6 Human Health Risk Assessment

The integration of past and current HHRAs supports the development of remedial alternatives for waste sites and contaminated groundwater in the 100-D/H decision area. These risk assessments have been integrated with the cleanups performed under the interim action RODs to identify the need for further remedial action and, if needed, to develop PRGs.

Highlights

- Principal soil contaminants identified at one or more waste sites through the risk assessment included radionuclides, metals, PCBs, and PAHs.
- The baseline risk assessment identified Cr(VI), chromium, strontium-90, and nitrate as final groundwater COPCs for evaluation of potential remedial technologies in the FS.
- Data and process knowledge indicate that human health PRGs would be exceeded at unremediated waste sites and provide the basis for action.

As described in the previous sections, the remedial actions completed to date in the River Corridor were implemented primarily under interim action RODs. There is a requirement under CERCLA to perform a baseline risk assessment (BRA) to characterize current and potential threats to human health and the environment before final action RODs for final remedies can be issued. The RCBRA was prepared to address the regulatory requirement that a baseline risk assessment be performed. The RCBRA Report (DOE/RL-2007-21, Volume II) is a comprehensive HHRA for the River Corridor considering relevant sources of contamination, exposure pathways, and contaminants to evaluate current and potential future risks posed by hazardous substance releases. The following is the purpose of the RCBRA, as described in Section 1.1:

> *The purpose of the RCBRA is to characterize current and potential future risks to human health and the environment that may be posed by releases of hazardous substances in the River Corridor of the Hanford Site. DOE is required to assess human and ecological risk under CERCLA, Resource Conservation and Recovery Act of 1976 (RCRA), National Environmental Policy Act of 1969, and DOE orders. The "National Oil and Hazardous Substances Contingency Plan" (40 Code of Federal Regulations [CFR] 300), which implements CERCLA, specifically requires a site-specific baseline risk assessment to determine the need for action at sites, determine levels of contaminants that can remain onsite and still be protective, and provide a basis for comparing health impacts of various cleanup alternatives (40 CFR 300.430[d][4]).*

Per the risk assessment guide (EPA/540/1-89/002), a baseline risk assessment is an "analysis of the potential adverse health effects (current or future) caused by hazardous substance releases from a site in the absence of any actions to control or mitigate these releases (that is, under an assumption of no action)."

The baseline risk assessment is part of the CERCLA RI/FS process. The RI/FS is the methodology that the CERCLA program has established for characterizing the nature and extent of contamination associated with releases of hazardous substances to the environment, for assessing the potential risks posed by the environmental contamination to human and ecological receptors, and for developing and evaluating remedial options. Because the RI/FS is a process designed to support risk management decision making for CERCLA sites, the assessment of human health and environmental risk serves an essential role in the RI/FS process. The baseline risk assessment provides information to assist in the development, evaluation, and selection of appropriate response alternatives. The results of the baseline risk assessment are used to determine whether additional response action is necessary at the Site; support development of PRGs; support selection of the "no action" remedial alternative where it is appropriate; and document the magnitude of risk and primary contributors (for example, chemicals and exposure pathways) to risk at a site.

Interim action RODs were written for River Corridor sites to allow cleanup activities to move forward as potential risks were identified. However, final remedy selection must be completed in order for the NPL (40 CFR 300, Appendix B) CERCLA sites in the River Corridor to reach final closeout. One of the key evaluations needed to establish final action RODs for sites in the River Corridor was a baseline risk assessment (*Risk Assessment Work Plan for the 100 Area and 300 Area Component of the RCBRA* [DOE/RL-2004-37]). The RCBRA (DOE/RL-2007-21, Volume II) HHRA and the companion ecological risk assessment (DOE/RL-2007-21, Volume I) provided an evaluation of ecological and human health risk from residual contamination at waste sites remediated under the interim action RODs and from potentially affected environmental media under various exposure scenarios. Unacceptable risks are present in the River Corridor at waste sites that are identified in the IARODs but have yet to be remediated. The determination of the presence of unacceptable risk and basis for action at yet-to-be remediated waste sites is supported by field investigation data as well as information gathered through implementation of the observational-approach soil cleanup actions in the River Corridor over the past 15 years. The Site-specific risk information provided by the RCBRA (DOE/RL-2007-21) would be used to support final action RODs for the River Corridor.

6.1 Role of the RCBRA and the RI/FS Risk Assessment

The RCBRA (DOE/RL-2007-21) provided the following range of analyses:

- Assessment of residual risks for remediated waste sites using the Unrestricted Land Use exposure scenario that was the basis for the remedial action goals for the interim action ROD cleanup in the 100 Area
- An assessment of risks for several yet-to-be remediated waste sites using a broad range of exposure scenarios
- Assessment of residual risks for remediated waste sites and broad areas[1] using a broad range of exposure scenarios

Portions of these analyses were considered in the HHRA approach used to develop soil PRGs that are presented in the RCBRA (DOE/RL-2007-21). The following issues are addressed in this chapter as part of the integration of RCBRA and the RI/FS, which will support the development of final action RODs for the 100 Area decision areas:

- Incorporation of direct contact PRG values from the RCBRA (DOE/RL-2007-21) for radioisotopes and chemicals based on updated regulatory guidance
- Inclusion of all decision units[2] associated with a remediated waste site
- Inclusion of analytical data from focused sampling designs
- Analysis time frame (that is, waste sites cleaned up after the analysis conducted in the RCBRA [DOE/RL-2007-21])
- Use of EPCs consistent with the waste site decision units (for example, shallow zone, deep zone) and based on current EPA guidance

[1] The term "broad area" is used in the RCBRA to refer to an exposure area that could potentially be as large as an individual interim action ROD decision area or as large as the entire River Corridor.

[2] The floor and sidewalls of an excavated waste site are divided into one or more decision units. A sample design is developed for each decision unit. See Section 6.2.2.2 for additional information.

