purposes. Water quality criteria are designed to protect the designated uses and are used to assess the general health of Washington surface waters and set permit limits.

Designated uses of the Columbia River, identified in "Water Quality Standards for Surface Waters of the State of Washington," "Table 602—Use Designations for Fresh Waters by Water Resource Inventory Area (WRIA)" [WAC 173-201A-602]), include the following:

- Aquatic life uses—spawning and rearing
- Recreational uses—primary contact
- Water supply uses—drinking water, industrial water, agricultural water, and stock water
- Miscellaneous uses—wildlife habitat, harvesting, commercial/navigation, boating, and aesthetics

The groundwater risk assessment presented in Section 6.3 of this report evaluates potential exposure of aquatic organisms to contaminants in the 100-BC-5 OU. This assessment uses the most stringent federal and state water quality criteria to support the basis for action and to support PRG development.

8.1.3 Remedial Action Objectives

Under CERCLA and the NCP (40 CFR 300), soil and groundwater remedies must be protective of human health and the environment and meet ARARs (or satisfy criteria for an ARAR to be waived). RAOs must be developed to address COCs, media of concern, potential receptors, and exposure pathways. RAOs are general descriptions of what a cleanup under CERCLA is expected to accomplish. They are narrative statements that define the extent to which waste sites require cleanup to protect human health and the environment.

The RAOs are based on the results of the HHRAs, ERAs, and the RI. Several expedited response and interim remedial actions already have been implemented (including characterization), thereby providing considerable information concerning contamination and risk from the 100-BC OUs. Media-specific RAOs were developed for groundwater (RAO 1), surface water (RAO 2), and soil (RAOs 3 through 5).

The following is a list of preliminary RAOs prepared for the 100 Area. Final RAOs are determined when the ROD selects the remedy:

RAO 1. Prevent unacceptable risk to human health from ingestion of and incidental exposure to groundwater containing contaminant concentration above federal and state standards and risk-based thresholds.

RAO 2. Prevent unacceptable risk to human health and ecological exposure to surface water containing contaminant concentrations above federal and state standards and risk-based thresholds.

RAO 3. Prevent unacceptable risk from contaminants migrating and/or leaching through soil that will result in groundwater concentrations that exceed standards and risk-based thresholds for protection of surface water and groundwater.

RAO 4. Prevent unacceptable risk to human health and ecological receptors from exposure to the upper 4.6 m (15 ft) of soil contaminated with nonradiological constituents at the concentrations above the unrestricted land use criteria for human health (provided in MTCA B) or soil contaminant levels for ecological receptors.

RAO 5. Prevent unacceptable risk to human health and ecological receptors from exposure to the upper 4.6 m (15 ft) of soil and to structures and debris contaminated with radiological constituents.

- Prevent exposure to radiological constituents at concentrations at or above a dose rate limit that causes an excess cancer lifetime risk threshold of 10^{-6} to 10^{-4} above background for the residential exposure scenario.
- Protect ecological receptors based on a dose rate limit of 0.1 rad/day for terrestrial wildlife populations, which is a TBC criterion.

8.1.4 Preliminary Remediation Goals

To meet the RAOs, PRGs are established. These goals generally are quantitative cleanup levels that would meet ARARs and risk-based levels and would be protective of HHE. The PRGs will be used to assess the effectiveness of the selected remedial alternatives in meeting the RAOs. A summary of the 100-BC Human Health, Groundwater Protection, Surface Water Protection, and Ecological SSLs and PRGs is shown in Table 8-3. The interim action ROD RAGs identified in the 100 Area RDR/RAWP (DOE/RL-96-17) are also listed in Table 8-3 for a direct comparison to the PRGs from this RI/FS. In this table, selected human health PRGs for radionuclides (highlighted in yellow) are the lowest of the PRGs calculated for the residential exposure scenario (based on a target cancer risk level) and the residential interim action ROD RAG (based on radiological dose) as defined in the 100 Area RDR/RAWP (DOE/RL-96-17). For nonradionuclides, selected human health PRGs (also highlighted in yellow) are the RI/FS MTCA Method B values. Also presented are the ecological PRGs for the four receptors (plants, invertebrates, birds, and mammals) that will be used within the SMDP for ecological protection. Green highlighting denotes the selected PRG (calculated in this RI/FS) above background for each analyte for groundwater/surface water protection except for Cr(VI), which is compared to the interim action ROD RAG of 2.0 mg/kg.

PRGs represent a core component of the overall technology screening and remedial alternative development process in the FS. PRGs are numerical values expressed as concentrations for a chemical or radionuclide in an environmental media. A remedial action achievement of PRGs results in residual contamination that is protective of human health and the environment (NCP "Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(2)(i)]). PRGs are also used to identify the area and volume of environmental media that must be addressed; therefore, PRGs are determined before the development of the remedial alternatives.

Meeting PRGs and the potential ARARs and, by extension, achieving RAOs, can be accomplished by reducing concentrations (or activities) of contaminants to PRG levels or by eliminating potential exposure pathways/routes. Contaminant-specific and numeric soil PRGs for direct exposure, protection of groundwater, and protection of surface water typically are presented as concentrations or activities, which for nonradionuclides are in milligrams per kilogram and in picocuries per gram for radionuclides. Contaminant-specific and numeric PRGs for groundwater typically are expressed in micrograms per liter for nonradiological COCs and picocuries per liter for radiological COCs.

Residual risks following completion of remediation of the waste sites must meet the 10^{-4} to 10^{-6} ELCR for radiological and carcinogenic COCs and must be less than or equal to an HI value of 1.0 for hazardous substances (as described in Chapter 6 of this RI/FS).

If selected ecological PRGs are exceeded, the Hanford Site managers will evaluate this exceedance using the SMDP process described in Chapter 7 of this RI/FS.

Finally, to demonstrate that cleanups have achieved the groundwater protection PRGs, the cleanup verification process, can involve the evaluation of the conceptual site model at the waste sites against the assumptions used to develop these PRGs (described in Chapter 5 of this RI/FS). To the extent a significant deviation from the groundwater/surface water protection PRGs assumptions is observed, site-specific conditions can be used to revise the fate and transport models to evaluate the potential for the waste site to act as a source of groundwater contamination.

8.1.4.1 Development Approach

PRGs are presented for each environmental media of interest (soil and groundwater), each type of contaminant (hazardous substances and radionuclides), human and ecological receptors, and each potentially complete exposure pathway.

Soil PRGs have been developed for the following exposure pathways and receptors:

- Direct contact PRGs for the protection of human health
- Direct contact PRGs for protection of ecological receptors
- Groundwater protection PRGs
- Surface water protection PRGs

Table 8-3 presents the soil PRGs for 100-BC COCs and COPCs of waste site remaining for remediation, based on the chemical-specific ARARs described in Section 8.1.2. Table 8-4 presents a summary of the 100-BC-5 Groundwater OU PRGs. The following sections describe the approach that was taken to develop PRGs for each media, receptor, and exposure pathway.

8.1.4.2 Direct-Contact Exposure PRGs for Nonradiological Contaminants

Development of the PRGs for direct-contact exposure to nonradiological contamination for both human and ecological receptors is described in the following subsections.

Table 8-3. Summary of 100-BC Operable Unit Human Health, Groundwater Protection, Surface Water Protection, and Ecological Soil PRGs

Analyte Name	Units	Hanford Site Background Concentration[a]	Human Health PRGs						PRGs Protective of Groundwater and Surface Water					Ecological PRGs				
			RI/FS Soil MTCA B —Direct Contact PRG[b]	RI/FS Residential PRG[c]	RI/FS Soil Method B Inhalation PRG[d]	RI/FS Casual Recreational User—Direct Contact PRG[e,f]	RI/FS Resident Monument Worker—Direct Contact PRG[g]	DOE/RL-96-17 Residential RAG[h]	100-BC 70:30/100:0 Contaminant Source Model GWP PRG[i]	100-BC 70:30/100:0 Contaminant Source Model SWP SSL[i]	100-BC 70:30/100:0 Contaminant Source Model SWP PRG[i]	DOE/RL-96-17 GWP RAG[h]	DOE/RL-96-17 SWP RAG[h]	Plant PRG[j]	Invertebrate PRG[j]	Avian PRG[j]	Mammal PRG[j]	Wildlife PRG[j]
Radionuclides																		
Americium-241	pCi/g	--	--	155	--	2,570	275	32	--[k]	--[k]	--[k]	--	--	21,500	--	11,900	4,840	37,500
Carbon-14	pCi/g	--	--	81	--	328,000	52,000	8.7	--[k]	--[k]	--[k]	--	--	60,700	--	50	32	60
Cesium-137	pCi/g	1.1	--	4.4	--	100	6.2	6.2	--[k]	--[k]	--[k]	1,470	2,930	2,210	--	1,430	924	2,510
Cobalt-60	pCi/g	0.0084	--	3.1	--	63	3.3	1.4	--[k]	--[k]	--[k]	13,900	27,800	6,130	--	805	805	805
Curium-243	pCi/g	--	--	30	--	527	37	22	--[k]	--[k]	--[k]	--	--	--	--	--	--	--
Europium-152	pCi/g	--	--	3.7	--	66	3.8	3.3	--[k]	--[k]	--[k]	--	--	14,700	--	1,740	1,740	1,740
Europium-154	pCi/g	0.033	--	4.4	--	78	4.8	3.0	--[k]	--[k]	--[k]	--	--	12,500	--	1,610	1,610	1,610
Europium-155	pCi/g	0.054	--	327	--	5,870	354	125	--[k]	--[k]	--[k]	--	--	153,000	--	33,400	33,400	33,400
Iodine-129	pCi/g	--	--	0.076	--	3,035	434	0.25	--[k]	0.33	--[k]	0.25	0.25	--	--	--	--	--
Neptunium-237	pCi/g	--	--	8.9	--	202	15	2.4	--[k]	118	--[k]	0.90	1.8	8,150	--	7,880	7,880	8,170
Nickel-63	pCi/g	--	--	608	--	575,000	91,600	4,013	--[k]	--[k]	--[k]	83	166	--	--	--	--	--
Niobium-94	pCi/g	--	--	1.4	--	26	1.7	2.4	--[l]	--[l]	--[l]	--	--	--	--	--	--	--
Plutonium-238	pCi/g	0.0038	--	236	--	3,820	605	39	--[k]	--[k]	--[k]	--	--	17,500	--	20,900	5,980	83,600
Plutonium-239/240	pCi/g	0.025	--	203	--	3,340	539	35	--[k]	--[k]	--[k]	--	--	12,700	--	22,300	6,270	89,200
Plutonium-241	pCi/g	--	--	5,080	--	--	77,200	--	--[k]	--[k]	--[k]	--	--	--	--	--	--	--
Technetium-99	pCi/g	--	--	1.5	--	114,449	17,322	5.8	38	20	38	0.46	0.92	21,900	--	5,360	8,670	8,670
Total beta radiostrontium (strontium-90)	pCi/g	0.18	--	2.3	--	5,060	518	4.5	--[k]	--[k]	--[k]	28	55	3,580	--	112	91	453
Tritium	pCi/g	--	--	623	--	15,400	>1,000,000	459	1,217	868	1,217	13	25	>1,000,000	--	936	420	1,920
Uranium-233/234	pCi/g	1.1	--	133	--	5,810	931	1.1	--[m]	--[m]	--[m]	1.1	1.1	51,600	--	6,370	14,200	24,800
Uranium-235	pCi/g	0.11	--	16	--	295	22	0.61	--[m]	--[m]	--[m]	0.50	0.50	27,400	--	4,360	8,060	8,130
Uranium-238	pCi/g	1.1	--	54	--	1,093	93	1.1	--[m]	--[m]	--[m]	1.1	1.1	15,700	--	5,150	11,000	11,000
Metals																		
Aluminum	mg/kg	11,800	80,000	--	>1,000,000	912,453	--	--	--[k]	--[k]	--[k]	--	--	--	--	18,600	2,710	3,988
Antimony	mg/kg	0.13	32	--	--	365	--	32	--[k]	6.2	--[k]	5.0	5.0	842	842	--	146	146
Arsenic	mg/kg	6.5	20	--	42,414	4.5	--	20	--[k]	--[k]	--[k]	20	20	128	128	2,280	127	127

Table 8-3. Summary of 100-BC Operable Unit Human Health, Groundwater Protection, Surface Water Protection, and Ecological Soil PRGs

Analyte Name	Units	Hanford Site Background Concentration[a]	Human Health PRGs						PRGs Protective of Groundwater and Surface Water					Ecological PRGs				
			RI/FS Soil MTCA B —Direct Contact PRG[b]	RI/FS Residential PRG[c]	RI/FS Soil Method B Inhalation PRG[d]	RI/FS Casual Recreational User—Direct Contact PRG[e,f]	RI/FS Resident Monument Worker—Direct Contact PRG[g]	DOE/RL-96-17 Residential RAG[h]	100-BC 70:30/100:0 Contaminant Source Model GWP PRG[i]	100-BC 70:30/100:0 Contaminant Source Model SWP SSL[i]	100-BC 70:30/100:0 Contaminant Source Model SWP PRG[i]	DOE/RL-96-17 GWP RAG[h]	DOE/RL-96-17 SWP RAG[h]	Plant PRG[j]	Invertebrate PRG[j]	Avian PRG[j]	Mammal PRG[j]	Wildlife PRG[l]
Barium	mg/kg	132	16,000	--	>1,000,000	182,000	--	5,600	--[k]	--[k]	--[k]	200	400	500	358	1,690	2,270	2,265
Beryllium	mg/kg	1.5	160	--	75,991	1,825	--	10	--[k]	--[k]	--[k]	1.5	1.5	10	40	--	18	18
Boron	mg/kg	3.9	16,000	--	>1,000,000	183,000	--	7,200	--[k]	--[l]	--[l]	320	--	30	58	91	91	91
Cadmium	mg/kg	0.56	40	--	101,000	821	--	14	--[k]	--[k]	--[k]	0.81	0.81	9.8	20	29	624	115
Chromium	mg/kg	19	120,000	--	--	>1,000,000	--	80,000	--[k]	--[k]	--[k]	19	19	259	149	109	517	331
Cobalt	mg/kg	16	24	--	20,264	274	--	24	--[k]	--[k]	--[k]	16	--	16	16	484	2,140	1,935
Copper	mg/kg	22	3,200	--	--	36,500	--	2,960	--[k]	234	--[k]	59	22	70	58	213	579	579
Cr(VI)	mg/kg	--	240	--	2,171	2,740	--	2.1	6.0[n]	6.0[n]	2.0	4.8	2.0	--	--	--	1,250	--
Iron	mg/kg	32,600	56,000	--	--	638,750	--	--	--[k]	--[k]	--[k]	--	--	--	--	--	--	--
Lead	mg/kg	10	250	--	--	--	--	353	--[k]	--[k]	--[k]	10	10	9,090	1,700	156	1,580	623
Lithium	mg/kg	13	160	--	--	1,825	--	160	--[k]	--[l]	--[l]	34	--	2.0	--	--	1,664	1,664
Manganese	mg/kg	512	11,200	--	>1,000,000	128,000	--	3,760	--[k]	--[k]	--[k]	512	512	1,260	1,260	14,400	3,320	3,322
Mercury	mg/kg	0.013	24	--	>1,000,000	274	--	24	--[k]	--[k]	--[k]	0.33	0.33	0.30	13	2.0	1.6	1.6
Molybdenum	mg/kg	0.47	400	--	--	4,563	--	400	--[k]	23,887	--[k]	8.0	--	2.0	28	95	5.7	5.7
Nickel	mg/kg	19	1,600	--	701,000	18,250	--	1,600	--[k]	--[k]	--[k]	19	27	38	280	361	247	247
Selenium	mg/kg	0.78	400	--	>1,000,000	4,560	--	400	--[k]	7.4	--[k]	5.0	1.0	2.0	4.1	2.4	1.4	1.4
Silver	mg/kg	0.17	400	--	--	4,563	--	400	--[k]	--[k]	--[k]	8.0	0.73	560	3.0	983	9,810	3,933
Strontium	mg/kg	--	48,000	--	--	547,500	--	48,000	--[k]	--[k]	--[k]	960	--	--	--	--	1,210	1,214
Thallium	mg/kg	0.19	--	--	--	--	--	--	--[k]	--[k]	--[k]	--	--	1.0	0.46	--	6.2	6.2
Tin	mg/kg	--	48,000	--	--	547,500	--	48,000	--[k]	--[k]	--[k]	960	--	838	838	204	279	131
Uranium	mg/kg	3.2	240	--	>1,000,000	2,737	--	240	--[k]	489	--[k]	3.2	3.2	250	100	82	40	123
Vanadium	mg/kg	85	400	--	--	4,560	--	560	--[k]	--[l]	--[l]	85	--	89	116	43	260	161
Zinc	mg/kg	68	24,000	--	--	274,000	--	24,000	--[k]	--[k]	--[k]	480	68	621	8,980	856	1,040	3,331
Polyaromatic Hydrocarbons (PAHs)																		
Acenaphthene	mg/kg	--	4,800	--	--	40,139	--	4,800	--[k]	1,207	--[k]	96	129	20	29	1,100	2,420	2,785
Acenaphthylene	mg/kg	--	--	--	--	--	--	4,800	--[l]	--[l]	--[l]	96	129	--	29	74	156	179
Anthracene	mg/kg	--	24,000	--	--	200,696	--	24,000	--[k]	--[k]	--[k]	240	1,920	--	29	678	4,210	2,574

Table 8-3. Summary of 100-BC Operable Unit Human Health, Groundwater Protection, Surface Water Protection, and Ecological Soil PRGs