The following sections discuss the integration of the RCBRA (DOE/RL-2007-21) and the RI/FS risk assessment:

- Section 6.1.1 summarizes the evaluation of residual risks performed in the RCBRA (DOE/RL-2007-21) for waste sites cleaned up under the interim action ROD. The results from this evaluation have been compared with the PRGs developed in the RCBRA (DOE/RL-2007-21) for use in the RI/FS.
- Section 6.1.2 and 6.1.3 describe Unrestricted Land Use and other scenarios used in the River Corridor, their associated uncertainties, and the way they have been incorporated into the RI/FS.

The HHRA supporting the RI/FS is presented in two sections. Section 6.2 presents the methods and the results for the soil risk assessment and Section 6.3 presents the methods and results for the analysis of groundwater risks.

The soil risk assessment supporting the RI/FS (Section 6.2) provides the data analysis (Section 6.2.1), estimated EPCs (Section 6.2.2), exposure assessment (Section 6.2.3), toxicity assessment (Section 6.2.4), risk characterization (Section 6.2.5), and the uncertainties assessment (Section 6.2.6).

The groundwater risk assessment supporting the RI/FS (Section 6.3) discusses findings and uncertainties of the RCBRA (DOE/RL-2007-21) (Section 6.3.1). The Integrated Work Plan (DOE/RL-2008-46) adds activities that would help reduce uncertainties, verify conclusions, and ensure that no contaminants were inadvertently overlooked based on the use of the existing dataset. The risk assessment involves the following steps: identification of COPCs (Section 6.3.2), exposure assessment (Section 6.3.3), toxicity assessment (Section 6.3.4), risk characterization (Section 6.3.5), risk characterization using action levels (Section 6.3.6), the tap water risk characterization (Section 6.3.7), and the uncertainties assessment (Section 6.3.9). The results of Section 6.3 will be used to identify COPCs, which represent contaminants that will be evaluated in the FS to define the COCs and guide the selection of remedial alternatives.

Section 6.4 presents conclusions of the riparian and near shore environment from the RCBRA (DOE/RL-2007-21, Volume II) and conclusions from the CRC (DOE/RL-2010-117, Volume II) are in Section 6.4.1. Section 6.5 presents a summary and conclusions for the soil risk assessment (Section 6.5.1) and the groundwater risk assessment (Section 6.5.2).

6.1.1 Evaluation of Residual Risks for Interim Action ROD Cleanups from the RCBRA

This section discusses the results of the screening-level evaluation presented in Chapter 2 of the RCBRA (DOE/RL-2007-21, Volume II). It also compares the results from the screening-level evaluation to the methodology used to develop the interim action remedial action goals and describes how analytical data from CVP/RSVP were used in the screening evaluation. Finally, the screening-level risk results from the RCBRA (DOE/RL-2007-21, Volume II) are compared to the results of the soil risk assessment. The risk results from the soil risk assessment are based on guidance and exposure assumptions that have been updated since the interim action remedial action goals were published. The methods used in the risk assessment are described in Sections 6.1.2 and 6.1.3.

Chapter 2 of the RCBRA (DOE/RL-2007-21, Volume II) presents a screening-level assessment of residual direct contact risks and noncancer hazards for the remediated waste sites using the exposure scenarios that were the basis of the residential remedial action goals for the interim action ROD cleanups in the 100 Area. This assessment was done to provide information about the residual risks and noncancer hazards associated with post-interim action conditions at the remediated waste sites and help assess whether residual conditions protect human health.

Interim action ROD cleanup activities for the 100 Areas were based on an unrestricted scenario that was the basis for the remedial action goals. The interim action ROD residential scenario for radionuclides is a Rural Residential scenario that, in addition to direct contact, includes food chain exposure pathways (for example, ingestion of homegrown produce, beef, and milk). The interim action ROD residential scenario for chemicals is based on the 1996 MTCA Method B direct contact soil cleanup levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]). The 1996 MTCA (WAC 173-340) Method B direct contact soil cleanup levels are based solely on incidental soil ingestion and do not address the food exposure pathways that were included for the radionuclide Rural Residential scenario[3]. The interim action remedial action goal for arsenic was based on the 1996 MTCA Method A soil cleanup level ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]). The interim action remedial action goal for lead was calculated using *Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children* (EPA/540/R-93/081). It should be noted that the radionuclide PRGs for the residential scenario used in the soil risk assessment incorporate exposure assumptions that were updated to reflect current EPA guidance as described in Section 6.1.2.

CVPs or RSVPs were prepared to document completion of interim action ROD cleanup actions in accordance with the applicable decision document and support waste site reclassification. The screening-level calculations presented in Chapter 2 of the RCBRA (DOE/RL-2007-21) use the interim action ROD risk assessment models, but differ from the calculations used in the CVPs and RSVPs to document the interim action ROD cleanups.

Twenty-eight waste sites from the 100-D Source OU and eight wastes sites from the 100-H Source OU were evaluated in the RCBRA (DOE/RL-2007-21). Sixty-seven additional waste sites at the 100-D Source OU and 39 additional waste sites at the 100-H Source OU have been remediated since 2005, and are not addressed in the RCBRA. Residual cumulative cancer risks for the direct contact pathway from chemicals evaluated in the RCBRA are less than 1×10^{-5} using the interim action ROD residential scenario (that is, 1996 MTCA Method B direct contact soil cleanup levels Unrestricted Land Use scenario). This is with the exception of 100-H-21, where the risk driver is arsenic with a reasonable maximum exposure (RME) concentration of 13.8 mg/kg, which is less than the direct exposure remedial action goal of 20 mg/kg published in the 100 Area RDR/RAWP (DOE/RL-96-17).

Residual cumulative cancer risks from radionuclides for all remediated waste sites are less than 1×10^{-4} based on the interim action ROD Rural Residential scenario with the exception of the following waste sites:

- 100-D-48:3
- 116-DR-9

The noncancer hazard indices (HIs) for chemicals do not exceed a threshold of 1 at the 28 100-D remediated waste sites and the eight 100-H waste sites. A summary of the risk assessment results for a residential scenario using approaches from both the RCBRA and the RI/FS is provided in Tables 6-1 to 6-3.

[3] Note that for beryllium, cadmium, and Cr(VI), the interim action remedial action goal for direct contact is based on the inhalation pathway.

Table 6-1. Summary of Residential Scenario Risk Assessment Results for Chemical Carcinogens

Waste Site Name	RI/FS Decision Unit	Chemical Carcinogens and Cancer Risk Drivers			
		RCBRA Chemical Risk	RCBRA Chemical Risk Driver	RI/FS Chemical Risk	RI/FS Chemical Risk Driver
100-D Source OU Waste Sites					
100-D-4	Shallow	2×10^{-7}	None	3.8×10^{-7}	None
100-D-12	Shallow	--	--	--	--
100-D-20	Shallow	--	--	--	--
100-D-21	Shallow	--	--	--	--
100-D-22	Shallow	--	--	--	--
100-D-48:1	Shallow	--	--	--	--
100-D-48:2	Shallow	--	--	--	--
100-D-48:3	Shallow	--	--	--	--
100-D-48:4	Shallow	--	--	--	--
100-D-49:2	Shallow	--	--	--	--
100-D-49:4	Shallow	--	--	3.4×10^{-7}	None
100-D-52	Shallow	--	--	--	--
116-D-1A	Shallow	--	--	--	--
116-D-2	Shallow	--	--	--	--
116-D-4	Shallow	--	--	--	--
116-D-7	Shallow	--	--	--	--
116-D-9	Shallow	--	--	--	--
116-DR-1&2	Shallow	--	--	--	--
116-DR-4	Shallow	--	--	--	--
116-DR-6	Shallow	--	--	--	--
116-DR-7	Shallow	--	--	--	--
116-DR-9	Shallow	--	--	--	--
118-DR-2:2	Shallow	5×10^{-6}	Arsenic (5×10^{-6})	4.9×10^{-6}	Arsenic (4.8×10^{-6})
122-DR-1:2	Shallow	5×10^{-6}	Arsenic (5×10^{-6})	5.0×10^{-6}	Arsenic (4.7×10^{-6})
1607-D2:1	Shallow	2×10^{-6}	Arsenic (2×10^{-6})	1.7×10^{-6}	Arsenic (1.7×10^{-6})
1607-D2:3	Shallow	--	--	3.5×10^{-10}	None
1607-D2:4	Shallow	--	--	--	--
1607-D4	Shallow_Focused	2×10^{-6}	Arsenic (2×10^{-6})	2.3×10^{-6}	Arsenic (2.3×10^{-6})

Table 6-1. Summary of Residential Scenario Risk Assessment Results for Chemical Carcinogens

Waste Site Name	RI/FS Decision Unit	Chemical Carcinogens and Cancer Risk Drivers			
		RCBRA Chemical Risk	RCBRA Chemical Risk Driver	RI/FS Chemical Risk	RI/FS Chemical Risk Driver
100-H Source OU Waste Sites					
100-H-5	Shallow	6×10^{-6}	Arsenic (6×10^{-6})	6.9×10^{-6}	Arsenic (6.9×10^{-6})
100-H-17	Shallow	5×10^{-6}	Arsenic (5×10^{-6})	5.1×10^{-6}	Arsenic (5.1×10^{-6})
100-H-21	Shallow	2×10^{-5}	Arsenic (2×10^{-5})	2×10^{-5}	Arsenic (2.0×10^{-5})
100-H-24	Shallow	6×10^{-6}	Arsenic (6×10^{-6})	6.4×10^{-6}	Arsenic (6.3×10^{-6})
116-H-1	Shallow	1×10^{-5}	Arsenic (1×10^{-5})	9.9×10^{-6}	Arsenic (9.9×10^{-6})
116-H-7	Shallow	8×10^{-6}	Arsenic (8×10^{-6})	9.6×10^{-6}	Aroclor-1260 (1.3×10^{-6}) Arsenic (8.3×10^{-6})
1607-H2	Shallow	1×10^{-5}	Arsenic (1×10^{-5})	1.1×10^{-5}	Arsenic (1.1×10^{-5})
	Shallow_Focused	--	--	2.3×10^{-6}	Arsenic (2.3×10^{-6})
1607-H4	Shallow	Not Evaluated	Not Evaluated	1.5×10^{-5}	Arsenic (1.1×10^{-5}) Benzo(a)pyrene (2.8×10^{-6})

Notes: Chemical drivers shown have an associated risk greater than 1×10^{-6}.

The risk value for the individual drivers is shown in parentheses after the name of the risk driver chemical.

Risks are based on reasonable maximum EPCs.

Source: RCBRA data: *River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment* (DOE/RL-2007-21), Volume II, Part 2, Table 2-10.

RI/FS data: (DOE/RL-2010-95), Appendix G, Table G-17 (100-D) and G-36 (100-H).

-- = Carcinogenic COPCs were not identified.

Table 6-2. Summary of Residential Scenario Risk Assessment Results for Noncarcinogens

Waste Site Name	RI/FS Decision Unit	Noncancer Hazard Index and Noncancer Hazard Drivers			
		RCBRA Hazard Index	RCBRA Chemical Hazard Driver	RI/FS Hazard Index	RI/FS Chemical Hazard Driver
100-D Source OU Waste Sites					
100-D-4	Shallow	0.001	None	0. 053	None
100-D-12	Shallow	--	--	--	--
100-D-20	Shallow	0.01	None	0.011	--
100-D-21	Shallow	--	--	--	--
100-D-22	Shallow	--	--	0.01	--
100-D-48:1	Shallow	0.01	None	0.008	None

Table 6-2. Summary of Residential Scenario Risk Assessment Results for Noncarcinogens