Analyte Name	Units	Hanford Site Background Concentration[a]	Human Health PRGs						PRGs Protective of Groundwater and Surface Water					Ecological PRGs				
			RI/FS Soil MTCA B —Direct Contact PRG[b]	RI/FS Residential PRG[c]	RI/FS Soil Method B Inhalation PRG[d]	RI/FS Casual Recreational User—Direct Contact PRG[e,f]	RI/FS Resident Monument Worker—Direct Contact PRG[g]	DOE/RL-96-17 Residential RAG[h]	100-BC 70:30/100:0 Contaminant Source Model GWP PRG[i]	100-BC 70:30/100:0 Contaminant Source Model SWP SSL[i]	100-BC 70:30/100:0 Contaminant Source Model SWP PRG[i]	DOE/RL-96-17 GWP RAG[h]	DOE/RL-96-17 SWP RAG[h]	Plant PRG[j]	Invertebrate PRG[j]	Avian PRG[j]	Mammal PRG[j]	Wildlife PRG[l]
Benzo(a)anthracene	mg/kg	--	1.4	--	>1,000,000	1.7	--	1.4	--[k]	--[k]	--[k]	0.015	0.015	--	18	2.0	64	73
Benzo(a)pyrene	mg/kg	--	0.14	--	165,799	0.17	--	0.14	--[k]	--[k]	--[k]	0.015	0.015	--	18	2.4	76	81
Benzo(b)fluoranthene	mg/kg	--	1.4	--	>1,000,000	1.7	--	1.4	--[k]	--[k]	--[k]	0.015	0.015	--	18	1.3	39	41
Benzo(ghi)perylene	mg/kg	--	--	--	--	--	--	2,400	--[l]	--[l]	--[l]	48	192	--	18	1.1	32	32
Benzo(k)fluoranthene	mg/kg	--	1.4	--	>1,000,000	1.7	--	1.4	--[k]	--[k]	--[k]	0.015	0.015	--	18	1.3	39	45
Chrysene	mg/kg	--	14	--	>1,000,000	17	--	14	--[k]	--[k]	--[k]	0.12	0.10	--	18	1.4	45	51
Dibenz[a,h]anthracene	mg/kg	--	1.4	--	>1,000,000	1.7	--	1.4	--[k]	--[k]	--[k]	0.030	0.030	--	18	1.4	44	49
Fluoranthene	mg/kg	--	3,200	--	--	26,760	--	3,200	--[k]	--[k]	--[k]	64	18	--	18	1.1	839	841
Fluorene	mg/kg	--	3,200	--	--	26,760	--	3,200	--[k]	2,600	--[k]	64	260	--	29	175	267	307
Indeno(1,2,3-cd)pyrene	mg/kg	--	1.4	--	>1,000,000	1.7	--	1.4	--[k]	--[k]	--[k]	0.33	0.33	--	18	1.2	36	40
Naphthalene	mg/kg	--	1,600	--	1.4	62	--	1,600	--[k]	1,773	--[k]	16	988	--	29	340	100	100
Phenanthrene	mg/kg	--	--	--	--	--	--	24,000	--[l]	--[l]	--[l]	240	1,920	--	29	943	5,920	3,608
Pyrene	mg/kg	--	2,400	--	--	20,070	--	2,400	--[k]	--[k]	--[k]	48	192	--	18	1.9	600	600
Other Organics																		
Total Petroleum Hydrocarbons–Diesel Range	mg/kg	--	2,000	--	--	--	--	200	2,000[p]	--[l]	--[l]	200	200	--	200	356,000	452,000	451,807
Total petroleum hydrocarbons–motor oil (high boiling)	mg/kg	--	2,000	--	--	--	--	200	2,000[p]	--[l]	--[l]	200	200	--	--	--	--	451,807

Table 8-3. Summary of 100-BC Operable Unit Human Health, Groundwater Protection, Surface Water Protection, and Ecological Soil PRGs

			Human Health PRGs						PRGs Protective of Groundwater and Surface Water					Ecological PRGs				
Analyte Name	Units	Hanford Site Background Concentration[a]	RI/FS Soil MTCA B —Direct Contact PRG[b]	RI/FS Residential PRG[c]	RI/FS Soil Method B Inhalation PRG[d]	RI/FS Casual Recreational User—Direct Contact PRG[e,f]	RI/FS Resident Monument Worker—Direct Contact PRG[g]	DOE/RL-96-17 Residential RAG[h]	100-BC 70:30/100:0 Contaminant Source Model GWP PRG[i]	100-BC 70:30/100:0 Contaminant Source Model SWP SSL[l]	100-BC 70:30/100:0 Contaminant Source Model SWP PRG[i]	DOE/RL-96-17 GWP RAG[h]	DOE/RL-96-17 SWP RAG[h]	Plant PRG[j]	Invertebrate PRG[j]	Avian PRG[j]	Mammal PRG[j]	Wildlife PRG[l]

Notes:

Yellow highlighting denotes the most conservative PRG above background for each analyte for HHE protection (except for arsenic which is compared to the "Model Toxics Control Act-Cleanup," "Tables" [WAC 173-340-900], Table 740-1, Method A soil cleanup level for unrestricted Land Use, and Cr(VI) which is compared to the interim action RAG of 2.1 mg/kg). For Ecological PRGs, yellow is used to highlight the lowest protective value across the four receptors (plants, invertebrates, birds, and mammals).
Green highlighting denotes the most conservative PRG above background for each analyte for groundwater/surface water protection except for Cr(VI) which is compared to the interim action RAG of 2.0 mg/kg.

a. Hanford Site background values for nonradionuclides: *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes* (DOE/RL-92-24);, *Soil Background Data for Interim Use at the Hanford Site* (ECF-HANFORD-11-0038); Hanford site background values for radionuclides: *Hanford Site Background: Part 2, Soil Background for Radionuclides* (DOE/RL-96-12).

b. ECF-HANFORD-10-0444, *Documentation of Standard Method B Contact Cleanup Levels for Unrestricted Land Use*; PRGs for arsenic, lead, and total petroleum hydrocarbons are based on MTCA "Tables" (WAC 173-340-900), Table 740-1, "Method A Soil Cleanup Levels for Unrestricted Land Uses."

c. ECF-HANFORD-10-0429, *Documentation of Preliminary Remediation Goals (PRGs) for Radionuclides Using the IAROD Exposure Scenario for the 100 and 300 Area Remedial Investigation/Feasibility Study (RI/FS) Report.*

d. ECF-HANFORD-11-0033, *Calculation of Inhalation Pathway Preliminary Remediation Goals Using Standard Method B Air Cleanup Levels for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports.*

e. ECF-HANFORD-10-0445, *Calculation of Nonradionuclides Preliminary Remediation Goals in Soil for a Casual Recreational User Scenario for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports.*

f. ECF-HANFORD-10-0446, *Calculation of Radiological Preliminary Remediation Goals in Soil for a Casual Recreational User Scenario for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports.*

g. ECF-HANFORD-11-0142, *Calculation of Radiological Preliminary Remediation Goals in Soil for a Resident Monument Worker Scenario for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports.*

h. DOE/RL 96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, Rev. 6.

i. ECF-HANFORD-11-0065, *STOMP 1-D Modeling for Determination of Preliminary Remediation Goals for 100 Area Vadose Zone Operable Unit BC.* A 70:30 initial source distribution is used for analytes with $K_d \geq 2$ mL/g; a 100:0 initial source distribution is used for analytes with $K_d < 2$ mL/g. The SSL and PRG value for all analytes defaults to the estimated quantitation limit (EQL) when the calculated value is less than the EQL. EQL values are obtained from the *Sampling and Analysis Plan for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units Remedial Investigation/Feasibility Study* (DOE/RL-2009-44).

j. CHPRC-00784, *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site.*; CHPRC-01311, *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site;* ECF-HANFORD-11-0158, *Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionculides for Use at the Hanford Site;* ECF-300NPL-12-0032, *Remedial Action Goals Protective of Populations of Ecological Receptors in the River Corridor.* These PRGs will be used within the scientific management decision point (SMDP) process described in Chapter 7 of this RI/FS.

k. The SSL or PRG value for GWP or SWP is considered non-representative because there is no breakthrough of the analyte simulated within 1,000 years for the majority of soil columns (breakthrough is defined as concentrations above 1E-04 µg/L or 1E-04 pCi/L).

l. A GWP or SWP SSL or PRG is not calculated because a groundwater or surface water cleanup level or MCL is not available for the analyte.

m. A soil screening level is calculated for total uranium (CAS # 7440-61-1) but not isotopic uranium because an MCL is not available for isotopic uranium. When total uranium analytical results (µg/kg) are available, exposure point concentrations are compared to the total uranium soil screening level. When only isotopic uranium results (pCi/g) are available, uranium is addressed by converting the isotopic uranium from activity-based (pCi/g) to mass-based (µg/kg) concentrations and summing to provide a mass-based total uranium exposure point concentration (identified as Total_U_Isotopes), as described in ECF-100BC-1-0082, *Computation of Exposure Point Concentrations for the 100-BC-1 and 100-BC-2 Source Operable Units.* The Total_U_Isotopes exposure point concentration is then compared to the total uranium soil screening level.

n. The SSL and PRG values for Cr(VI) are set to a maximum value of 6.0 mg/kg because the K_d value used in the model was derived from experiments with soil concentrations less than 6 mg/kg.

o. Value converted from "as nitrogen" values in *Remedial Design Report/Remedial Action Work Plan for the 100 Area* (DOE/RL-96-17) using the following conversion factors as applicable: 4.43 g NO_3^-/g N and 3.29 g NO_2^-/ g N.

p. The SSL for total petroleum hydrocarbons is a default screening level obtained from MTCA "Tables" (WAC 173-340-900), Table 747-5, "Residual Saturation Screening Levels for TPH."

Table 8-4. 100-BC-5 Groundwater OU PRGs

Contaminant	Units	90th Percentile Concentration	Dose (mrem/yr) Based on 90th Percentile Concentration	ELCR Based on 90th Percentile Concentration	HQ Based on 90th Percentile Concentration	Drinking Water Standard	WAC 173-340-720 Cleanup Levels		AWQC			WAC 173-201A	40 CFR 131 Water Quality Standard		100-BC-5 Groundwater OU PRG[a]
							Noncarcinogens at HQ = 1	Carcinogens at 1×10^{-5} Risk Level	Freshwater CMC (acute)	Freshwater CCC (chronic)	Human Health Water + Organism at 1×10^{-5} Risk Level	Freshwater CCC (chronic)	Freshwater CMC (acute)	Freshwater CCC (chronic)	
Near River Exposure Area															
COCs—for Remedial Technology Screening and Alternative Development															
Strontium-90	pCi/L	38	19.2	4.0×10^{-5}	--	8	--	--	--	--	--	--	--	--	8
Tritium	pCi/L	33,200	6.8	3.2×10^{-5}	--	20,000	--	--	--	--	--	--	--	--	20,000
Hexavalent chromium[b]	µg/L	50	--	--	1.0	--	48	--	16	11	--	10	15	10	10
Trichloroethene	µg/L	1.9	--	3.9×10^{-6}	--	5	--	4.9	--	--	25	--	--	--	4.9
COPCs															
Cobalt	µg/L	0.18	--	--	0.04	--	4.8	--	--	--	--	--	--	--	4.8
Upland Exposure Area															
COCs—for Remedial Technology Screening and Alternative Development															
Strontium-90	pCi/L	1.2	0.6	1.3×10^{-6}	--	8	--	--	--	--	--	--	--	--	8
Tritium	pCi/L	11,000	2.2	6.9×10^{-5}	--	20,000	--	--	--	--	--	--	--	--	20,000
Hexavalent chromium[b]	µg/L	23	--	--	0.48	--	48	--	16	11	--	10	15	10	10
Trichloroethene	µg/L	2.4	--	4.9×10^{-6}	--	5	--	4.9	--	--	25	--	--	--	4.9
COPCs															
Cobalt	µg/L	0.10	--	--	0.02	--	4.8	--	--	--	--	--	--	--	4.8

Note: Drinking water standard from "National Primary Drinking Water Regulations" (40 CFR 141)

Sources:

"Water Quality Standards" (40 CFR 131)

"Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A)

"Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards" (WAC 173-340-720)

a. The final cleanup levels achieved at the conclusion of the remedial action will correspond to an ELCR less than 1×10^{-5} and HI of less than 1.

b. There is no drinking water standard specific to hexavalent chromium.

N/A = not applicable

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Human Exposure. For human receptors, soil PRGs developed for direct-contact and inhalation exposure pathways are risk-based standards for hazardous substances. Risk-based standards for individual hazardous substances are established using applicable federal and state laws and risk equations. Risk-based standards for individual carcinogens in an unrestricted exposure scenario are based on an ELCR of 1×10^{-6} and an HQ of 1.0 for individual noncarcinogenic substances as described in MTCA "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740(3)(b)(iii)(B)).

Consistent with this approach, the methodology described for unrestricted land use under MTCA "Unrestricted Land Use Soil Cleanup Levels" (WAC 173-340-740(3)) is used to calculate the risk-based standards for soil ingestion. Risk-based standards for inhalation pathways use equations and input parameters described in MTCA "Cleanup Standards to Protect Air Quality" (WAC 173-340-750(3)) and EPA-published volatilization factors and particulate emission factors.

Table 8-3 presents a summary of the RAGs reported in the 100 Area RDR/RAWP (DOE/RL-96-17) and MTCA "Unrestricted Land Use Soil Cleanup Levels" (WAC 173-340-740(3)). Although residential is not within DOEs reasonably anticipated future land use, DOE has proposed unrestricted cleanup levels for chemicals and residential cleanup levels for radionuclides. The direct contact PRGs for radionuclides were set as the lower of the radionuclide dose (interim action cleanup values) or risk-based calculations. Direct contact PRGs for nonradionuclides are based on current MTCA methods (WAC 173-340).

For arsenic and lead, Table 740-1 in the Method A "Soil Cleanup Levels for Unrestricted Land Use" (MTCA "Tables" [WAC 173-340-900]) is used as the PRG for direct contact exposure.

Soil PRG values are also developed for the direct-contact and inhalation pathways, combined, using the casual user exposure scenario. The casual user scenario is used to represent reasonably anticipated future land use. The casual recreational user scenario is a site-specific scenario representing occasional recreational use that focuses on activities such as walking and picnicking in areas along the Columbia River where paths and benches are likely to exist. Adults and children could potentially be exposed to site contaminants in shallow vadose zone material along the river through incidental soil ingestion, dermal absorption, and inhalation of vapors and dust in ambient air. PRG values for individual carcinogens are based on an ELCR of 1 × 10-6 and an HQ of 1.0 for individual noncarcinogenic substances. The PRG values listed in Table 8-3 for this exposure scenario are provided to aid in determining whether the clean up actions achieve the CERCLA threshold criteria.

Risk-based standards for some contaminants are calculated to be less than area background values or PQLs. Where risk-based standards are less than area background concentrations, PRGs may be set at concentrations that are equal to the agreed-upon site or area background concentrations. Area background values for selected nonradioactive contaminants in soil have been characterized for the Hanford Site (Non-Rad Soil Background document [DOE/RL-92-24]). Similarly, where risk-based standards are less than PQLs, PRGs will default to the PQLs. Therefore, the PRGs for individual nonradioactive contaminants in solid waste and particulate reflect the value that is greatest among risk-based standards, area background values, or PQLs.

The following subsections describe how ecological PRGs are developed for the 100-BC OUs. Ecological COPECs are identified using a tiered screening process for wildlife (birds and mammals), plants, and soil invertebrates. Ecological PRGs are developed using a tiered approach; the appropriate tier is identified through answering key questions.

Ecological Exposure. Ecological PRGs for the protection of plants, soil invertebrates, and wildlife (birds and mammals) are developed using a tiered approach (*Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-00784]). The objective of a tiered approach is to

refine available generic screening levels (EcoSSLs in MTCA [WAC 173-340], Table 749-3, or BCGs), as needed, with additional literature-derived or site-specific information to more realistically represent Hanford Site-specific ecological risks. The ecological PRGs are developed in Section 7.3.4 of this RI/FS.

8.1.4.3 Direct-Contact Exposure PRGs for Radiological Contaminants

The PRGs for direct-contact exposure to radioactive contamination for both human and ecological receptors are described in the following subsections.

Human Exposure. PRGs for radioactive waste and radioactively contaminated soil for human receptor direct-contact exposures are based on EPA radionuclide soil cleanup guidance. As established by the NCP (40 CFR 300), CERCLA cleanup actions generally should achieve a level of risk within the 10^{-4} to 10^{-6} ELCR based on the RME for an individual. Furthermore, EPA policy has noted that the upper boundary of the risk range is not a discrete line at 10^{-4}, and that a specific risk estimate around 10^{-4} may be considered acceptable if justified based on site-specific conditions (*Radiation Risk Assessment At CERCLA Sites: Q & A* [EPA 540/R/99/006]). Demonstration that the 10^{-4} to 10^{-6} residual risk-range goal has been achieved will be accomplished through final verification sampling during closeout of individual sites. The PRGs are developed for a number of exposure scenarios in the risk assessment. Each of these exposure scenarios are discussed in the following paragraphs.