Waste Site Name	RI/FS Decision Unit	Noncancer Hazard Index and Noncancer Hazard Drivers			
		RCBRA Hazard Index	RCBRA Chemical Hazard Driver	RI/FS Hazard Index	RI/FS Chemical Hazard Driver
100-D-48:2	Shallow	0.01	None	0.006	--
100-D-48:3	Shallow	0.01	None	0.01	None
100-D-48:4	Shallow	0.01	None	0.015	None
100-D-49:2	Shallow	0.005	None	0.004	--
100-D-49:4	Shallow	0.01	None	0.11	None
100-D-52	Shallow	0.01	None	0.011	None
116-D-1A	Shallow	0.01	None	0.009	None
116-D-2	Shallow	0.01	None	0.006	--
116-D-4	Shallow	0.01	None	0.005	--
116-D-7	Shallow	0.01	None	0.011	None
116-D-9	Shallow	0.01	None	0.007	--
116-DR-1&2	Shallow	0.01	None	0.006	--
116-DR-4	Shallow	0.01	None	0.006	--
116-DR-6	Shallow	0.01	None	0.006	--
116-DR-7	Shallow	0.01	None	0.007	--
116-DR-9	Shallow	0.01	None	0.008	None
118-DR-2:2	Shallow	0.14	None	0.15	None
122-DR-1:2	Shallow	0.13	None	0.23	None
1607-D2:1	Shallow	0.06	None	0.06	None
1607-D2:3	Shallow	0.002	None	0.007	None
1607-D2:4	Shallow	0.01	None	0.009	None
1607-D4	Shallow_Focused	0.07	None	0.56	None
100-H Source OU Waste Sites					
100-H-5	Shallow	0.19	None	0.20	None
100-H-17	Shallow	0.15	None	0.15	None
100-H-21	Shallow	0.58	None	0.56	None
100-H-24	Shallow	0.17	None	0.17	None
116-H-1	Shallow	0.29	None	0.28	None
116-H-7	Shallow	0.23	None	0.24	None

Table 6-2. Summary of Residential Scenario Risk Assessment Results for Noncarcinogens

Waste Site Name	RI/FS Decision Unit	Noncancer Hazard Index and Noncancer Hazard Drivers			
		RCBRA Hazard Index	RCBRA Chemical Hazard Driver	RI/FS Hazard Index	RI/FS Chemical Hazard Driver
1607-H2	Shallow	0.54	None	0.52	None
	Shallow_Focused	Not Evaluated	Not Evaluated	0.07	None
1607-H4	Shallow	--	--	0.32	None

Notes: Chemical drivers shown have an associated hazard quotient (HQ) greater than 1. The HQ for the individual drivers is shown in parentheses after the name of the risk driver chemical.

HIs are based on reasonable maximum EPCs.

Sources: RCBRA data: *River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment* (DOE/RL-2007-21), Part 2, Table 2-10.

RI/FS data: Appendix G, Table G-17 (100-D) and G-36 (100-H).

--- = Noncarcinogenic COPCs were not identified.

Table 6-3. Summary of Residential Scenario Risk Assessment Results for Radionuclides

Waste Site Name	RI/FS Decision Unit	Radionuclides and Radiological Risk Drivers			
		RCBRA Radiological Risk	RCBRA Radiological Risk Driver	RI/FS Radiological Risk	RI/FS Radiological Risk Driver
100-D-4	Shallow	3×10^{-5}	None	1.7×10^{-5}	None
100-D-12	Shallow	--	--	--	--
100-D-20	Shallow	9×10^{-5}	None	5.3×10^{-5}	None
100-D-21	Shallow	8×10^{-6}	None	6.4×10^{-7}	None
100-D-22	Shallow	--	--	3.1×10^{-5}	None
100-D-48:1	Shallow	4×10^{-5}	None	2.4×10^{-5}	None
100-D-48:2	Shallow	1×10^{-4}	None	5.1×10^{-5}	None
100-D-48:3	Shallow	2×10^{-4}	Cesium-137 (2×10^{-4})	1.4×10^{-4}	Strontium-90 (1.2×10^{-4})
100-D-48:4	Shallow	7×10^{-5}	None	4.0×10^{-5}	None
100-D-49:2	Shallow	3×10^{-5}	None	1.3×10^{-5}	None
100-D-49:4	Shallow	1×10^{-4}	None	5.9×10^{-5}	None
100-D-52	Shallow	4×10^{-6}	None	1.3×10^{-5}	None
116-D-1A	Shallow	7×10^{-5}	None	4.2×10^{-5}	None
116-D-2	Shallow	7×10^{-6}	None	3.0×10^{-6}	None
116-D-4	Shallow	4×10^{-6}	None	2.6×10^{-6}	None
116-D-7	Shallow	5×10^{-5}	None	2.0×10^{-5}	None

Table 6-3. Summary of Residential Scenario Risk Assessment Results for Radionuclides

Waste Site Name	RI/FS Decision Unit	Radionuclides and Radiological Risk Drivers			
		RCBRA Radiological Risk	RCBRA Radiological Risk Driver	RI/FS Radiological Risk	RI/FS Radiological Risk Driver
116-D-9	Shallow	2×10^{-5}	None	2.8×10^{-5}	None
116-DR-1&2	Shallow	5×10^{-5}	None	2.3×10^{-5}	None
116-DR-4	Shallow	1×10^{-5}	None	2.8×10^{-6}	None
116-DR-6	Shallow	4×10^{-5}	None	3.5×10^{-5}	None
116-DR-7	Shallow	2×10^{-5}	None	9.8×10^{-6}	None
116-DR-9	Shallow	4×10^{-4}	Cesium-137 (4×10^{-4})	2.6×10^{-4}	Cesium-137 (2.3×10^{-4})
118-DR-2:2	Shallow	1×10^{-4}	None	2.3×10^{-4}	Technetium-99 (1.6×10^{-4})
122-DR-1:2	Shallow	6×10^{-6}	None	3.1×10^{-6}	None
1607-D2:1	Shallow	6×10^{-6}	None	1.9×10^{-6}	None
1607-D2:3	Shallow	1×10^{-5}	None	7.1×10^{-6}	None
1607-D2:4	Shallow	4×10^{-6}	None	2.2×10^{-6}	None
1607-D4	Shallow_Focused	--	--	--	--
100-H Source OU Waste Sites					
100-H-5	Shallow	1×10^{-5}	None	3.8×10^{-6}	None
100-H-17	Shallow	5×10^{-5}	None	5.5×10^{-5}	None
100-H-21	Shallow	6×10^{-5}	None	5.6×10^{-5}	None
100-H-24	Shallow	--	--	--	--
116-H-1	Shallow	1×10^{-4}	None	6.1×10^{-5}	None
116-H-7	Shallow	5×10^{-5}	None	2.3×10^{-5}	None
1607-H2	Shallow	9×10^{-6}	None	3.7×10^{-6}	None
	Shallow_Focused	Not Evaluated	Not Evaluated	--	--
1607-H4	Shallow	--	--	4.6×10^{-6}	None

Notes: Radionuclide drivers shown have an associated risk greater than 1×10^{-4}.

The risk value for the individual drivers is shown in parentheses after the name of the risk driver chemical.

Risks are based on reasonable maximum EPCs.

Sources: RCBRA data: *River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment* (DOE/RL-2007-21), Part 2, Table 2-10.

RI/FS data: Appendix G, Table G-17 (100-D) and G-36 (100-H).

-- = Radionuclide COPCs were not identified.

6.1.2 RI/FS Risk Assessment (Unrestricted Land Use)

As shown in Tables 6-1 to 6-3, the risk assessment results are similar between the RCBRA (DOE/RL-2007-21, Volume II) and the RI/FS for the residential scenario. Differences in results are

generally attributed to the COPC identification process, the method used to calculate EPCs, and the PRG value used for comparison. The soil risk assessment provided in this chapter supplements the RCBRA (DOE/RL-2007-21, Volume II) because there are several key differences between the scope and purpose of the RCBRA (DOE/RL-2007-21, Volume II) and the scope and purpose of the RI/FS. Differences between the RCBRA (DOE/RL-2007-21, Volume II) and the RI/FS in the methodologies used for assessing residual risks are described in Table 6-4; these include methods for COPC identification, selection of exposure factors used for the remedial action goals and PRGs, inclusion of all decision units associated with a waste site, and inclusion of analytical data from focused sampling designs. As a result of these differences, the soil risk assessment provided in the RI/FS more directly supports the evaluation of remedial alternatives in the FS. Table 6-4 also provides the methods used for preparing the closeout documentation.

RAOs are narrative statements that define the extent to which waste sites require cleanup to protect human health and the environment. Further, PRGs (also used as risk-based screening levels [RBSL]) are the numeric values that would be expected to achieve the RAOs presented in Chapter 8. The 100-D/H OU PRGs are developed in the RCBRA (DOE/RL-2007-21) and presented in this chapter.

For the 100-D/H Source OU, the results of the soil risk assessment presented in this chapter will be used to determine whether additional remedial action may be necessary for waste sites where remediation has been completed, and whether the goals and objectives of the interim action RODs have been met, as demonstrated by verification sampling and analysis. It is important to note that another objective of the soil risk assessment is to determine and affirm a basis for action. Although the RI/FS risk assessment and the RCBRA (DOE/RL-2007-21) focus on the protection of human health and the environment at waste sites that have been remediated, there are significant potential risks at unremediated sites that require continuation of cleanup actions. The risk-based screening evaluation for the residential scenario in this chapter provides information necessary to resolve the following questions and provides information needed to support final remedial decisions that will ensure protection of human health and the environment:

- Are residual conditions for cleanup actions completed under the interim action RODs protective of human health and the environment based on comparison to RBSLs calculated in accordance with current EPA guidance?
- Are there waste sites with a no action or interim closed out reclassification status that should be carried into the FS?
- What uncertainties are associated with the risk results that require a risk management decision?

Waste sites evaluated in the River Corridor were Interim Closed using remedial action goals related to direct contact soil exposure by human receptors. These remedial action goals are reported in the 100 Area RDR/RAWP (DOE/RL-96-17). The remedial action goals for radionuclides have not been revised since originally published in 1996. Remedial action goals in the 100 Area of the River Corridor (for direct contact) were based on a Rural Residential exposure scenario. The interim action ROD residential scenario for radionuclides is a Rural Residential scenario that, in addition to direct contact, includes food chain exposure pathways (for example, ingestion of homegrown produce, beef, and milk). Since the 100 Area RDR/RAWP (DOE/RL-96-17) was originally published, EPA has published a change in policy associated with health protectiveness thresholds as well as updates in guidance associated with several exposure assumptions. PRGs presented in this chapter incorporate exposure assumptions that were updated to reflect current EPA guidance (see Table 6-4).

Table 6-4. Comparison of Methods and Assumptions Used for the Residential Scenario