PRGs for radiological contaminants are developed using a residential exposure scenario. Residents could potentially be exposed to shallow zone soil from residential yards or groundwater from domestic wells. Residents could potentially be exposed to soil from direct external exposure, incidental soil ingestion, or inhalation of dust generated from wind or from yard maintenance activities. Residents could also be potentially exposed to radiological contaminants through food chain pathways (uptake of contamination from soil to plants and animals). From the leaching pathway, residents could potentially consume drinking water from a downgradient well, use the well for irrigation of crops and watering livestock, and consume fish raised in a pond filled with water from the downgradient well. The PRGs are calculated using a target cancer risk level of 1×10^{-4}, which is comparable with the cleanup achieved through the interim actions as established by the 100 Area RDR/RAWP (DOE/RL-96-17). An annual dose rate of 15 mrem/yr was used in the 100 Area RDR/RAWP (DOE/RL-96-17) as an RAO for protection of human health, which is approximately equivalent to an increased lifetime cancer risk of 3×10^{-4} for the residential exposure scenario. Table 8-3 presents a summary of the RAGs reported in the 100 Area RDR/RAWP (DOE/RL-96-17) and the PRGs developed for the residential scenario. To satisfy RAOs for protection of human health, the lower of the two values will be selected.

Soil PRG values are developed for the direct-contact and inhalation pathways, combined, using the resident Monument worker exposure scenario. The resident Monument worker scenario is used to represent reasonably anticipated future land use. This scenario assumes that the resident Monument worker resides on the waste site and spends a fraction of the day there, and spends the remaining fraction of the same day in a region as large as an individual ROD decision area and potentially as large as the entire River Corridor, conducting worker activities. The PRG value represents the concentration of soil the resident Monument worker is exposed to on the waste site. An adult could potentially be exposed to site contaminants in shallow vadose zone material from the waste site through direct external exposure, incidental soil ingestion, and inhalation of dust in ambient air. PRG values for individual radioisotopes are based on an ELCR of 1×10^{-4}. The PRG values listed in Table 8-3 for this exposure scenario are provided for additional consideration.

Soil PRG values are also developed for the direct-contact and inhalation pathways, combined, using the casual user exposure scenario. The casual recreational user scenario is a site-specific scenario representing occasional recreational use that focuses on activities such as walking and picnicking in areas

along the Columbia River where paths and benches are likely to exist. Adults and children could potentially be exposed to site contaminants in shallow vadose zone material along the river through direct external exposure, incidental ingestion, and inhalation of dust in ambient air. PRG values for individual radioisotopes are based on an ELCR of 1×10^{-4}. The PRG values listed in Table 8-3 for this exposure scenario are provided for additional consideration.

Ecological Exposure. BCGs are proposed for use as ecological PRGs for radionuclides for terrestrial plants and animals (including soil invertebrates). A discussion of the application of BCGs to radionuclide toxicity data is presented in Section 7.3. BCGs are also evaluated at the SMDP and population basis for decisions. Additional evaluation may be conducted where biological exposures exceed BCGs.

8.1.4.4 Soil Concentrations Protective of Groundwater and Surface Water PRGs

Modeling was conducted to assess the fate and transport of contaminants in the vadose zone and their potential impacts on groundwater or surface water. One-dimensional numerical simulations were constructed to represent the key factors of the conceptual model for 100-BC using the STOMP code (*STOMP: Subsurface Transport Over Multiple Phases Version 2.0: Theory Guide* [PNNL-12030]). Modeling with STOMP was performed with different waste distributions, recharge scenarios, and stratigraphic columns that represented the range of conditions expected within 100-BC. Constituents that were persistent (i.e., do not degrade or decay in a reasonable time frame) and that had a peak concentration in groundwater occurring within 10,000 years in the future were evaluated.

PRGs were calculated for COCs assuming that the contaminant source was uniformly distributed through the entire vadose zone thickness beneath the backfill for contaminants with a K_d less than 2. The contaminant source was uniformly distributed in the upper 70 percent of the vadose zone thickness beneath the backfill for contaminants with a K_d greater than or equal to 2. The recharge rates are representative of reestablishment of the native xerophytic plant communities (Table 8-3). This set of assumptions is referred to as the 100:0 and 70:30 base case scenarios, as described in Section 5.6.

8.1.4.5 Groundwater and Surface Water PRGs

A groundwater risk assessment was presented in Section 6.3 of this report. The list of COCs presented in Table 8-4 was determined in Section 6.3 Contaminants with EPCs greater than or equal to the DWS, federal or state water quality standard, or calculated cleanup levels per the MTCA "Groundwater Cleanup Standards" (WAC 173-340-720) were retained as COCs. Those with EPCs less than the DWS, federal or state water quality standard, or federal MCL, federal or state water quality standard, or calculated cleanup levels per the MTCA "Groundwater Cleanup Standards" (WAC 173-340-720) were not carried forward as COCs. Based on the results of this evaluation, the list of COCs includes strontium, strontium-90, tritium, and Cr(VI).

8.2 General Response Actions

GRAs consistent with RAOs were identified for 100-BC. GRAs are basic actions that might be undertaken to remediate a site or prevent exposure to contaminants and are assembled based on the CSM and the nature and extent of contamination, as presented in Chapter 4. For each GRA, several possible remedial technologies may exist, which can be further divided into a number of process options. This section discusses the remedial technology selection and screening process.

Potential remedial technologies are selected for evaluation based on their ability to mitigate the identified risks or achieve compliance with the ARARs for the remedial action. Technologies and process options selected for evaluation are assessed with respect to their implementability, effectiveness, and relative cost in accordance with CERCLA RI/FS Guidance (EPA/540/G-89/004) and NCP "Remedial Investigation/

Feasibility Study and Selection of Remedy" (40 CFR 300.430(e). The selected final remedy must comply with ARARs and protect human health and the environment.

CERCLA RI/FS Guidance (EPA/540/G-89/004) suggests development and evaluation of a range of responses, including a no action alternative, to ensure identification and selection of an appropriate remedy. The technology screening process consists of the following steps:

- Identify GRAs that may meet RAOs, either individually or in combination with other GRAs
- Identify, screen, and evaluate remedial technology types for each GRA
- Select representative process option(s)

Following the technology screening, representative process options are assembled into remedial alternatives (presented in Chapter 9) that are evaluated further in the detailed and comparative analyses of alternatives (presented in Chapter 10).

GRAs identified for contaminated soil in 100-BC are as follows:

- No action
- Institutional controls
- MNA
- Containment
- Removal, ex situ treatment, and disposal
- In situ treatment

GRAs identified for contaminated groundwater in 100-BC are as follows:

- No action
- Institutional controls
- MNA
- Pump-and-treat (collection, ex situ treatment, and discharge)
- In situ treatment
- Containment

8.2.1 Target Remediation Areas

In accordance with CERCLA RI/FS Guidance (EPA/540/G-89/004), the FS is required to determine the areas or volumes of media to which general response actions might be applied. This section summarizes the waste site and groundwater areas that will be evaluated in the FS, based on the findings of the HHRA, ERA, and RI presented in Chapters 4 through 7.

8.2.1.1 Waste Sites

As discussed previously in Chapter 1, the determination on which areas within 100-BC represent waste sites was performed following specific procedures defined in the 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039) and associated TPA documents (TPA [Ecology et al., 1989a]; TPA Action Plan [Ecology et al., 1989b]). The areas suspected to be waste sites are identified and tracked in the WIDS database. As information is learned about each site, or as they are remediated and confirmation data are collected, they are classified depending on their status.

Of the140 waste sites in the WIDS database for 100-BC, 10 were carried forward into the FS. The status of the 100-BC waste sites is summarized in Table 8-5. Waste sites excluded from the FS included those

that were appropriately closed, not accepted or rejected (35 sites), and sites identified for no further action (92). The locations of these first two groups of sites are shown on Figure 8-1. Sites identified for no further action included those that met PRGs for protection of human health and the environment (65 sites), sites that fail groundwater/surface water protection soil screening levels (6), sites that exceed HH PRGs for direct contact with contaminated soil present at depths below 4.6 m (15 ft) (25 sites), and the River Outfall Pipeline (1). Also excluded from the FS were sites to be remediated under interim actions that achieve final PRGs before ROD signature (2 sites).

In addition, the 105-C Reactor at 100-BC (Waste Site 118-C-3) is not discussed in the FS. In September 1993, DOE issued the NEPA Reactor Decommissioning ROD (58 FR 48509) that established a path forward for the Hanford Site reactors. An "Amended Record of Decision for the Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, WA" (75 FR 43158) was issued in July 2010. The NEPA Reactor Decommissioning ROD (58 FR 48509) provided options for immediate dismantlement for reactor decommissioning, and one-piece disposal of the reactor cores after an ISS period of approximately 75 years, which allowed for decay of the radionuclide that presented the major risk for site workers. As detailed in Cleanup Completion Framework (DOE/RL-2009-10), the NEPA Reactor Decommissioning ROD (58 FR 48509) indicated DOE's intent to complete these decommissioning actions consistent with the proposed cleanup schedule for remedial actions, which includes the 105-C Reactor at 100-BC. Until reactor removal is complete, DOE will continue to conduct routine maintenance, surveillance, and radiological monitoring activities to ensure continued protection of during the ISS period. There are no sites near the 105-C reactor that cannot be remediated because of their location near the reactor. The 105-B Reactor, which was designated a national historic landmark, has three associated sites that are evaluated in the FS.

Six sites exceed groundwater/surface water protection soil screening levels (Table 8-5). These sites do not pose a threat to groundwater or surface water as long as no-irrigation controls are implemented at the sites. Therefore, DOE or the federal government will maintain controls on the land to prevent leaching of these materials. For this reason, no further technology application is required for the sites. No further evaluation of these six waste sites is presented in the FS.

There are 25 sites that exceed HH PRGs for direct contact with contaminated soil present at depths below 4.6 m (15 ft). The locations of these waste sites are shown on Figure 8-2. These sites do not pose a threat to human health because the exposure pathway is incomplete under MTCA-RME assumptions ("Human Health Risk Assessment Procedures" [WAC 173-340-708]) and the MTCA definition for standard point of compliance. Under MTCA regulations ("Remedial Investigation and Feasibility Study" [WAC 173-340-350(8)(a)]), "If concentrations of hazardous substances do not exceed the cleanup level at a standard point of compliance (4.6 m [15 ft]), no further action is necessary." The rough order of magnitude cost to excavate and remove the contaminants at these sites is estimated at $366 million. However, the contaminants at these sites will decay to activity levels less than residential RBSLs by the dates presented in Table 8-6. During this time, DOE or the federal government will maintain controls on the land to prevent exposure to these materials. For this reason, no further technology application is required for the sites. No further evaluation of these 25 deep exposure waste sites is presented in the FS.

Table 8-5. Summary of 100-BC Waste Site Status

100-BC Waste Sites – 140 Total		NUMBER OF WASTE SITES FOR FURTHER EVALUATION	
Sites not carried in FS. (35) **Site Correctly Classified as Closed, Not Accepted, or Rejected, or Off-ramped based on site specific considerations. (34)** 100-B-10, 100-B-12, 100-B-14:4, 100-B-17, 100-B-2, 100-B-21:1, 100-B-24, 100-B-29, 100-B-3, 100-B-30, 100-B-4, 100-B-7, 100-C-2, 100-C-4, 100-C-5, 100-C-8, 118-B-7, 124-C-4, 126-B-1, 126-B-2, 126-B-4, 128-B-1, 1607-B3, 1607-B4, 1607-B6, 600-230, 600-231, 600-252, 600-253, 600-264, 600-33, 600-34, 600-56, 600-67 **Reactor Core Safe Storage Enclosure (1)** 118-C-3:1	Evaluate Based on Waste Site Status / Tank Removal / Reactor Site Chapter 1	105	REMEDIAL INVESTIGATION
Sites Identified for No Further Action (92) **Sites Passing Initial Screening for Groundwater/Surface Water Protection, Human Health Risk Assessment, and Ecological Risk Assessment. (62)** 100-B-11, 100-B-14:3, 100-B-14:5, 100-B-14:6, 100-B-14:7, 100-B-16, 100-B-19, 100-B-20, 100-B-21:2, 100-B-21:3, 100-B-22:2, 100-B-23, 100-B-25, 100-B-26, 100-B-27, 100-B-28, 100-B-31, 100-B-32, 100-B-33, 100-C-3, 100-C-9:1, 100-C-9:2, 100-C-9:3, 116-B-10, 116-B-12, 116-B-13, 116-B-15, 116-B-6B, 116-B-7, 116-B-9, 116-C-6, 118-B-10, 118-B-2, 118-B-3, 118-B-4, 118-B-5, 118-B-9, 118-C-2, 118-C-3:3, 118-C-4, 120-B-1, 126-B-3, 128-B-2, 128-B-3, 128-C-1, 132-B-1, 132-B-3, 132-B-4, 132-B-6, 132-C-1, 132-C-2, 132-C-3, 1607-B1, 1607-B10, 1607-B11, 1607-B2:1, 1607-B2:2, 1607-B7, 1607-B8, 1607-B9, 600-232, 600-233 **Sites that Fail Groundwater/Surface Water Protection Soil Screening Levels. Require No Irrigation ICs. (4)** 100-B-1, 100-B-14:2, 100-B-18, 116-B-14, 116-B-4*, 118-C-1* **Sites where the Direct Exposure Pathway is Incomplete. These are deep zone radionuclide sites with deep contamination only. Require No Dig ICs. (25)** 100-B-14:1, 100-B-21:4, 100-B-5, 100-B-8:1, 100-B-8:2, 100-C-6:1, 100-C-6:2, 100-C-6:3, 100-C-6:4, 116-B-1, 116-B-11, 116-B-16, 116-B-2, 116-B-3, 116-B-4*, 116-B-5, 116-B-6A, 116-C-1, 116-C-2A, 116-C-2B, 116-C-2C, 116-C-3, 116-C-5, 118-C-1*, 118-C-3:2 **River Pipelines (1)** 100-B-15	Evaluate in Chapters 5, 6, 7, and 8	13	
Sites to be Remediated under Interim Action. These sites are currently under remediation and/or no future remediation is being assumed. They are included in the FS. (2) 100-C-7, 100-C-7:1	Assume Interim Actions Achieve Required Standards		FEASIBILITY STUDY
Part of the B Reactor Museum, but not included in the NEPA ROD. Two of the three sites are included in FS (3) 118-B-8:2, 118-B-8:3, 132-B-2	**Develop Remedial Action Alternatives and Cost Estimates to Achieve Final Cleanup**		
Sites Remaining for Remedial Action. These are under active utilities. They are included in the FS. (2) 100-B-34, 1607-B5			
Sites Evaluated in the FS. (6) 100-B-22:1, 100-C-9:4, 118-B-1, 118-B-6, 118-B-8:1, 132-B-5			

*The waste site is accounted for in more than one category (116-B-4, 118-C-1).

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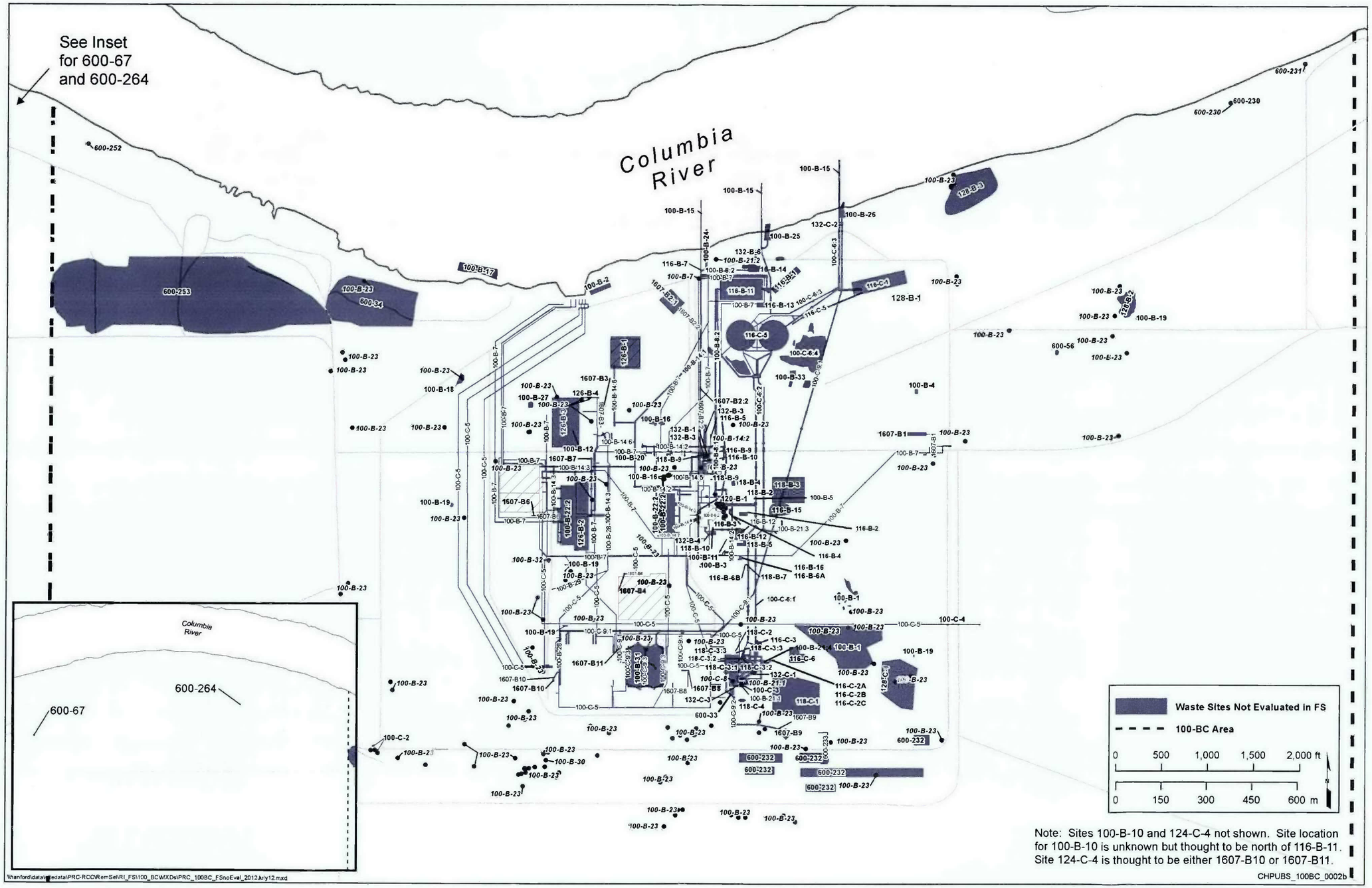