Parameter	Method Used in Closeout Documentation	Method Used in RCBRA	Method Used in RI/FS	Overall Effect on RI/FS
Basis of PRG Values for Radioisotopes and Chemicals				
Residential PRG value for radioisotopes	Radionuclide cancer risk is evaluated using the interim action ROD Rural Residential exposure scenario reported in *Remedial Design Report/Remedial Action Work Plan for the 100 Area* DOE/RL-96-17. Radionuclide remedial action goals were calculated based on a dose threshold of 15 millirems per year (mrem/yr).	Radionuclide cancer risk is evaluated using the interim action ROD Rural Residential exposure scenario reported in *Remedial Design Report/Remedial Action Work Plan for the 100 Area* DOE/RL-96-17. Radionuclide remedial action goals were calculated based on a dose threshold of 15 mrem/yr. In the RCBRA, these remedial action goals were converted to RBSLs based on a risk threshold of 1×10^{-4} (pg 2-41 of the RCBRA). The interim action ROD Rural Residential exposure scenario is considered a Local Area exposure scenario (located on a waste site).	Radionuclide cancer risk is evaluated using the residential exposure scenario. This exposure scenario is similar to the interim action ROD Rural Residential scenario but incorporates updates to reflect recent EPA guidance as identified in the following text.	The residential scenario used in the RI/FS reflects updates in methodology (risk-based versus dose-based threshold) and recent recommendations in exposure assumptions. RBSL/PRG values differ slightly between the remedial action goals reported in the closeout documentation, RCBRA and the RI/FS for key COPCs (gamma emitters and strontium-90). Risk-based PRG values reported in the RI/FS for gamma emitters and strontium-90 are slightly lower than the remedial action goals reported in the closeout document and in the RCBRA. Risk-based PRG values reported in the RI/FS for some alpha emitters are greater than the remedial action goals reported in the closeout document and in the RCBRA.
Updates to EPA guidance for residential PRG	External gamma shielding factor is 0.8 based on *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals)* (EPA, 1991). Outdoor time fraction is 0.2 (5 hours/day over 350 days/year), which was obtained from *Hanford Guidance for Radiological Cleanup* (WDOH/320-015). Annual dose rate is 15 mrem/year based on "Radiation Site Cleanup Standards" (40 CFR 196).	External gamma shielding factor is 0.7, which is based on the default value recommended in the RESRAD code. Outdoor time fraction is 0.2 (5 hours/day over 350 days/year) from WDOH/320-015. Target cancer risk value is 1×10^{-4} based on the recommendations published in *Radiation Risk Assessment at CERCLA Sites: Q & A* (EPA/540/R/99/006).	External gamma shielding factor is 0.4 from *Soil Screening Guidance for Radionuclides: User's Guide* (EPA/540-R-00-007). Outdoor time fraction is 0.12 (3 hours/day over 350 days/year) published in the Exposure Factors Handbook (EPA/600/P-95/002Fb). Target cancer risk value is 1×10^{-4} based on the recommendations published in *Radiation Risk Assessment at CERCLA Sites: Q & A* (EPA/540/R/99/006).	The gamma-shielding factor was revised from 0.7 to 0.4. The current assumption accounts for a 60 percent reduction in external exposure due to shielding from structures rather than a 30 percent reduction. The use of the updated assumption results in slightly less exposure and a less conservative PRG value (higher). The outdoor time fraction was revised from 0.2 to 0.12. The current assumption assumes the resident spends 3 hours/day outside rather than 5 hours/day. Use of the updated assumption results in less exposure and a less conservative PRG value (higher). The protectivethreshold value was updated from a dose-based value to a risk-based value. The overall outcome is that updated PRG values used in the RI/FS are slightly lower for beta- and gamma-emitting radioisotopes and higher for alpha-emitting radioisotopes.
MTCA Method B direct contact soil cleanup levels for unrestricted land use	Separate 1996 MTCA Method B direct contact soil cleanup levels were calculated for incidental soil ingestion and inhalation.	2007 MTCA Method B direct contact soil cleanup levels are based solely on incidental soil ingestion.	Separate 2007 MTCA Method B direct contact soil cleanup levels were calculated for incidental soil ingestion and inhalation.	Chemicals that only report toxicity values for the inhalation exposure route are not included in the RCBRA evaluation (beryllium, cadmium, cobalt, Cr(VI), and nickel). Remedial action goals are reported for chemicals that only report toxicity values for the inhalation exposure route (beryllium, cadmium, cobalt, Cr(VI), and nickel). The RI/FS separately reports cancer risks and noncancer HIs for both incidental soil ingestion and inhalation exposure routes.
MTCA Method B inhalation cleanup levels for unrestricted land use	*Remedial Design Report/Remedial Action Work Plan for the 100 Area,* DOE/RL-96-17 reports remedial action goals for beryllium, cadmium, Cr(VI) based on the inhalation exposure pathway, based on WAC 173-340-750 (3), 1996. A PEF value of 1.0×10^{7} m^3/kg was used to convert air concentrations to soil concentrations. The PEF value of 1.0×10^{7} m^3/kg is based on the default mass loading factor in RESRAD. This is roughly two orders of magnitude smaller than EPA's default PEF of 1.4×10^{9} m^3/kg.	2007 MTCA Method B inhalation cleanup levels were not evaluated in the RCBRA.	2007 MTCA Method B inhalation cleanup levels were calculated for the inhalation exposure route. A PEF value of 7.3×10^{10} m^3/kg is used to convert air concentrations to soil concentrations. This PEF uses meteorological data from Boise, Idaho, and Hanford Site-specific annual wind speed. The PEF of 7.3×10^{10} m^3/kg is within a factor of two of EPA's default PEF of 1.4×10^{9} m^3/kg published in the Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (OSWER 9355.4-24).	Inhalation pathway cleanup levels that use a PEF value based on the default mass loading factor in RESRAD are lower values (more conservative) than those cleanup levels that are based on EPA methodology.

Table 6-4. Comparison of Methods and Assumptions Used for the Residential Scenario

Parameter	Method Used in Closeout Documentation	Method Used in RCBRA	Method Used in RI/FS	Overall Effect on RI/FS
Data Analysis				
Waste site decision units and analysis time frame	The floor and sidewalls of an excavated waste site are divided into one or more decision units. A sample design is developed for the decision unit. Sampling requirements for each decision unit are described in *100 Area Remedial Action Sampling and Analysis Plan* (DOE/RL-96-22).	For Local Area exposure scenarios (including the interim action ROD Rural Residential scenario), the RCBRA used only the CVP/RSVP datasets from shallow zone decision units. These datasets are from waste sites that were excavated/remediated through calendar year 2005. The shallow zone decision unit is typically represented by soils from the excavation floor if at or above 4.6 m (15 ft) and any sidewalls from grade level (0 m [0 ft]) to a depth of 4.6 m (15 ft).	The RI/FS used CVP/RSVP datasets from all decision units associated with an excavated/remediated waste site through July 2011. In addition to the shallow zone decision unit, the RI/FS evaluates the risk contribution from soils associated with the overburden, staging pile footprint area, and the deep zone decision units.	The RI/FS soil risk assessment is intended to supplement the analysis in Chapter 2 of the RCBRA. The RI/FS soil risk assessment results will be used to identify waste sites that warrant evaluation of remedial alternatives in the FS. The RI/FS soil risk assessment can also be used to disposition the waste site from an interim status to final closure status when risk thresholds are not exceeded.
Statistical and focused sample designs	The layout and orientation of sampling designs are based on the size, shape, and depth of the Site. The datasets from the sample design are used to confirm attainment of RAOs.	When both focused and statistical samples exist for an analyte at a waste site, only the statistical samples were used to calculate the representative concentrations. An uncertainty analysis was performed to evaluate the effect the selection of focused and/or statistical samples has on the risk assessment results. Representative concentrations for these waste sites are also calculated using the combined focused and statistical samples. The statistical representative concentrations were compared to the combined focused and statistical samples and shown in Table C3-11 in Appendix C, Section C-3, "Representative Concentrations."	The approach used to evaluate the dataset for each sample design is the same as that used for the closeout documentation.	Evaluation of only the data from statistical sample designs when focused sample data are also collected has the potential to understate risk. Frequently focused sample results are collected in areas with the highest potential for contamination to be present. The RI/FS soil risk assessment results will be used to identify waste sites that warrant evaluation of remedial alternatives in the FS. The RI/FS soil risk assessment can also be used to disposition the waste site from an interim status to final closure status when risk thresholds are not exceeded.
COPC Identification	Closeout documentation did not incorporate a COPC identification step. All detected analytes with remedial action goals reported in *Remedial Design Report/Remedial Action Work Plan for the 100 Area* (DOE/RL-96-17) were evaluated in the closeout documentation. It should be noted that the remedial action goals listed in DOE/RL-96-17 do not include analytes that meet exclusion criteria.	The COPC refinement process includes a number of complementary steps and criteria, including a preselected list of contaminants that were excluded and a list that were included, as determined and agreed upon among the Tri-Parties. Additional selection steps include evaluation of all data according to detection status, statistical comparisons of Hanford Site data to background and reference site data, and an analyte-specific evaluation. Each interim action ROD area has a separate list of COPCs.	COPC identification uses the exclusion criteria defined in Section 6.2.1.3 of this Chapter. The inclusion list and other refinement steps used in the RCBRA were not incorporated into the RI/FS. When a COPC was detected at least once in a waste site decision unit (and it did not meet the exclusion criteria) it was carried into all risk calculations.	COPC refinement in RCBRA often included analytes that were not detected at the waste site. The inclusion of analytes that were not detected at a waste site decision unit results in an overstatement of risk. The method used to identify COPCs in the RI/FS is similar to the method used in the closeout documentation. The RI/FS and closeout documentation did not evaluate analytes that met exclusion criteria. Although two different COPC identification processes were used in the RCBRA and the RI/FS, similar risk drivers were identified in the risk characterization step of the analysis as shown in Tables 6-1 to 6-3.
Exposure point concentrations	The primary statistical calculation to support closeout documentation was the 95 percent UCL on the arithmetic mean of the data for waste sites closed using a statistical/random sampling design. Statistical calculations were performed in compliance with *Statistical Guidance for Ecology Site Manager* (Ecology Publication 92-54). This guidance addresses two kinds of data distributions: normal, and lognormal. This guidance also implements the substitution method where a proxy value of one-half the detection limit is assigned to nondetected results. For small datasets (n<10) a nonparametric distribution was assumed. When a nonradionuclide was detected in fewer than 50 percent of the samples collected and for focused sampling designs, the maximum detected value was used for comparison purposes. For radionuclides, a 95 UCL was always calculated using a nonparametric method based on the "z" statistic.	Representative concentrations pertain to sampled medium, whereas EPCs also include modeled concentrations in other exposure media. In general, the process used in the RCBRA follows EPA guidance as provided in the *ProUCL Version 4.0 User Guide* (EPA/600/R-07/038). The ProUCL software was not used to calculate representative concentrations.	*Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (OSWER 9285.6-10) is the EPA guidance for UCL calculation and ProUCL 4.00.05 serves as the companion software package for this guidance. ProUCL 4.00.05 contains rigorous parametric and nonparametric (including bootstrap methods) statistical methods that can be used on full datasets without nondetects and on datasets with below detection or nondetect observations. Both ProUCL and *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (OSWER 9285.6-10) were used to recalculate the UCLs for the 100-D/H Source OU.	*ProUCL Version 4.0 User Guide* (EPA/600/R-07/038) draws from guidance documented in *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (OSWER 9285.6-10). Methodologies for calculating 95 UCLs are similar between the RCBRA and the RI/FS. The methodology used in the closeout documentation addresses only two data distributions for the 95 UCL calculation and implemented the substitution of one-half the detection limit value for nondetected results.

Table 6-4. Comparison of Methods and Assumptions Used for the Residential Scenario

Parameter	Method Used in Closeout Documentation	Method Used in RCBRA	Method Used in RI/FS	Overall Effect on RI/FS
Waste Site Specific Information				
Exclusion of focused sample design data from waste site 1607-H2	Both focused and statistical sample design datasets were evaluated in the closeout documentation.	Focused sample design datasets were not evaluated. Only statistical sample design datasets were evaluated.	Both focused and statistical sample design datasets were evaluated in the RI/FS.	Exclusion of some datasets has the potential to understate risks in the RCBRA.
Exclusion of shallow zone waste site 1607-H4	Both focused and statistical sample design datasets were evaluated in the closeout documentation.	COPCs on OU-specific list were not detected.	All analytes detected at 1607-H4 were identified as COPCs and carried forward into the risk characterization step of the analysis	Exclusion of some datasets has the potential to understate risks in the RCBRA.
Chemical Risk for 100-D-49:4	Aroclor-1254 was included in the closeout documentation for this waste site.	Analyte-specific evaluation for 100-D/H COPCs excluded Aroclor-1254.	COPC selection process for RI/FS included all detected analytes, which includes Aroclor-1254 for 100-D-49:4.	May have the potential to overstate risks.
Chemical Risk for 1607-D2:3	bis(2-ethylhexyl)phthalate was included in the closeout documentation for this waste site.	Analyte-specific evaluation for 100-D/H COPCs did not include bis(2-ethylhexyl)phthalate.	COPC selection process for RI/FS included all detected analytes, which includes bis(2-ethylhexyl)phthalate for 1607-D2:3	May have the potential to overstate risks.