Figure 8-1. 100–BC Sites Not Evaluated in the Feasibility Study

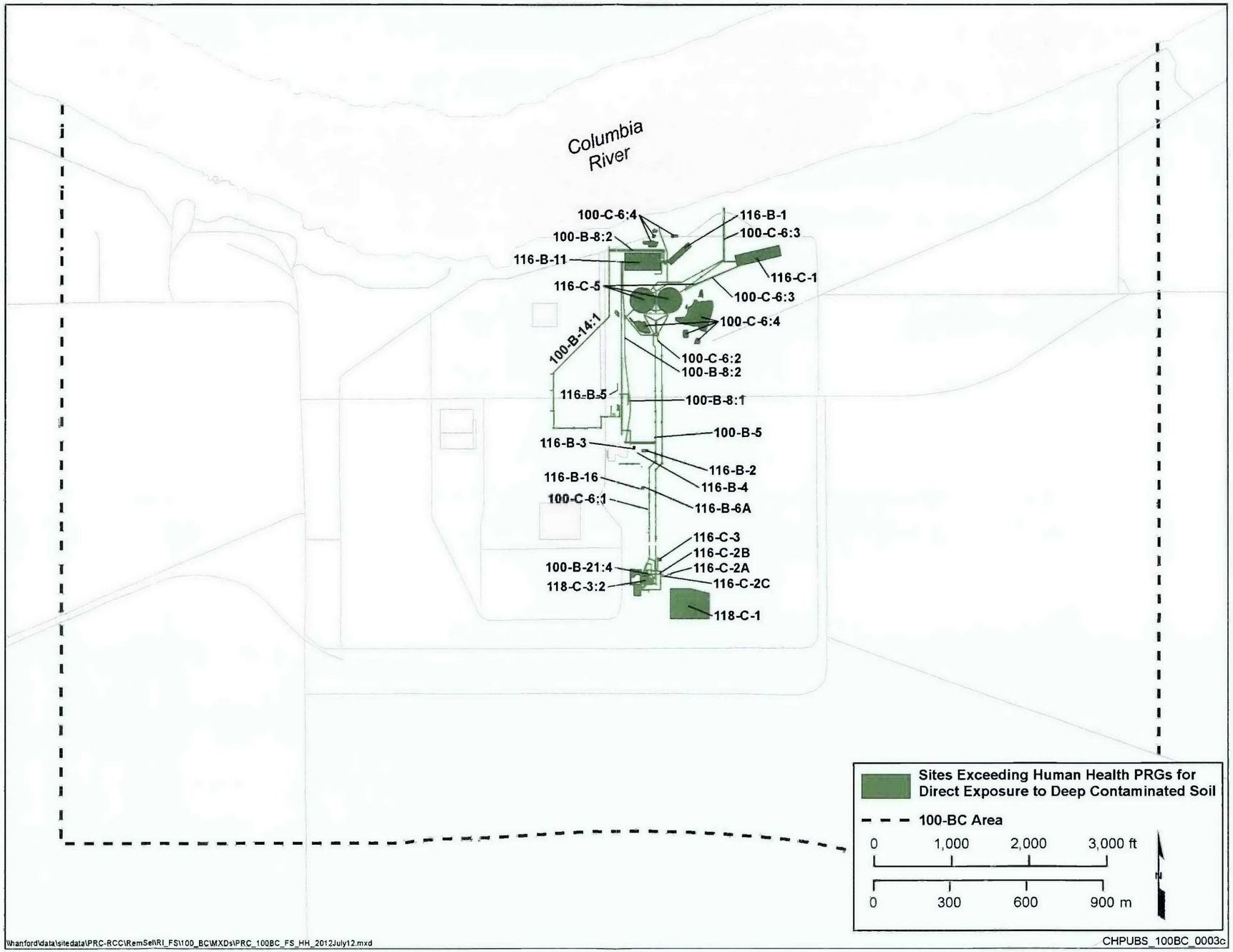

Figure 8-2. 100-BC Sites Exceeding Human Health PRGs for Direct Contact with Deep Contaminated Soil

Table 8-6. Time frame for Decay to Residential RBSLs of Deep Zone Soil Concentrations at 100-BC Waste Sites

Waste Site	Sample Collection Date	Risk Driver	Endpoint Concentration (pCi/g)	Residential PRGs	Year When EPC < Residential PRG
100-B-5	5/7/2003	Cesium-137	2.24E+01	4.40E+00	2073
100-B-14:1	9/21/2006	Carbon-14	2.75E+02	8.10E+01	12110
100-B-8:1	11/19/2003	Cesium-137	9.58E+00	4.40E+00	2037
100-B-8:2	7/23/2003	Cesium-137	1.25E+01	4.40E+00	2048
100-B-21:4	8/31/2009	Cesium-137	8.02E+00	4.40E+00	2035
100-C-6:1 (included with 100-B-8:1)	11/19/2003	Cesium-137	9.58E+00	4.40E+00	2037
100-C-6:2 (included with 100-B-8:2)	7/23/2003	Cesium-137	1.25E+01	4.40E+00	2048
100-C-6:3 (included with 100-B-8:2)	7/23/2003	Cesium-137	1.25E+01	4.40E+00	2048
100-C-6:4 (included with 100-B-8:2)	7/23/2003	Cesium-137	1.25E+01	4.40E+00	2048
116-B-1	2/1/1999	Europium-152	7.08E+00	3.66E+00	2012
116-B-11	11/20/1998	Nickel-63	2.70E+03	6.05E+02	2205
116-B-16 (included with 116-B-6A)	6/2/1999	Strontium-90	2.11E+01	2.27E+00	2093
116-B-2	6/7/1999	Cesium-137	4.72E+01	4.40E+00	2102
116-B-3	5/4/1999	Cesium-137	1.97E+01	4.40E+00	2064
116-B-4	4/29/1999	Cesium-137	1.12E+02	4.40E+00	2139
116-B-5	7/7/1995	Europium-152	9.95E+00	3.66E+00	2014
116-B-6A	6/2/1999	Strontium-90	2.11E+01	2.27E+00	2093
116-C-1	1/6/1998	Cesium-137	5.69E+03	4.40E+00	2308
116-C-2A	6/16/1999	Cesium-137	2.30E+01	4.40E+00	2071
116-C-2B (included with 116-C-2A)	6/16/1999	Cesium-137	2.30E+01	4.40E+00	2071

Table 8-6. Time frame for Decay to Residential RBSLs of Deep Zone Soil Concentrations at 100-BC Waste Sites

Waste Site	Sample Collection Date	Risk Driver	Endpoint Concentration (pCi/g)	Residential PRGs	Year When EPC < Residential PRG
116-C-2C (included with 116-C-2A)	6/16/1999	Cesium-137	2.30E+01	4.40E+00	2071
116-C-3	12/26/2007	Strontium-90	1.41E+01	4.40E+00	2094
116-C-5	1/25/1999	Cesium-137	5.20E+01	4.40E+00	2106
118-C-1	9/12/2006	Carbon-14	1.82E+02	8.10E+01	8698
118-C-3:2	3/12/1998	Cesium-137	171	4.40E+00	2156

The two sites to be remediated under interim actions are currently being remediated under the 100 Areas Remaining Sites ROD (EPA/ROD/R10-99/039) with the remedial action anticipated to be complete by the time the ROD is signed. The locations of the sites to be remediated under interim actions are shown on Figure 8-3. These sites will be evaluated against the PRGs once the sites achieve interim closed status and the CVP data are available for risk evaluations. For this FS, it is assumed these sites will meet PRGs and the criteria for no further action met. If the sites fail to meet PRGs, they will be managed based on the identified risk drivers and the sites addressed as waste sites remaining for remedial action.

The basis for action for the 10 waste sites carried into the FS is summarized in Table 8-7. These waste sites fall into four different categories:

1. **Waste sites remaining for remedial action (two sites).** The interim actions planned for these two waste sites (100-B-34 and 1607-B5) will not be completed before ROD signature. Sites 100-B-34 and 1607-B5 are located under active utilities, which preclude conducting interim actions. Based on process knowledge and analogous site data, these sites need to be included in the FS. Therefore, the two sites will be remediated on a post-ROD basis. The locations of the waste sites remaining for remedial action are shown on Figure 8-4.

2. **Human health PRG exceedances (two sites).** Waste sites in this group exceed human health PRGs from direct contact with COCs present in shallow soil (<4.6 m [15 ft] bgs). This group includes the 118-B-1 and 118-B-8:1 waste sites where radionuclide contamination was identified above human health PRGs. The locations of the sites that exceed human health PRGs for direct exposure to shallow contaminated soil are shown on Figure 8-5.

3. **Surface and/or Groundwater Protection PRG exceedances (two sites).** The two waste sites in this group, 118-B-1 and 118-B-6, exceed the surface water and groundwater protection PRGs for tritium. The location of these sites is shown on Figure 8-6. Site 118-B-1 is also included with the sites that exceed human health PRGs from direct contact with COCs present in shallow soil (<4.6 m [15 ft] bgs).

4. **Allowable Residual Contamination Level, Special, and Reactor Museum sites (two sites).** Six allowable residual contamination level (ARCL) sites were remediated previously under the 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039). The remedy for these six sites consisted of demolishing the support facility structure and placing the demolition debris in trenches that were subsequently covered with clean overburden. The Tri-Party regulatory agencies have requested that

these sites be re-evaluated in the FS because the completed remedial action relies on shielding provided by the overburden to meet RAOs. One of the six ARCL sites, 132-B-5, contains residual contamination that exceeds the HH exposure criteria for direct contact with the debris and is included in the FS. The special waste sites consist of two pipeline sites, 100-B-22:1 and 100-C-9:4, which contain residual contamination on the interior pipe surfaces. These waste sites do not pose a threat to human health and the environment in their current configuration. However, if the sites were exposed or removed in the future, because of a construction activity or other event, the excavated debris/material would need to be managed as potentially hazardous. There are three waste sites associated with the 105-B Reactor Museum. Two of the three waste sites, 118-B-8:3 and 132-B-2, contain residual contamination on their interior surfaces and are included in the FS. The third site associated with the 105-B Reactor Museum, 118-B-8:2, was eliminated from the FS based on data from an analogous site at the 105-C Reactor. The locations of the ARCL, Special, and Reactor Museum waste sites included in the FS are shown on Figure 8-7.

8.2.1.2 Groundwater

Areas exceeding groundwater PRGs are where the concentrations of one or more groundwater contaminants exceed their respective MCLs or other water quality standard. Figures 4-23, 4-27, and 4-30 illustrate the groundwater contaminant plumes for Cr(VI), strontium-90, and tritium at 100-BC. The plume boundaries shown in the figures are the areas that exceed PRGs and may require additional remediation to meet ARARs.

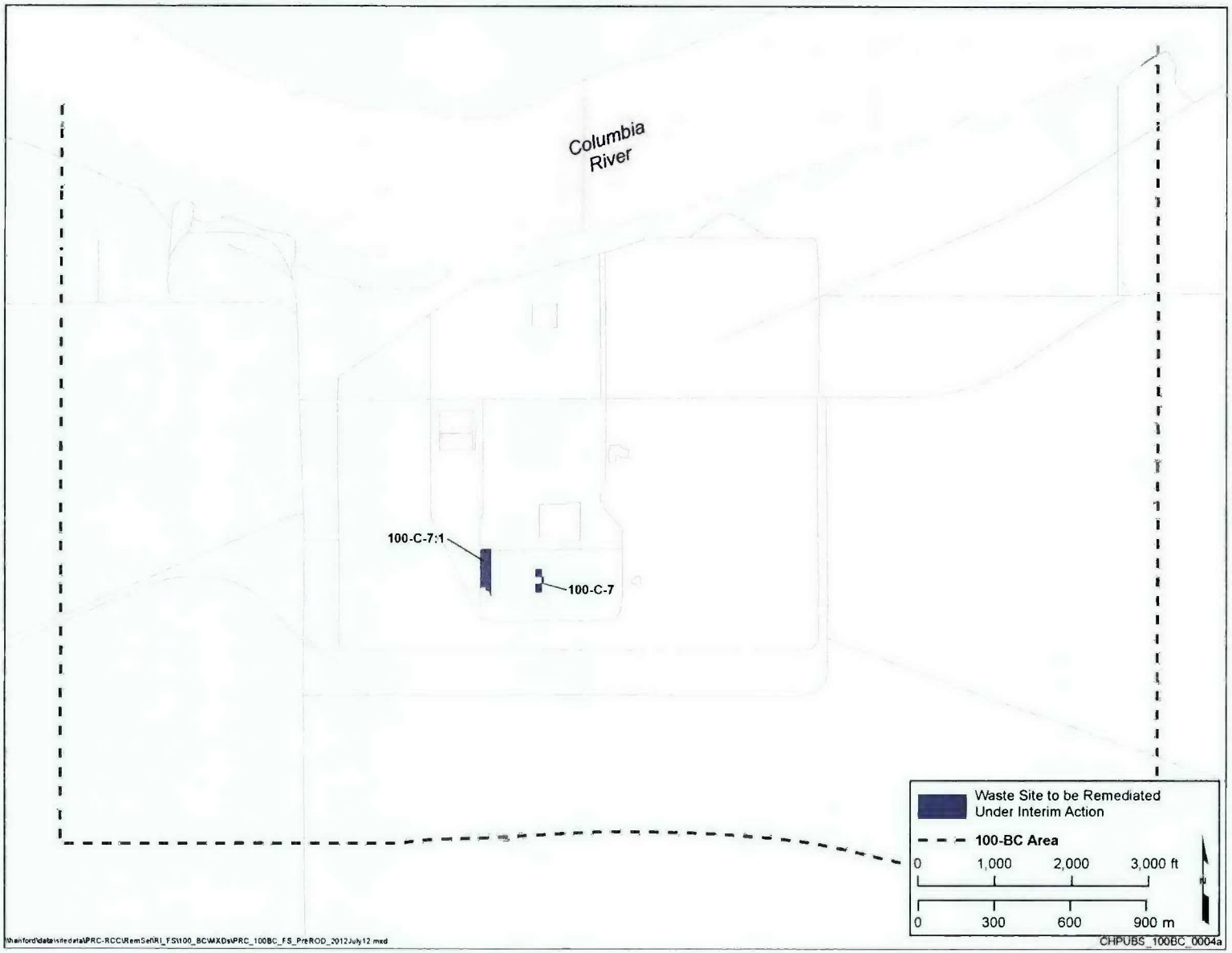

Figure 8-3. 100-BC Waste Sites to be Remediated Under Interim Actions

Table 8-7. Sites Evaluated in Feasibility Study - Basis for Action

Waste Site	WIDS Site Type	Basis for Action	Known or Suspected Contaminants
100-B-22:1	Process Sewer	Special case site. Confirmation sampling needed to confirm the presence of hazardous substances.	Cr(VI)
100-B-34	Radioactive Process Sewer	Site remaining for remedial action. Site does not pose a risk in its current configuration but may if pipelines are exposed at the surface.	Radionuclides, Chromium (total), Cr(VI), Mercury, and Lead
100-C-9:4	Process Sewer	Special case site. Site does not pose an unacceptable risk in its current configuration but may if the pipelines are exposed at the surface.	Cr(VI)
118-B-1	Burial Ground	Human health direct contact risk in shallow soil (less than 4.6 m [15 ft] bgs. Waste site soil exceeds the surface water and groundwater protection PRGs for tritium.	Strontium-90, Tritium
118-B-6	Burial Ground	Waste site soil exceeds the surface water and groundwater protection PRGs for tritium.	Tritium
118-B-8:1	Reactor, Fuel Storage Basin	Human health direct contact risk in shallow soil (less than 4.6 m [15 ft] bgs.	Strontium-90, Cesium-137
118-B-8:3	Reactor, Process Sewer	Pipeline site and part of the B Reactor National Historic Monument. Site does not pose an unacceptable risk in its current configuration but may if the pipelines are exposed at the surface.	Radionuclides, Metals
132-B-2	Stack	Site is part of the B Reactor National Historic Monument. Contains residual radionuclide contamination on the interior of the stack.	Radionuclides
132-B-5	Process Unit/Plant	Contains radionuclide-contaminated debris associated with facility decommissioning. RESRAD dose assessment calculations included an allowance for 1 m (3.3 ft) of clean soil over debris.	Radionuclides
1607-B5	Septic Tank	Site remaining for remedial action. Remediation required in accordance with the interim action ROD.	Metals, Polycyclic Aromatic Hydrocarbons

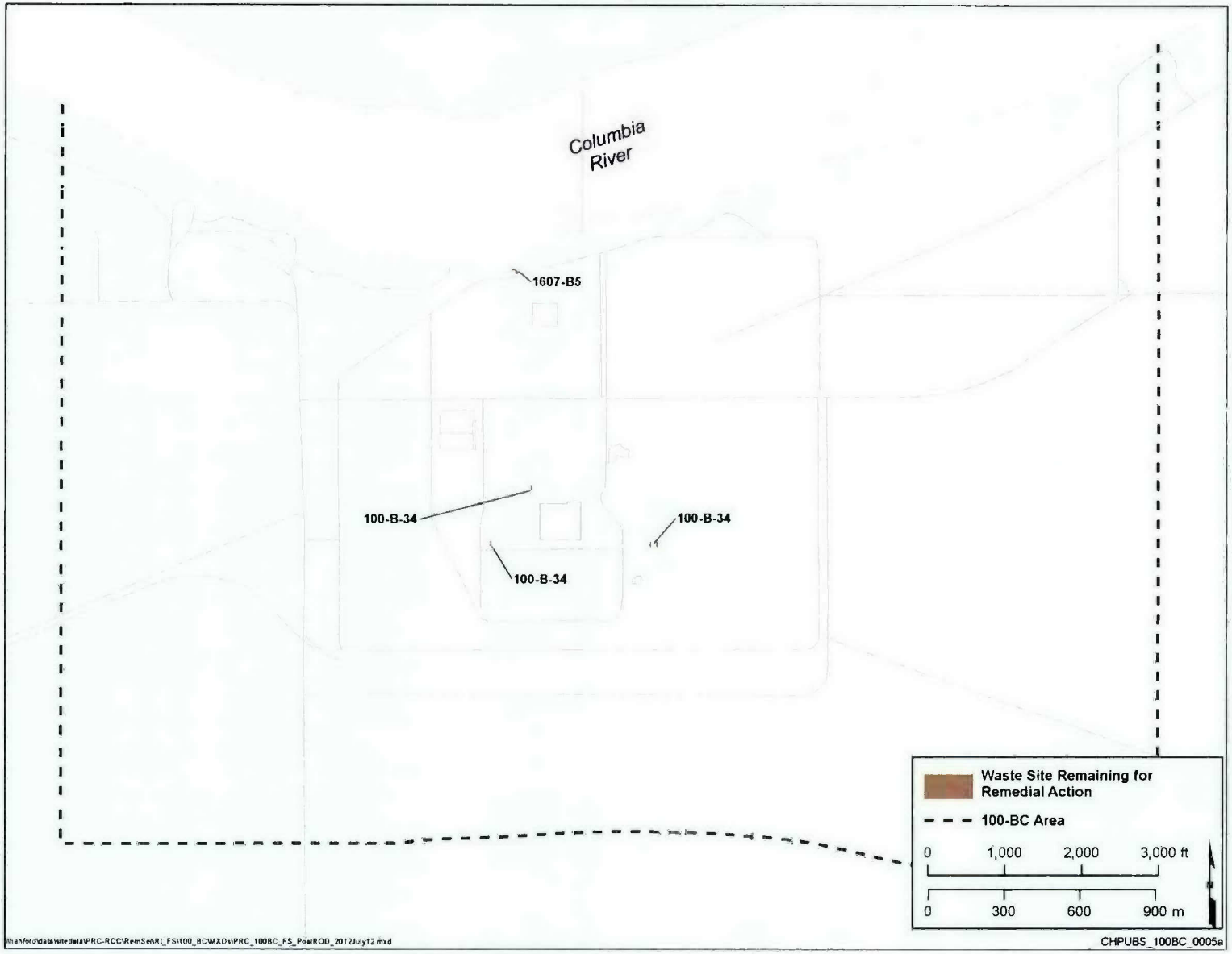

Figure 8-4. 100-BC Sites Remaining for Remedial Action

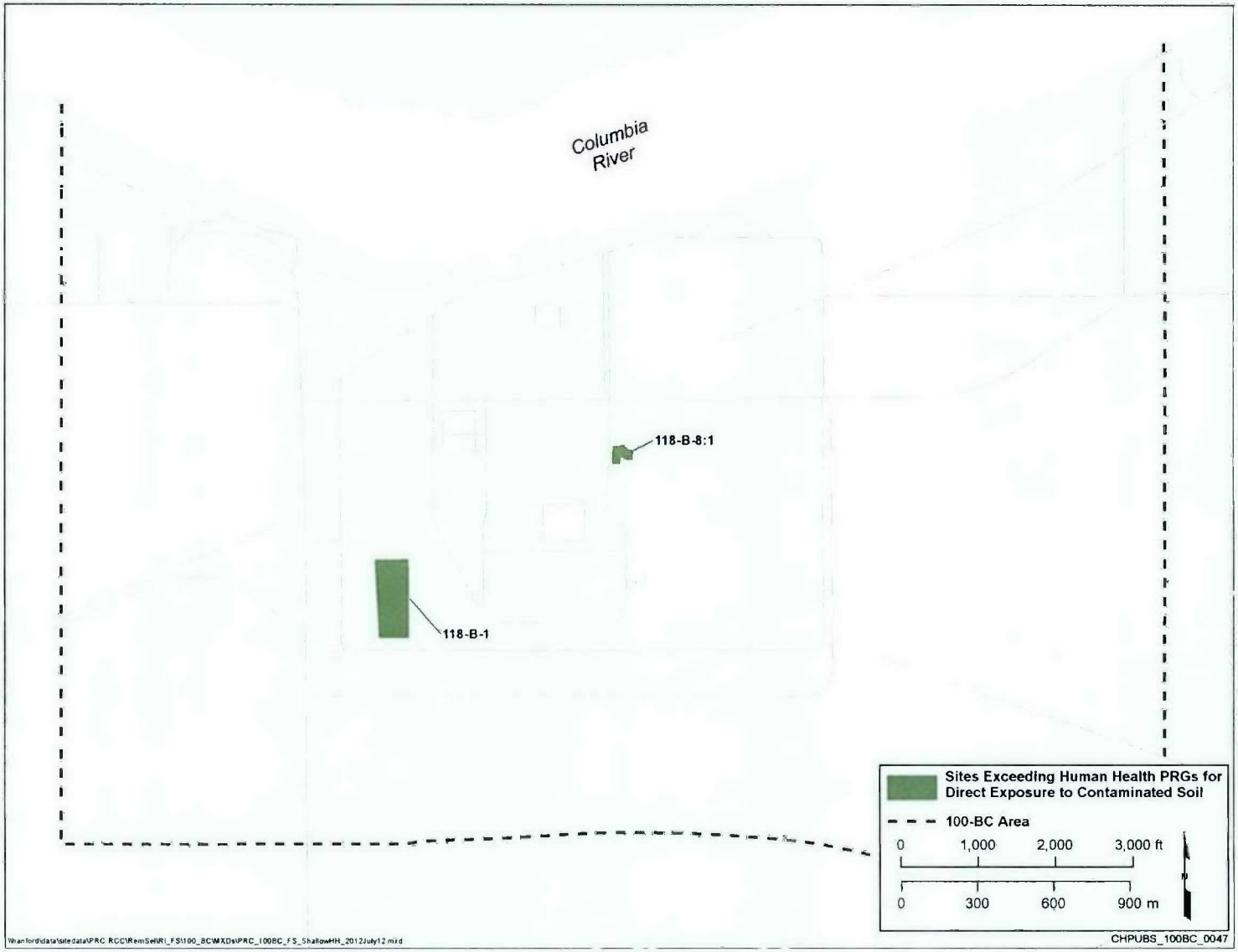

Figure 8-5. 100-BC Sites Exceeding Human Health PRGs for Direct Contact with Shallow Contaminated Soil

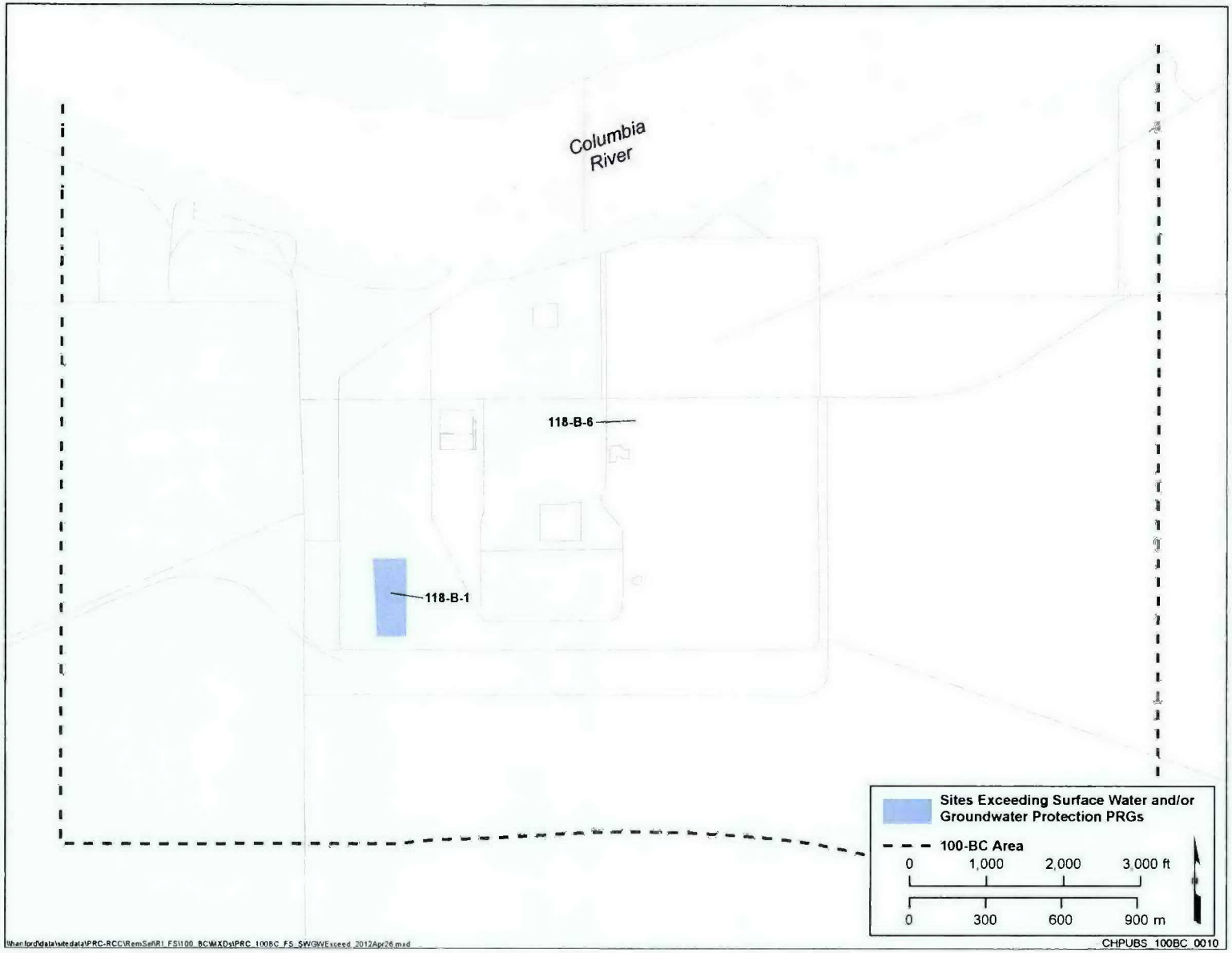

Figure 8-6. 100-BC Sites Exceeding Surface Water and and/or Groundwater Protection PRGs

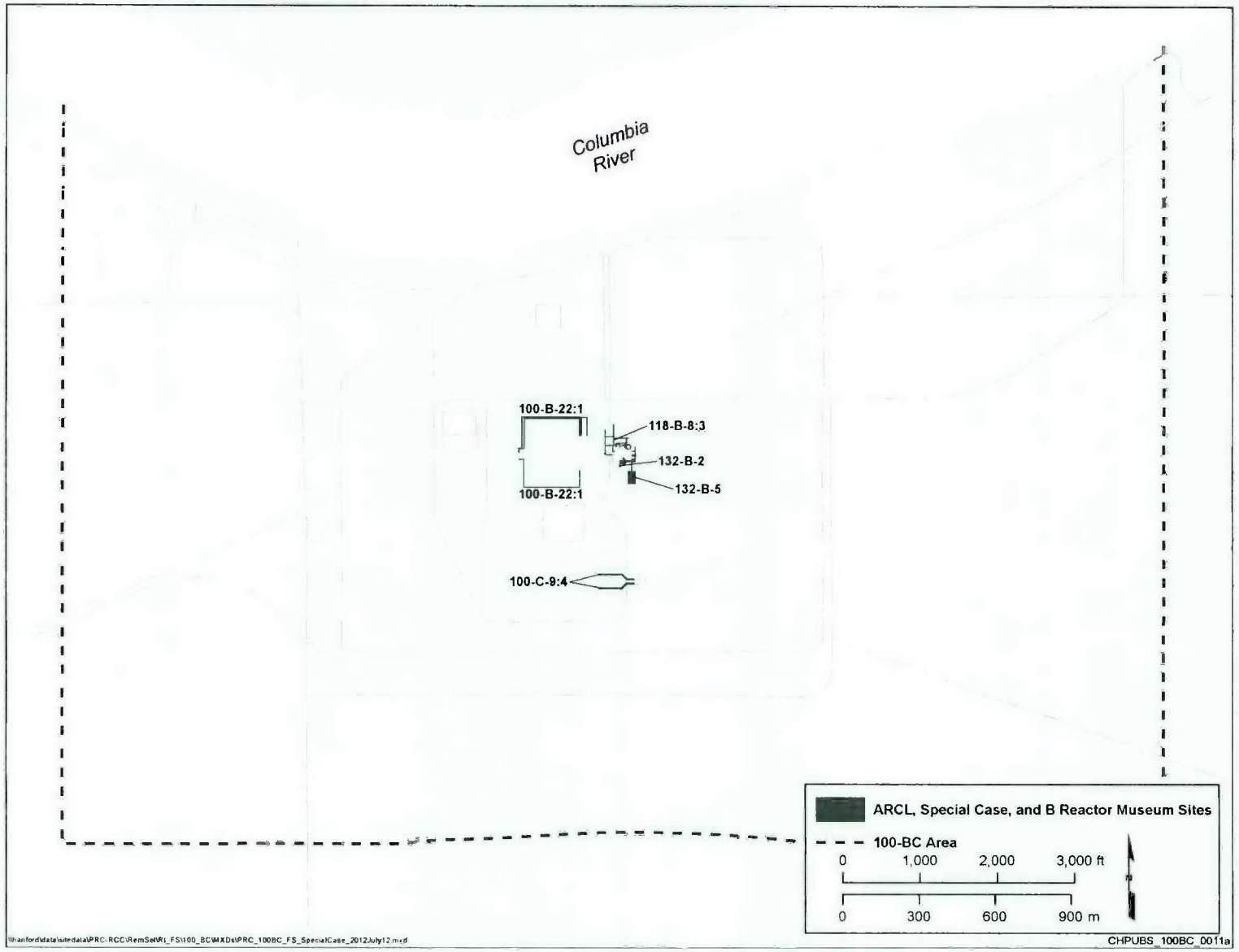

Figure 8-7. 100-BC ARCL, Special Case, and B Reactor Museum Sites

8.3 Identification and Screening of Technology Types and Process Options

This section presents remedial technologies and process options that are subsets of the selected GRAs, and that may potentially meet RAOs for contaminated soil and groundwater at 100-BC. The potential remedial technologies were evaluated and screened for implementability, effectiveness in eliminating, reducing, or controlling risks to human health and the environment, and relative cost. The identified technologies were then combined into a range of remedial alternatives in Chapter 9.

8.3.1 Identification and Screening of Technologies

Tables 8-8 and 8-9 present the identification and screening of technologies and remedial process options for 100-BC in tabular form. Table 8-8 presents technologies for vadose zone treatment for radionuclides, Cr(VI), other metals, and organic compounds. Technologies effective for COCs specific to 100-BC (Table 8-1) are presented, in addition to the applicability of these technologies for other contaminants. Table 8-9 present GRAs and process options for groundwater impacted with Cr(VI) and radionuclides.

The following text summarizes the technologies and process options considered as part of this evaluation. Although no action, institutional controls, and MNA are not considered remedial technologies, they are important response actions to be considered as part of the remediation approach, and discussed herein. Appendix I provides a thorough discussion of the technologies not retained. This appendix presents a description of the technology, followed by a description of relevant case studies and the screening rationale. The technology-specific fact sheets and Chapter 9 present information on technologies retained as part of the description of alternatives.

8.3.1.1 Identification and Screening of Technologies for Vadose Zone

No Action. The no action response means any further action to remove, remediate, monitor, or restrict access to contaminated sites is discontinued. Source areas and residual contaminants in the waste sites would be left untreated and current monitoring activities would cease. The CERCLA RI/FS Guidance (EPA/540/G-89/004) and the NCP (40 CFR 300) require this response to remain in the FS process, where it serves as a baseline against which to compare all other alternatives. Although generally considered unacceptable as a remedial alternative, no action may be an appropriate alternative component where interim actions have been completed as dictated by the 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039) and verification sampling data suggest the waste site does not present risks to HHE.

Institutional Controls. Institutional controls are nonengineered instruments, such as administrative and/or legal controls, that help to minimize the potential for human exposure to contamination and/or protect the integrity of a remedy. Institutional controls work by limiting land or resource use and/or by providing information that helps modify or guide human behavior at the site. The requirements for ICs are evaluated in the FS and recorded in CERCLA decision documents. The decision document is part of the Administrative Record for the selection of remedial actions.

As ICs are identified, DOE will apply and implement them in an integrated manner such that mechanisms in place will ensure controls are effective, implemented as planned, properly maintained, inventoried, periodically re-evaluated, and modified as necessary to reflect changes in conditions, needs, or technological advancements. DOE will maintain the ICs as long as necessary to perform their intended protective purposes and seek sufficient funds ("*Use of Institutional Controls*" [DOE P 454.1]).

Table 8-8. Screening Table—Technologies for Radionuclides, Cr(VI), Other Metals, and Organic Compounds in Waste Sites, Hanford Site River Corridor, 100-BC

General Response Actions	Remedial Technology	Process Option	COPC Applicability[a]	Depth Range[b]	Description	Relative Effectiveness	Relative Implementability	Relative Capital Cost	Relative O&M Cost	Sustainability[c]	Retained/ Not Retained[c]	Screening Comment
No Action	No Action	No Action	All	6 m [20 ft]/ greater than 6 m [20 ft]	No further actions to address contamination. Source areas and residual contaminants in vadose zone are left untreated.	Low/High No remedial actions are taken, but effectiveness could be high if risk is previously mitigated.	High No administrative or technical implementability challenges are associated with implementation of this option, since no actions are required.	Low No associated cost	Low No associated cost	Little impact	Retained	Retained per the NCP (40 CFR 300).
Monitoring	MNA	MNA	Radionuclides with reasonable half-lives. Select organic compounds	6 m [20 ft]/ greater than 6 m [20 ft]	Contaminants in the vadose zone are allowed to attenuate over time from natural biological processes, chemical processes, radioactive decay, and/or flushing from surface water infiltration. Rates of flushing must be low enough that groundwater standards are not exceeded. Involves ongoing monitoring to verify attenuation processes are occurring. Contingency measures are developed if attenuation is not adequate to control the risks. Typically combined with other technologies that manage the source areas and mitigate exposure.	Moderate/High Effectiveness of MNA is driven by the state of the existing site-specific intrinsic processes, given that under MNA, natural processes are not enhanced. Effectiveness is evaluated and documented through long-term monitoring and evaluation of geochemical conditions. Contaminant leaching into groundwater may be an acceptable component of the vadose zone remedy if the resultant dissolved contaminant concentrations still meet the groundwater cleanup criteria.	High No administrative or technical implementability challenges are associated with implementation of this option.	Low	Low	Little impact	Retained	
Removal	Excavation	Standard Excavation	All	6 m [20 ft]	Shallow soil in identified source areas is removed using conventional construction equipment. Excavation limited to approximately 6 m (20 ft) bgs. Excavated soil is segregated (automated or laboratory based) to determine disposal or treatment requirements.	High Shallow contaminated soil removed.	High Standard excavation is typically straightforward. An Excavation Permit is required in the 100, 200, and 300 Areas and the Hanford Reach National Monument.	Moderate/High	Low No associated cost	Waste generation if excavated soil is disposed of, GHG and energy for excavation equipment.	Retained	
		Deep Excavation	All	6 m [20 ft]/ greater than 6 m [20 ft]	Soil is removed from depths greater than 6 m (20 ft) bgs. Deep excavation would require implementation of more complex technologies (for example, large lay-back for open-pit type excavation or, alternatively, use of shoring). Excavated soil is segregated (automated or laboratory based) to determine disposal or treatment requirements.	High Locations of the deep sources will be difficult to identify, meaning large areas would have to be excavated to depth to ensure that the deep sources were removed.	Moderate Has been performed at the Hanford Site using lay-backs. Shoring may be difficult with cobbles and boulders. Increased safety issues with very deep excavations. An Excavation Permit is required for excavation in the 100, 200, and 300 Areas and the Hanford Reach National Monument.	High	Low No associated cost	Waste generation if excavated soil is disposed of, GHG and energy for excavation equipment.	Retained	
Ex Situ Treatment	Ex Situ Treatment[d]	Solidification/ Stabilization	Mobile to semimobile contaminants (technetium-99, Cr(VI), strontium-90, and uranium)	Depends on excavation method.	Contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants to reduce their mobility (stabilization). Agents include: soluble phosphates, pozzolan/portland cement, polyethylene extrusion, etc. The stabilized mass is returned to its original location and capped to shed water and prevent weathering, and the location is engineered to withstand seismic activity.	Low/Moderate Effective at immobilizing contaminants in excavated material. However, the stabilized mass must be protected from weathering and seismic activity for long-term durability.	Moderate Well-established technology. Site-specific studies need to be completed to evaluate equipment required and appropriate solidification/stabilization agents. Mechanically intense process; additional handling of the excavated soil could increase the potential for contaminant exposure, which could pose risk to workers.	High	Low	GHG and energy for production and delivery of reagent used, and for transport and mixing.	Not Retained	Screened out in favor of the safer alternative of disposal in the ERDF, a centralized facility engineered to protect against weathering and seismic activity.

Table 8-8. Screening Table—Technologies for Radionuclides, Cr(VI), Other Metals, and Organic Compounds in Waste Sites, Hanford Site River Corridor, 100-BC

General Response Actions	Remedial Technology	Process Option	COPC Applicability[a]	Depth Range[b]	Description	Relative Effectiveness	Relative Implementability	Relative Capital Cost	Relative O&M Cost	Sustainability[c]	Retained/ Not Retained[e]	Screening Comment
Ex Situ Treatment (cont.)	Ex Situ Treatment[d] (cont.)	Soil Washing	Cr(VI), technetium-99, nitrate, and possibly uranium	Depends on excavation method.	Consists of: (1) size separation of highly contaminated soil fractions (fines) from minimally contaminated soil fractions (coarse), followed by (2) mechanical abrasion or washing to remove surface contamination. Final contaminated fraction is typically treated by technologies such as solidification/stabilization before onsite or offsite disposal.	Low/Moderate Effectiveness is driven by the binding processes that exist between the contaminants and the soil particles (adsorbed or precipitated). Pilot testing at the Hanford Site suggests a number of contaminants strongly sorb to all sizes of soil.	Low/Moderate Mechanically intense. Conventional aggregate washing and screening technology is used to separate soil particles by size fraction. Contaminated soil and water are disposed of, or further treated. Soil that meet cleanup criteria (remediated coarse soil) can be returned to the site. Rinseate will need to be treated prior to disposal.	Moderate	Low No associated cost	Additional resource impact (water used in process), GHG and energy for process and additional treatment of contaminated fines and water.	Not Retained	Mechanically intense. Not proven for conditions similar to the Hanford Site.
		Ex Situ Vitrification	All	Depends on excavation method.	Thermal treatment process that converts excavated soil and other materials into glass matrix. The thermal treatment process is typically performed inside a chamber using plasma torches or electric arc furnaces to melt the soil. Organic contaminants are typically destroyed during the process by pyrolysis, while metals and radionuclides are retained in the molten soil.	High Heavy metals and radionuclides are incorporated into the glass structure, which is generally resistant to leaching	Low High complexity of equipment required. Ex situ joule heating vitrification uses furnaces that have evolved from the glass industry. Implementability is higher than for in situ application given use of proven technology (furnaces).	High	Low No associated cost	GHG and energy for heat generation. High energy requirements to sustain required heat.	Not Retained	Complex technology, safety concerns with implementation.
Disposal	Disposal	Backfill Treated Soil	All	6 m [20 ft]/ greater than 6 m [20 ft]	Excavation and ex situ treatment followed by onsite disposal (backfill).	High Contaminated material has been treated by ex situ technologies.	High Excavated and treated soil will need to be compared to cleanup criteria to verify backfill is appropriate.	Low/Moderate	Low No associated cost	GHG and energy for backfill.	Not Retained	No ex situ treatment technologies are retained.
		Disposal to ERDF			Disposal of excavated soil at onsite landfill (ERDF). Treatment is performed at the facility as required to meet land disposal restrictions.	High	High Implementability limited by COPC concentrations and onsite landfill requirements.	Low/Moderate	Low No associated cost	GHG and energy for transport.	Retained	
		Other EPA approved Landfill			Disposal of excavated soil at offsite landfill.	High Contaminated material has been treated by ex situ technologies.	High Implementability limited by COPC concentrations and offsite landfill requirements.	Moderate	Low No associated cost	GHG and energy for transport.	Retained	
In Situ Treatment	In Situ Treatment via Reagent	Reagent Approach: Physical/ Chemical/ Biological — In Situ Solidification	Mobile COCs to semimobile radionuclides, other metals, and organics	6 m [20 ft]	Contaminants are physically bound or enclosed within a stabilized mass. Agents include pozzolan/portland cement and polyethylene extrusion. With organics, typically only used for free phase to reduce mobility.	Low/Moderate There is debate about the long-term durability of the monolith and whether it is in fact permanent. Potential for exposure still exists if waste is shallow.	Moderate Depends on delivery method.	High	Low/Moderate	GHG and energy for production and delivery of substrate/reagent.	Not Retained	Potential for incomplete contact of grout in the targeted treatment zone, and uncertainty regarding the durability of shallow soil encapsulation.
		In Situ Stabilization/ Sequestration	Radionuclides	6 m [20 ft]/ greater than 6 m [20 ft]	Chemical reactions are induced between the stabilizing agent and contaminant to reduce mobility. Agents include soluble phosphates and polyphosphates.	Low/Moderate Potential for direct exposure still exists if waste is shallow.	Low/Moderate Depends on delivery method.	Moderate Depends on delivery method	Low/Moderate Assuming stabilized mass is permanent.	GHG and energy for production and delivery of substrate/reagent.	Not Retained	Uncertainty with uniform phosphate delivery and adequacy in removing risk associated with strontium-90. Not retained in favor of excavation.

Table 8-8. Screening Table—Technologies for Radionuclides, Cr(VI), Other Metals, and Organic Compounds in Waste Sites, Hanford Site River Corridor, 100-BC

General Response Actions	Remedial Technology		Process Option		COPC Applicability[a]	Depth Range[b]	Description	Relative Effectiveness	Relative Implementability	Relative Capital Cost	Relative O&M Cost	Sustainability[c]	Retained/ Not Retained[c]	Screening Comment
In Situ Treatment (cont.)	In Situ Treatment via Reagent (cont.)	Reagent Approach (cont.)	Physical/ Chemical/ Biological (cont.)	Chemical Reduction	Cr(VI), technetium-99, and uranium	6 m [20 ft]/ greater than 6 m [20 ft]	Chemical reductant (e.g., calcium polysulfide, dithionite, hydrogen sulfide gas, ferrous sulfate, zero-valent iron) is applied to the subsurface to treat contaminants within vadose zone. Chemical can be combined with solidification/stabilization or other treatment mechanisms.	Low/Moderate Chemical reductants are instantly reactive, which requires overloading to maintain reactive strength at depth. Reduction of technetium-99 and uranium are potentially reversible.	Moderate Depends on delivery method. Localized temporary generation of secondary byproducts may occur. May temporarily mobilize COPCs toward groundwater. Handling chemical reductants is an H&S concern.	Moderate	Moderate/High	GHG and energy for production and delivery of chemical agent.	Not Retained	More challenging to implement and costly as compared to biological reduction.
				Biological Reduction	Cr(VI), technetium-99, uranium, and nitrate		Biological carbon source (e.g., molasses, sodium lactate, emulsified oil, butane) is applied to the subsurface to treat contaminants within vadose zone.	Moderate/High Carbon source follows source release pathways. Biological reductants are activated by microbial activity, so reactive strength is maintained over relatively longer distances. Reduction of technetium-99 and uranium are potentially reversible.	Moderate Depends on delivery method. Localized temporary generation of secondary byproducts may occur. May temporarily mobilize COPCs (in first pore volume) toward groundwater.	Low/Moderate	Moderate	GHG and energy for production and delivery of substrate. Depends on which substrate is used.	Retained	
				Combined Chemical/ Biological Reduction	Cr(VI), technetium-99, uranium, and nitrate		Chemical reductant (e.g., calcium polysulfide, hydrogen sulfide gas, ferrous sulfate, zero-valent iron) and biological carbon source (e.g., molasses, sodium lactate, emulsified oil) are applied in combination to the subsurface to treat contaminants within vadose zone.	Moderate Amendments follow source release pathways. Combined chemical and biological might improve performance. Reduction of technetium-99 and uranium are potentially reversible.	Moderate Depends on delivery method. Localized temporary generation of secondary byproducts may occur. May temporarily mobilize COPCs (in first pore volume) toward groundwater. Handling chemical reductants is an H&S concern.	Low/Moderate	Moderate	GHG and energy for production and delivery of substrate/reagent. Depends on which substrate is used.	Not Retained	More challenging to implement and costly as compared to biological reduction.
				Gaseous Ammonia Injection	Mobile COPCs	6 m [20 ft]/ greater than 6 m [20 ft]	One of a number of possible gaseous reagents that are being investigated (along with ISGR below). It involves the injection of ammonia gas to increase pH to dissolve silica, The pH naturally decreases to ambient conditions over time and aluminosilicate minerals precipitate and possibly coat and immobilize various contaminants.	Unknown Effectiveness is being studied as part of a laboratory-scale investigation.	Unknown Implementation is unknown at a full-scale level. Containment of injected gases in the shallow vadose zone may be an issue.	Unknown Technology evaluation has been limited to laboratory tests.	Unknown Technology evaluation has been limited to laboratory tests.	GHG emissions from injection activities.	Not Retained	Evaluation of results from the ongoing treatability study is needed before making a decision regarding its full-scale use at the Site. This technology could be evaluated as a remedial alternative later.
				In Situ Gaseous Reduction with Chemical Reductant or Biological Substrate	Cr(VI), technetium-99, uranium, and nitrate		A gaseous mixture of chemical reductants (e.g., hydrogen sulfide) or biological substrate (e.g., butane) is injected into and drawn through the vadose zone to reduce Cr(VI), technetium-99, and uranium. Research is underway to evaluate other reagents to immobilize contaminants.	Unknown Soil heterogeneity will result in preferential flow and limit treatment effectiveness of lower permeability soil. Reductions of technetium-99 and uranium are potentially reversible.	Unknown Vapor extraction wells are installed around injection well at a radial spacing of approximately 4.6 m (15 ft). Large numbers of wells are required. Because of H&S risks, monitoring and emergency response plan are required for transporting, storing, and handling.	Unknown	Unknown	GHG emissions from injection activities.	Not Retained	Evaluation of results from the ongoing treatability study is needed before making a decision regarding its full-scale use at the Hanford Site. This technology could be evaluated as a remedial alternative later.
		Delivery Method	Mixing with Conventional Excavation Equipment		Dependent on type of reagent used	6 m [20 ft]	Use of conventional excavation equipment (backhoes, excavators, front end loaders) to mix amendments into the soil.	High Agents are uniformly mixed with soil column, providing good contact and reaction between COPC and chemical.	Moderate Simple technology. Dust mitigation techniques will need to be implemented to control/prevent mechanical dispersion of contaminants.	Low/Moderate	Low No associated cost	GHG emissions from injection activities.	Not Retained	Not retained in favor of surface infiltration. Could be used if shallow mobile contaminants are identified in the future.

Table 8-8. Screening Table—Technologies for Radionuclides, Cr(VI), Other Metals, and Organic Compounds in Waste Sites, Hanford Site River Corridor, 100-BC

General Response Actions	Remedial Technology		Process Option	COPC Applicability[a]	Depth Range[b]	Description	Relative Effectiveness	Relative Implementability	Relative Capital Cost	Relative O&M Cost	Sustainability[c]	Retained/ Not Retained[e]	Screening Comment
In Situ Treatment (cont.)	In Situ Treatment via Reagent (cont.)	Delivery Method (cont.)	Deep Soil Mixing (Vertical/ Horizontal)	Dependent on type of reagent used	6 m [20 ft]/ greater than 6 m [20 ft]	Large mixing augers (1.5 to 3 m [5 to 10 ft] in diameter) or horizontally rotating heads are used to blend and homogenize reactants with soil. The reactants may be chemical reductants, biological substrate, or solidification/ stabilization agents.	High Chemical agents are uniformly mixed with soil column, providing good contact and reaction between COPC and chemical. Cement or clay can also be mixed with the chemical slurry to reduce the hydraulic conductivity and leachability of the soil.	Low/Moderate Implementation will be more challenging in gravelly/cobbly lithology. Although deep soil mixing has been performed to depths of 30 m (100 ft) bgs, most field applications have been limited to approximately 15 m (50 ft) bgs.	High	Low No associated cost	GHG emissions from machinery.	Not Retained	Deep soil mixing implementability will be limited by site conditions and required depth of treatment.
			Foam Delivery of Reagents	Dependent on type of reagent used	6 m [20 ft]/ greater than 6 m [20 ft]	Injection of a foam into vadose zone. The foam is a mixture of a surfactant solution and a reagent, such as phosphate or calcium polysulfide. The foam increases the horizontal migration of the reagent away from the injection well.	Unknown Technology evaluation has been limited to laboratory-scale tests. The stability of the foam, which will dictate the well spacing, is unknown, as is the ability of the foam to sweep a large volume of the vadose zone.	Unknown Technology evaluation has been limited to laboratory scale tests.	Unknown Technology evaluation has been limited to laboratory scale tests.	Unknown Technology evaluation has been limited to laboratory scale tests.	GHG emissions from well installation, development, and injection activities; waste generation from soil cuttings.	Not Retained	Evaluation of results from the ongoing treatability study is needed before making a decision regarding its full-scale use at the Hanford Site. This technology could be evaluated as a remedial alternative later.
			Gas Delivery of Reagents	Dependent on type of reagent used		A gaseous mixture of chemical reagent is injected into and drawn through the vadose zone to reduce mobile COPCs.	Unknown Soil heterogeneity will result in preferential flow and limit treatment effectiveness of lower permeability soil.	Unknown Vapor extraction wells are installed around injection well at a radial spacing of approximately 4.6 m (15 ft). Large numbers of wells are required. Because of H&S risks, monitoring and emergency response plan are required for transporting, storing, and handling.	Unknown	Unknown	GHG emissions from well installation, development, and injection activities; waste generation from soil cuttings.	Not Retained	Evaluation of results from the ongoing treatability study is needed before making a decision regarding its full-scale use at the Hanford Site. This technology could be evaluated as a remedial alternative later.
			Injection Wells (Horizontal)	Dependent on type of reagent used		Delivery of amendments using horizontal wells. Wells are installed using horizontal drilling techniques.	Low/Moderate Effectiveness can be hindered by nonuniform amendment distribution. Soil heterogeneity will result in preferential flow and limit treatment effectiveness of lower permeability soil. Multiple injections could be required.	Low Implementation is challenging in gravelly/cobbly lithology. Lithology would also pose challenges with maintaining target depth and alignment with horizontal drilling. A pilot test of this technology encountered signification implementation challenges.	Moderate/High	Low	GHG emissions from well installation, development, and injection activities; waste generation from soil cuttings.	Not Retained	Testing at the Hanford Site has not been successful.
			Injection Wells (Vertical)	Dependent on type of reagent used	6 m [20 ft]/ greater than 6 m [20 ft]	Delivery of amendments using conventional vertical wells.	Low/Moderate Effectiveness can be hindered by nonuniform amendment distribution. Distribution of liquid amendments is highly ineffective because of gravelly/cobbly lithology. Distribution in lower-permeability soil can be enhanced with the use of shear-thinning fluids.	Moderate Radius of influence likely to be low, requiring large number of injection wells.	Moderate/High	Low	GHG emissions from well installation, development, and injection activities; waste generation from soil cuttings.	Not Retained	Not retained due to small radius of influence.

Table 8-8. Screening Table—Technologies for Radionuclides, Cr(VI), Other Metals, and Organic Compounds in Waste Sites, Hanford Site River Corridor, 100-BC

General Response Actions	Remedial Technology		Process Option		COPC Applicability[a]	Depth Range[b]	Description	Relative Effectiveness	Relative Implementability	Relative Capital Cost	Relative O&M Cost	Sustainability[c]	Retained/ Not Retained[c]	Screening Comment
In Situ Treatment (cont.)	In Situ Treatment via Reagent (cont.)	Delivery Method (cont.)	Jet Grouting		Dependent on type of reagent used		High-pressure injection of reactive slurry into soil to hydraulically mix the soil with the slurry. Fluidization of the soil is preferred.	Low/Moderate While jet grouting is capable of reaching the required treatment depth, jet grouting is not likely to achieve uniform distribution or a radius of influence greater than an order of 1.5 m (5 ft). Jet grouting of apatite and phosphate was pilot tested at 100-N for shallower and more limited application. Altered/decreased permeability of soil resulted from amendment precipitation and/or liquefaction of fine-grained sediment fractures.	Low/Moderate Implementation will be more challenging in gravelly/ cobbly litholog. Jet grouting has been performed to depths of up to 91 m (300 ft). Many closely spaced injection points (approximately 1.5 m (5 ft) spacing) will be required.	High Limited radius of influence would make jet grouting cost prohibitive over a large area.	Low	GHG emissions from injection activities.	Not Retained	Not retained. Could be considered in the future if technology develops. Currently, jet grouting has potentially limited effectiveness.
			Surface Infiltration		Dependent on type of reagent used		Reagent is applied to ground surface to treat contaminants within vadose zone. Surface infiltration can be done through drip irrigation and shallow basin systems. Systems are generally designed to be 30.5 cm (12 in.). below the surface and covered to be protected.	Moderate/High Amendments follow source release pathways. Distribution not likely to be uniform.	High Surface infiltration systems are simple to install and accessible for O&M.	Low	Low	Limited infrastructure. GHG emissions from production and delivery of substrate.	Retained	Retained for liquid substrates.
			Void-Fill Grouting		Dependent on type of reagent used	N/A (Pipelines)	Grouting for solidification of buried waste. Void grouting is considered for filling large voids, specifically pipelines.	High Established and commonly used technology for removing voids in pipelines.	Moderate/High Established and commonly used technology for removing voids in pipelines. Pipe branch lines/breaks need to be identified. Implementability can be more challenging and costly with long or large diameter pipelines.	Low	Low No associated cost	GHG and energy for production and delivery of grout used.	Retained	Retained for pipelines.
	In Situ Treatment Other		Physical/ Chemical/ Biological	Soil Blending	All	Depends on excavation method.	Contaminated soil is mechanically blended with clean soil or fill to reduce effective contaminant concentrations.	High	High Conventional equipment can be used.	Moderate	Low No associated cost	Waste generation if soil is still disposed of, GHG, and energy for excavation equipment.	Retained	
				Desiccation		Greater than 6 m [20 ft]	Remediation by injecting hot dry air and withdrawing moist air from soil, immobilizing contaminants by preventing their aqueous phase transport.	Unknown A treatability test for this technology will be conducted for waste sites in the Central Plateau contaminated with technetium-99. Theoretically, desiccation would reduce moisture content in the vadose zone. Reduction of COPC migration would be effective until the soil is re-wetted. The technology is not effective in the long term without concurrent infiltration control.	Unknown Implementation requires installation of injection and extraction wells, which are proven technology. However, there is uncertainty related with the number of wells, well spacing, and well configuration details required for optimal field/full-scale implementation. Would also require implementation of infiltration control.	Unknown	Unknown	GHG and energy for air injection. Waste generation from soil cuttings for well installation.	Not Retained	Evaluation of results from the ongoing treatability study is needed before making a decision regarding its full-scale use at the Hanford Site. This technology could be evaluated as a remedial alternative later.

Table 8-8. Screening Table—Technologies for Radionuclides, Cr(VI), Other Metals, and Organic Compounds in Waste Sites, Hanford Site River Corridor, 100-BC

General Response Actions	Remedial Technology	Process Option		COPC Applicability[a]	Depth Range[b]	Description	Relative Effectiveness	Relative Implementability	Relative Capital Cost	Relative O&M Cost	Sustainability[c]	Retained/ Not Retained[e]	Screening Comment
In Situ Treatment (cont.)	In Situ Treatment Other	Physical/ Chemical/ Biological (cont.)	In Situ Vitrification		6 m [20 ft]/ greater than 6 m [20 ft]	Thermal treatment process that converts soil and other materials into stable glass matrix. Contaminants are incorporated into the glass structure, which is generally strong, durable, and resistant to leaching.	High Metals and radionuclides are retained within the treated soil, which is generally resistant to leaching.	Low High complexity of equipment required. Process uses an electric current to melt soil or other earthen materials at extremely high temperatures (1,600 to 2,000°C [2,900 to 3,650°F]). It is important to also account for safety considerations from exposure to high heat.	High	Low No associated cost	GHG and energy for heat generation. High energy requirements to sustain required heat.	Not Retained	Complex and challenging to implement
			Soil Flushing-Vadose Zone, Water	Contaminants with high to moderate solubility (such as Cr(VI), technetium-99, uranium, and nitrate)	6 m [20 ft]/ greater than 6 m [20 ft]	Clean or treated water is applied to the ground surface or in infiltration trenches to flush contaminants out of the vadose zone to the water table, where it is captured/treated.	Moderate Water follows source release pathways, but contaminants that remain in adsorbed phase will not be treated. May create a larger groundwater problem if the groundwater capture is not effective.	High Drip irrigation system or trenches are simple to install and accessible for O&M.	Low/Moderate	Low	GHG and energy for installation	Retained	
			Phytoremediation	Bioavailable metals and organics	6 m [20 ft]	Phytoremediation uses plants and their associated rhizospheric microorganisms to remove, degrade, or contain contaminants.	Low Phytoremediation is only effective when plants are active, thus the technology is not effective during the winter. Phytoremediation only treats soil to the approximate depth of the plant roots, and is only appropriate for low concentrations of contaminants. It is a slow process that is applied over long periods of years or decades. Many metals and radionuclides are only taken up by the plants and not transformed to innocuous forms.	Moderate Involves large land requirements, and considerable work would be required to make a plot of land at the Hanford Site suitable for plant growth. If used to treat contaminants that are merely taken up and not transformed to innocuous forms, plants would need to be disposed of elsewhere to avoid ultimately returning the contaminants back to the soil they came from. Concerns about contaminants in the plants entering the food chain may need to be addressed.	Low	Low	GHG and energy for installation, and potential disposal of harvested plants containing metals. Implementation of phytoremediation could lead to a GHG reduction credit.	Not Retained	Phytoremediation would only be effective for low concentrations of contaminants in shallow soil over long periods, and many metals and radionuclides would accumulate in the plants and would not actually be treated, posing risks to ecological receptors.
Containment	Surface Barriers	Surface Barriers (e.g., Modified RCRA Subtitle C and/or D Barrier, Asphalt/Concrete Cap, Vegetative Cap [Evapo-transpiration (ET) Cap], Hanford Barrier)		All	Shallow/ Deep	Surface barriers are generally designed to be impermeable to prevent surface water infiltration through the vadose zone and limit contaminant leaching to groundwater. Surface barriers may also prevent direct contact to contaminants. Modified RCRA Subtitle C Barriers are designed for hazardous waste, category 3 and category 1 (mixed) low-level waste. Modified RCRA Subtitle D Barriers are designed for nonradiological and non-hazardous solid waste, or category 1 low level waste where hazardous constituents are not present. Evapotranspiration barriers consist of a fine-grained soil layer overlying a relatively coarse-grained soil layer designed to functionally increase the water-holding capacity.	Moderate/High Leaching of near-surface source COPCs will be controlled, but residual COPCs in capillary fringe and deeper vadose zone pore water will continue to impact groundwater because of water table fluctuation. Prevention of direct contact will depend on specific design. Effectiveness for asphalt caps is high in the short term; for increased effectiveness, barrier needs to be properly sealed, given that asphalt and concrete are permeable.	High No technical or administrative challenges are associated with implementing asphalt/concrete caps (high implementability). Modified RCRA Subtitle C and/or D Barrier and Evapotranspiration barriers are simple to install. Biointrusion may need to be considered as part of the barrier/cap design.	Low/High Hanford Barrier (High); Modified RCRA Subtitle C and/or D Barrier (Moderate); Asphalt/ Concrete Cap and Evapotranspiration Barrier (Low)	Low	GHG and energy for installation. Continued impact to soil resources.	Retained	

Table 8-8. Screening Table—Technologies for Radionuclides, Cr(VI), Other Metals, and Organic Compounds in Waste Sites, Hanford Site River Corridor, 100-BC

General Response Actions	Remedial Technology	Process Option	COPC Applicability[a]	Depth Range[b]	Description	Relative Effectiveness	Relative Implementability	Relative Capital Cost	Relative O&M Cost	Sustainability[c]	Retained/ Not Retained[e]	Screening Comment
Containment (cont.)	Surface Barriers (cont.)	Surface Barriers (for example, Modified RCRA Subtitle C and/or D Barrier, Asphalt/ Concrete Cap, Vegetative Cap [Evapotranspiration {ET} Cap], Hanford Barrier) (cont.)			Asphalt/concrete barriers can be placed around structures to remain in place (for example, reactors) in the short term (75-years) to promote drainage, prevent infiltration into possible sources below the reactors, and prevent exposure to contaminated soil. The Hanford Barrier design was developed for sites containing low-level waste greater than Class C, and/or significant inventories of transuranic constituents.							
		Jet Grouting, Soil Freezing, or Wire Saw Barriers	All	6 m [20 ft]/ greater than 6 m [20 ft]	Barriers placed beneath the contaminated zone to limit further migration. Jet grouting is as discussed above at one specific depth. Soil freezing involves placement of cooling media distribution systems into the subsurface to freeze a soil layer below the contamination. Wire saw barrier involves cutting a thin horizontal trench that is filled with grout using a diamond wire saw. The saw is placed in an excavation around the soil mass to be contained.	Low Significant uncertain on the completeness of the barrier with all methods.	Low Would be difficult or impossible to implement at the Hanford Site due to presence of gravels and cobbles, and/or the depth of application.	High	Low	Large amount of waste would be generated during installation and GHG and energy for installation.	Not Retained	Difficult to implement.
	Compaction	Dynamic Compaction			Dynamic compaction is used for consolidation of soil and buried waste, and can be used to minimize the potential subsidence for a subsequent barrier. The process involves dropping a weight from a predetermined height onto the area to be compacted.	Moderate/High Effective at removing void spaces and compacting surface soil, where voids exist around buried waste. Not effective for native soil. Not effective for treatment of hazardous waste.	Moderate Simple and widely used technology.	Low	Low No associated cost.	GHG and energy for installation.	Not Retained	No waste sites including solid and buried waste are present at the site.

a. Indicates the contaminants that can be addressed by a technology based on geochemical properties. A COPC Applicability of "All" indicates implementation of a technology is not dependent on the nature of a contaminant.

b. Depth range is based on practical limitations of implementing the given technology.

c. Sustainability includes potential impacts to the environment that could arise from implementing this technology (such as GHG emissions, waste generation, water use and resource impacts, and energy use).

d. Ex situ treatment does not include treatment done for disposal at the ERDF or an approved offsite landfill. Treatment performed at the ERDF or at the waste site as required to meet disposal restrictions is assumed to be part of the "disposal to ERDF" or "other approved EPA landfill".

e. Additional details on technologies not retained are provided in Appendix I.

Table 8-9. Screening Table—Technologies for Cr(VI) and Other COPCs in Groundwater, Hanford Site River Corridor, 100-BC

General Response Actions	Remedial Technology	Process Option	COPC Applicability[c]	Description	Relative Effectiveness		Relative Implementability	Relative Capital Cost	Relative O&M Cost	Sustainability[b]	Retained/Not Retained	Screening Comment
No Action	No Action	No Action	All	No remedial actions taken.	Low/High No remedial actions are taken, but effectiveness could be high if risk is previously mitigated.		High	Low	Low	Little impact	Retained	Retained per the NCP (40 CFR 300).
Monitored Natural Attenuation (MNA)	MNA	MNA	Radionuclides with reasonable half-lives. Select organic compounds, Cr(VI), and select metals.	Relies on natural attenuation processes to manage the contamination onsite. Monitor groundwater plume to track natural attenuation processes until RAOs are achieved. Typically combined with other technologies that manage the source areas and mitigate exposure. Natural attenuation processes include: • Biological reduction – processes where naturally occurring microorganisms, such as yeast, fungi, and bacteria, break down target substances into less toxic or non-toxic substances • Chemical reduction – geochemical process where natural reductants in sediments reduce contaminants into less toxic or non-toxic substances • Adsorption - occurs in groundwater, as dissolved chemicals are removed from the solution and attach to soil particles • Dispersion - the spreading of a chemical in groundwater outward from its expected path. As groundwater moves through different soil types and geological features, it travels at different velocities. This creates mechanical mixing, so groundwater spreads away from source areas into wider plumes • Dilution – the decrease in the chemical concentration in a fluid caused by mixing with a fluid containing a lower concentration • Radioactive decay – spontaneous disintegration of the nucleus of radionuclide resulting in reduction in radionuclide activity	Biological reduction Chemical reduction Adsorption Dispersion Dilution Radioactive decay	Low/Moderate Moderate/High Low/Moderate High High Low/High depending on decay half-life of radioactive contaminant	High	Low/Moderate	Low/Moderate	Little impact	Retained	
Pump-and-Treat	Collection	Extraction	Groundwater Extraction System	All dissolved COPCs	Operation of existing and/or new groundwater extraction wells.	Moderate/High Pump-and-treat is a proven treatment technology for Cr(VI) in groundwater, although there is some uncertainty as to its ability to achieve standards everywhere for other COPCs, such as carbon-14.		High	Low	Moderate/High	Energy consumption and GHG emissions from pumping systems.	Retained	
	Ex Situ Treatment	Chemical	Ion Exchange	Cr(VI, nitrate, strontium-90	Ions from the aqueous phase are removed by exchange with innocuous ions on the exchange medium.	Moderate/High Effective for Cr(VI) treatment. Variable, depending on COPC.		High Vendors and equipment readily available. Currently used at the site.	Low/Moderate	Moderate/High	Waste generation from ion exchange regeneration disposal or regeneration. Energy consumption from process equipment.	Retained	

Table 8-9. Screening Table—Technologies for Cr(VI) and Other COPCs in Groundwater, Hanford Site River Corridor, 100-BC

General Response Actions		Remedial Technology	Process Option	COPC Applicability[c]	Description	Relative Effectiveness	Relative Implementability	Relative Capital Cost	Relative O&M Cost	Sustainability[b]	Retained/Not Retained	Screening Comment
Pump-and-Treat (cont.)	Ex Situ Treatment (cont.)	Chemical (cont.)	Chemical Reduction/ Softening and Precipitation	Cr(VI)	Dissolved COPCs are transformed into an insoluble solid, which is removal by flocculation, sedimentation, and filtration. COPCs are removed with the sludge.	Low/Moderate Effective for Cr(VI) treatment.	Moderate/High Vendors and equipment readily available, but no experience with the technology at the Hanford Site. Large volume of sludge would be produced.	Moderate/High	Moderate	Waste generation from chemical precipitation. Energy consumption from process equipment.	Not Retained[a]	For Cr(VI), there are implementability challenges given large sludge volume and the fact that the ion exchange treatment plants are in place.
			Electrocoagulation	Cr(VI)	Relies on electrochemical generation of ferrous iron. The ferrous iron reduces metals that are susceptible to reduction and converts them to insoluble solids, which are removed by sedimentation and filtration.	Low/Moderate Not widely used for Cr(VI) removal. Pilot testing at the site had challenges.	Low/Moderate Additional development and testing would be required. Potential negative impacts on re-injection of water.	Moderate/High	Moderate	Waste generation from chemical precipitation. Energy consumption from process equipment.	Not Retained[a]	For Cr(VI), implementability issues since the ion exchange treatment is plants are in place.
		Biological	Wetlands	Cr(VI), nitrate, petroleum, trichloroethene, and possibly technetium-99	Extracted groundwater is pumped to a constructed wetland where contaminants are biologically reduced, or taken up by plants and algae. Petroleum aerobically degraded. trichloroethene may volatilize.	Moderate/High Effective for nitrate, but additional research/pilot testing is required to verify effectiveness for other COPCs.	Low/Moderate May require large surface area for extended period of time.	Moderate Depends on land and construction requirements.	Low	Little impacts, except for land required.	Not Retained[a]	Performance uncertainty will require research to determine effectiveness. Not retained since ion exchange treatment system is already in place.
			Subgrade Bioreactors	Cr(VI), nitrate, petroleum, trichloroethene, and possibly technetium-99	Extracted groundwater is pumped into a lined excavated area that has been backfilled with organic media (e.g., wood mulch with zero-valent iron). Cr(VI), nitrate, trichloroethene, and technetium-99 are biologically reduced as it passes through the media. A second stage aeration/filtration stage could be provided to remove any biological byproducts (e.g., iron), petroleum, and solids prior to infiltrating or injecting back to groundwater.	Moderate/High Effective for nitrate, but treatability testing is required to verify effectiveness for other COPCs.	Moderate/High Excavation and backfilling is easy to implement. Piping can be incorporated into the design to facilitate future delivery of liquid carbon sources (e.g., vegetable oil). Treatability testing required to verify implementability.	Low/Moderate Depends on land requirements.	Low	Impacts include spent media disposal land required.	Not Retained[a]	Has not been demonstrated on a full scale for Cr(VI) or nitrate remediation.
			Bioreactors	Cr(VI), nitrate, petroleum, trichloroethene, and possibly technetium-99	Groundwater is amended with electron donor (carbon source) and passes through a matrix (fixed bed, fluidized bed, or membranes) with microbial films, where contaminants are biologically reduced. Effluent is oxygenated, filtered, and amended before recharge back into the ground.	Low/Moderate Bioreactors commonly used for nitrate removal, but less commonly for Cr(VI) reduction. Little experience with other COPCs.	Moderate/High Vendors and equipment readily available, but no current experience with the technology at the Hanford Site.	High	Moderate	Waste generation from biological sludge. Energy consumption from process equipment.	Not Retained[a]	Performance uncertainty for Cr(VI). Considering large and complex system requirements for nitrate removal, and since in situ bioremediation or subgrade bioreactors could be used, ex situ bioreactors have not been retained.
			Phytoremediation	Cr(VI), nitrate, petroleum, trichloroethene, and possibly technetium-99	Use of plants and their associated rhizospheric microorganisms to remove, reduce/degrade, or contain chemical contaminants in soil or groundwater. Contaminants in groundwater can also be removed by applying it as irrigating water for plants.	Low/Moderate Low/moderate for Cr(VI). Additional research/pilot testing is required to verify effectiveness for site conditions. Could be used as a barrier approach, but there would be challenges with the depth to the water table even close to the river. Commonly used for nitrate removal. Plants used for remediating radionuclides would require harvesting.	Low/Moderate Requires large surface area for plants. Potential cultural issues with implementation near river.	Low	Low	Impacts include land required and potential disposal of harvested plants containing radionuclides.	Not Retained[a]	Would only be effective for low concentrations of contaminants where groundwater is shallow over long periods, or when applied as irrigation water. Many metals and radionuclides would accumulate in the plants and not actually be treated, posing risks to ecological receptors.
		Physical	Air Stripping	VOCs	Water is passed through an air stripper where air	High	High	Moderate	Low/Moderate	Some energy for the	Conditionally	Retained for

Table 8-9. Screening Table—Technologies for Cr(VI) and Other COPCs in Groundwater, Hanford Site River Corridor, 100-BC

General Response Actions		Remedial Technology	Process Option	COPC Applicability[c]	Description	Relative Effectiveness	Relative Implementability	Relative Capital Cost	Relative O&M Cost	Sustainability[b]	Retained/Not Retained	Screening Comment
					is injected and strips out volatile compounds or carbon dioxide from the water phase. The stripper maybe a packed tower, tray stripper, or similar device. Off-gas treatment, typically using granular activated carbon, may be required if emissions exceed limits.	With appropriate design and operation, can achieve discharged standards.	Currently used at the Hanford Site for VOCs. Testing required for carbon-14.	Air strippers are relatively inexpensive.		blower. Energy consumption from process equipment.	Retained if COPCs need to be addressed	trichloroethene and chloroform.
Pump-and-Treat (cont.)	Ex Situ Treatment (cont.)	Physical (cont.)	Activated Carbon	VOCs and petroleum	Water is passed through a vessel of activated carbon where organic compounds are sorbed to the carbon.	High	High	Moderate	Low/Moderate	GAC would be the only waste. Energy consumption from process equipment.	Not Retained[a]	Not retained in favor of air stripping.
						With appropriate design and operation, can achieve discharged standards.	Currently used at the site.	GAC systems are relatively inexpensive.				
			Membrane Separation (e.g., Reverse Osmosis)	All except tritium	Water pressure is used to force water molecules through a very fine membrane, leaving the contaminants behind. Purified water is collected from the "clean" or "permeate" side of the membrane, and water containing the concentrated contaminants is disposed.	High	Low/Moderate	High	High	Waste generation in the form of brine and high energy use. Energy consumption from process equipment.	Not Retained[a]	Implementability challenges from large volumes of brine produced would require further reduction and then disposal.
						With the appropriate design, RO can be effective for almost any compound.	Vendors and equipment readily available, although additional site-specific testing would be required. Pretreatment likely necessary, and a large volume of brine would be produced that would need to be treated and handled.					
	Discharge	Onsite Discharge	Groundwater Injection Wells	All	Treated groundwater is injected into onsite wells.	High	High	Low/Moderate	Low/Moderate	Waste generation from soil cuttings for well installation.	Retained	
						Will enhance contaminant flushing, hydraulic control and capture of plume.	Readily implementable at the site, currently used in existing pump-and-treat system. The wells may be subject to clogging because of the buildup of chemical precipitates or microbial biofouling.					
			Surface	All	Treated groundwater is infiltrated into onsite trenches/	High	Moderate/High	Low	Low/Moderate	Little impact.	Retained	
						Effective means of disposal and may enhance contaminant flushing, hydraulic control, and capture of plume if trenches can be located appropriately.	Infiltration would be easy to engineer and implement.					
			Beneficial Reuse of Treated Water	All	Use of treated water for a beneficial use such as irrigation, cooling water, or dust control.	High	Moderate	High	Low	Water needs to be transported for reuse.	Retained	May be useful if water can be used for dust control and similar uses.
						Effective means of treated water disposal, although it may impact the in situ removal mechanisms.	No nearby facility that could use large quantities of water. May be simple to implement for dust control for nearby earthwork.					
		Offsite Discharge	Discharge to Surface Water	All	Discharge of treated groundwater directly to the river at an outfall.	High	Low	Low	Low	Little impact.	Not Retained[a]	Not allowed.
						Effective means of treated water disposal	Although surface water discharge is commonly practiced for treated wastewater, no new outfalls are allowed on the Hanford Reach National Monument.		Little or no maintenance required.			
In Situ Treatment	Reagent Approach	Chemical	In Situ Chemical Stabilization	Strontium-90	Subsurface delivery of chemical reagents (e.g., phosphate) in a regular pattern of wells in the aquifer to sequester the contaminants. Chemical reactions are induced between the stabilizing agent and contaminant to reduce mobility.	Moderate/High	Moderate	Moderate/High	Moderate	Waste generation from soil cuttings for well installation. GHG and energy from chemical production and transport.	Not Retained[a]	Not retained in favor of MNA. Strontium-90 does not present a significant risk and, therefore, will not be actively treated.
						Currently being implemented at 100-N in a barrier approach for strontium-90 with favorable results. Achieving even distribution may be difficult.	Requires large number of wells to cover a large area.	Function of number of injection wells required.	Periodic re-injection may be required.			
			In Situ Chemical	trichloroethen	Subsurface delivery of chemical oxidant (e.g.,	Moderate/High	Moderate	Moderate/High	Moderate	Waste generation from	Not Retained[a]	Large number of injection

Table 8-9. Screening Table—Technologies for Cr(VI) and Other COPCs in Groundwater, Hanford Site River Corridor, 100-BC

General Response Actions		Remedial Technology	Process Option	COPC Applicability[c]	Description	Relative Effectiveness	Relative Implementability	Relative Capital Cost	Relative O&M Cost	Sustainability[b]	Retained/Not Retained	Screening Comment
			Oxidation	e	ozone or sodium persulfate) in a regular pattern of wells in the aquifer to degrade trichloroethene. Ozone commonly applied via sparge wells.	Commonly applied for trichloroethene. Achieving even distribution may be difficult.	May require large number of wells.	Function of number of injection wells required.	Re-injection may be required.	soil cuttings for well installation. GHG and energy from chemical production and transport.		wells may make implementation challenging, especially compared to other technologies such as air sparging.
In Situ Treatment (cont.)	Reagent Approach (cont.)	Chemical (cont.)	In Situ Chemical Reduction	Cr(VI) and trichloroethene	Subsurface delivery of chemical reductants (such as calcium polysulfide) within plume to stimulate reduction of contaminant.	Moderate/High Chemical reductants instantly reactive, thus strongest reduction achieved near injection well, requiring tighter spacing of injection wells. Recirculation approach may increases size of reducing zone, and allows broader well spacing. Iron and sulfate reduction increases reductive capacity of subsurface, which makes the formation less sensitive to rebound.	Moderate May require large number of wells.	Moderate/High Dependant on number and type of wells. Likely higher capital cost compared to in situ biological.	Moderate	Waste generation from soil cuttings for well installation. GHG and energy for production and delivery of chemicals.	Retained	Retained for Cr(VI), trichloroethene, and chloroform.
		Biological	In Situ Biological Treatment (Anaerobic)	Cr(VI), nitrate, and trichloroethene	Subsurface delivery and recirculation of various organic substrates in a regular pattern of wells in the aquifer to stimulate anaerobic bioreduction of Cr(VI) and reduction of nitrate. Cr(VI) and nitrate in groundwater that is reinjected would be reduced in situ.	High Reactive life of biological electron donors is longer than chemical reductants so that reactive strength is maintained over relatively longer distances compared to in situ chemical treatment. Iron and sulfate reduction increases reductive capacity of subsurface, which makes the formation less sensitive to rebound.	Moderate/High Requires large number of wells to cover a large area.	Moderate/High Dependant on number and type of wells.	Moderate	Waste generation from soil cuttings for well installation. GHG and energy for production and delivery of substrate. Depends on which substrate is used.	Retained	
			In Situ Aerobic Co-metabolism (Biological Treatment)	trichloroethene	Injection of air and methane (gas, or dissolved in water) in a regular pattern of wells in the aquifer to destroy trichloroethene by co-metabolic oxidation. Petroleum will be biodegraded due to addition of oxygen.	Low Difficult process to control to be effective.	Moderate/High May require large number of wells.	Moderate/High Function of number of injection wells required.	Moderate	Waste generation from soil cuttings for well installation. GHG and energy for operation.	Not Retained[a]	Limited effectiveness.
	Reagent Approach (cont.)	Biological (cont.)	Hydrogen or other Organic Gas Sparging	Cr(VI)	Injection of biodegradable organic gasses (e.g., propane or butane) or hydrogen into sparge wells that are screened below the water table.	Low Distribution of gasses likely to be poor under local heterogeneous geologic conditions. Has not be demonstrated for Cr(VI).	Low The radius of influence around each sparge well is likely to be low, so a large number of wells would be required. Safety challenges exist because of residual explosive gasses that may accumulate.	High Large number of wells would be required.	Moderate	Waste generation from soil cuttings for well installation. GHG and energy for production and delivery of chemicals.	Not Retained[a]	Challenge in the distribution of the gases and safety risk associated with using explosive gases.
			Air Sparging/ Biosparging	trichloroethene	Injection of air through wells in the aquifer to volatilize VOCs and to provide oxygen for biodegradation.	High Commonly applied for petroleum and trichloroethene. Achieving even distribution of air may be difficult.	Moderate May require large number of wells, and SVE system to capture fugitive vapors.	Moderate Function of number of injection wells required and need for SVE system.	Moderate	Waste generation from soil cuttings for well installation. Waste from drilling and GHG and energy for operation.	Not Retained[a]	Not retained due to the low concentrations of trichloroethene that exist at 100-BC.

Table 8-9. Screening Table—Technologies for Cr(VI) and Other COPCs in Groundwater, Hanford Site River Corridor, 100-BC

General Response Actions		Remedial Technology	Process Option	COPC Applicability[c]	Description	Relative Effectiveness	Relative Implementability	Relative Capital Cost	Relative O&M Cost	Sustainability[b]	Retained/Not Retained	Screening Comment
		Chemical/ Biological	In Situ Treatment using Combination of Biological and Chemical Substrates	Cr(VI), nitrate, and trichloroethene	Subsurface delivery and recirculation of both chemical reductants and electron donors within plume to stimulate chemical and anaerobic biological reduction of Cr(VI).	High Chemical reductants could be used to treat smaller hot spot areas, while biological reductants could be used to sustain treatment over larger dilute plume areas. Recirculation approach increases the size of reducing zone, and allows broader well spacing. Iron and sulfate reduction increases reductive capacity of subsurface. Less sensitive to rebound from residual sources because of residual reactive phase.	Moderate Recirculation will likely be limited by extraction rate—addition of fresh water can be used to enhance coverage around injection wells. The formation of secondary byproducts may impact restoration to beneficial use.	Moderate/High Dependant on number and type of wells	Moderate	Waste generation from soil cuttings for well installation. GHG and energy for production and delivery of chemicals	Retained	May be more challenging to implement and costly as compared to biological reduction.
In Situ Treatment (cont.)	Reagent Approach (cont.)	Physical	In Situ Thermal Treatment (Electrical Resistance, Steam Injection, or Conductive)	trichloroethene	Direct application of heat (such as, using electrical heater elements, injection of steam, electrical resistance, etc.) to increase the temperature of soil and destroy or volatilize organic compounds.	High Technology can achieve rapid removal/destruction of a mix of volatile and semi-volatile organics, and achieve low residual concentrations.	Low Technology is applied using vertical drilling methods, and requires a spacing of 5 to 10 feet. Recovery of COPC vapors will require soil vapor extraction network and vapor barrier over entire treatment area.	High	Low	GHG and energy for production of heat and vapor recovery. Waste generation from soil cuttings for well installation.	Not Retained[a]	Challenging to implement and not likely to be cost effective.
			Flushing—Saturated Zone, Water	Cr(VI), nitrate, and trichloroethene	Clean/treated water is injected to flush out contaminated groundwater to expedite remediation of plumes. Would be component of a pump-and-treat system.	Moderate/High The extraction wells system should be able to capture any contaminants mobilized. However, performance will depend on residual contamination in lower permeability layers.	High Standard wells or infiltration trenches used for injection.	Moderate Costs for wells and piping	Low	GHG and energy for installation. Waste generation from soil cuttings for well installation.	Retained	
	Delivery Method	Surface Infiltration	Surface Infiltration	NA	Trenches, French drains or drip irrigations systems are used to inject water or reagents.	High Effective with appropriate design, installation, and maintenance.	Moderate Location of vadose zone contamination in relation to the water table needs to be known.	Low	Moderate	Less GHG and energy for installation	Retained	
		Groundwater Circulation Wells (GCWs)	Groundwater Circulation Wells (GCWs)	NA	Installation of wells with two screened zones. Groundwater is typically pumped out of the formation from lower screen zone, and injected back into the formation in the upper zone. A circulation patter is created in the formation. The groundwater can be stripped inside the well to remove VOCs, or the wells can be used to deliver reagents.	Low/Moderate The establishment of a reasonable circulation pattern depends on the formation characteristics. The low permeability lenses present in some locations may be problematic. Very high permeability may result in a small radius of influence so more wells will be required.	Low/Moderate A large number of wells may be required.	Moderate Depends on the number of wells required.	Moderate	Waste generation from soil cuttings for well installation. GHG and energy for operation.	Not Retained[a]	Asymmetrical groundwater flow and groundwater flow short-circuiting, may limit the effectiveness of GCWs.
		Vertical Wells	Vertical Wells	NA	Standard vertical wells are used to inject water or reagents.	High Effective with appropriate design, installation, and maintenance.	High Used extensively at the Hanford Site .	Moderate/High Wells at the Hanford Site are generally expensive.	Moderate	Waste generation from soil cuttings, GHG and energy for installation.	Retained	
		Horizontal Wells	Horizontal Wells	NA	Horizontally drilled wells are used to inject water or reagents.	Moderate/High Uncertain performance	Low Pilot test was not successful.	Moderate/High Costs are high but fewer wells are required	Moderate	Waste generation from soil cuttings, GHG and energy for installation.	Not Retained[a]	Pilot test was not successful.
Containment		Physical	Containment Wall	All	Slurry or grout wall barriers consist of a vertical	Moderate	Low	High	Low/Moderate	GHG and energy for	Not Retained[a]	Not likely to be