COPC = contaminant of potential concern
CVP = Cleanup Verification Package
EPA = U.S. Environmental Protection Agency
MTCA = Model Toxics Control Act
OU = operable unit
PEF = particulate emission factor
PRG = preliminary remediation goal
RAO = remedial action objective
RBSL = risk-based screening level
RCBRA = River Corridor Baseline Risk Assessment
RESRAD = Residual Radioactivity
RI/FS = Remedial Investigation/Feasibility Study
ROD = record of decision
RSVP = Remaining Site Verification Package
UCL = upper confidence limit
WDOH = Washington Department of Health

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The interim action ROD residential scenario for chemicals is based on the 1996 MTCA Method B direct contact soil cleanup levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]). The 1996 MTCA Method B direct contact soil cleanup levels are based solely on incidental soil ingestion and do not address the food exposure pathways that were included for the radionuclide Rural Residential scenario. The 2007 MTCA (WAC 173-340) Method B direct contact soil cleanup levels developed in this chapter are similar to those published in the most recent version of the 100 Area RDR/RAWP (DOE/RL-96-17) with the exception of those chemicals with remedial action goals based on the inhalation exposure route.

In addition to performing the risk-based screening evaluation, another purpose for updating the PRGs is to determine whether the remedial action goals developed and reported in the 100 Area RDR/RAWP (DOE/RL-96-17) are protective when compared to current guidance. Chapter 8 provides a summary of the remedial action goals reported in the 100 Area RDR/RAWP in addition to the PRGs presented in this chapter.

6.1.3 RI/FS Soil Risk Assessment (Reasonably Anticipated Future Land Use Scenarios)

The RCBRA (DOE/RL-2007-21) evaluated risks for a range of exposure scenarios that represent a range of upper bound and reasonably anticipated receptors and activities. When soil cleanup levels were initially established for the River Corridor, the TPA signatories agreed that it was appropriate to protect for a range of potential exposures in the future so that interim cleanup actions did not limit future use of the Site. The Resident Monument Worker and the Casual Recreational User scenario represent reasonably anticipated future land use.

PRGs are presented in this section for both scenarios (resident Monument worker and the casual recreational user), as well as residential PRGs, for use in the risk-based screening evaluation. CVP and RSVP data are compared to these PRGs. When the total risk for a waste site is less than 1×10^{-4} for radionuclides based on the residential scenario or 1×10^{-5} for chemicals based on 2007 MTCA Method B direct contact soil cleanup levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]), then protection of the resident Monument worker and casual recreational user is also achieved. The results of these comparisons can be used in risk management decisions (presented in Section 6.2.5.5) and show that the total risk calculated for the Residential and Resident Monument Worker scenarios are essentially identical. The Residential PRGs are slightly lower than the Resident Monument Worker PRGs because the Residential exposure scenario includes the food chain pathways.

The Resident Monument Worker scenario was evaluated in the RCBRA (DOE/RL-2007-21) as an occupational scenario and was applied on a local and broad area scale. In the RCBRA (DOE/RL-2007-21), the resident Monument worker spent a fraction of the day on the waste site at his residence (local area) and spent a fraction of the same day in a region as large as an individual ROD decision area (comparable to an OU) and potentially as large as the entire River Corridor conducting work activities (broad area). To incorporate the use of this exposure scenario in the RI/FS process, the scenario was modified to assume that the broad area concentration was equal to the RME broad area upland surface soil concentration reported in the RCBRA (DOE/RL-2007-21). The PRG value represents the concentration of soil the resident Monument worker is exposed to on the waste site (local area).

With the exception of the soil ingestion rate and exposure time, the exposure assumptions used to calculate the resident Monument worker local area PRGs are the same as those that would be used to provide an RME for the residential exposure scenario. With the exception of the soil ingestion rate, the exposure assumptions used to calculate the resident Monument worker broad area risks are the same as those that would be used to provide an RME for the Industrial Worker exposure scenario defined in *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual* *Supplemental Guidance* *"Standard Default Exposure Factors" Interim Final* (OSWER Directive 9285.6-03). Some

exposure assumptions were updated based on recent EPA guidance or modified to conform to recommended EPA methodology for calculation of PRGs. Exposure assumptions that were updated based on recent guidance include inhalation rates, PEFs, and the external gamma shielding factor. The exposure assumptions that were modified to correlate to standard PRGs equations include soil ingestion rates, indoor time fraction, onsite exposure time, and use of decay factors. These updates and modifications allow a PRG to be developed to confirm that cleanup actions at the waste site will protect reasonably anticipated future land uses. Table 6-5 summarizes the modifications made to the Resident Monument Worker exposure scenario for use as a PRG.

Table 6-5. Summary of Differences in Exposure Assumptions for the Resident Monument Worker between the RCBRA and RI/FS Risk Assessment

Parameter	RCBRA Resident Monument Worker	RI/FS Resident Monument Worker
Soil ingestion rate	A soil ingestion rate of 100 mg/day is assumed for this receptor. The soil ingestion rate is apportioned to the local area and the broad area based on the amount of time the receptor spends at each area. The RCBRA (DOE/RL-2007-21) allocated 52.2 mg/day to the residential portion (local area) of this scenario and 25 mg/day to the occupational portion (broad area) of this scenario.	A soil ingestion rate of 100 mg/day is assumed for this receptor. The RI/FS allocated 76.2 mg/day to residential portion (local area) of this scenario and 23.8 mg/day to the occupational portion (broad area) of this scenario for a total of 100 mg/day.
Inhalation rate	The RCBRA (DOE/RL-2007-21) assumed an inhalation rate of 0.63 m^3/hour based on an inhalation rate of 15 m^3/day.	The RI/FS assumed an inhalation rate of 0.83 m^3/hour based on an inhalation rate of 20 m^3/day.
Particulate Emission Factor	The RCBRA (DOE/RL-2007-21) used a PEF of 1.08×10^8 m^3/kg for the local area and a PEF of 4.3×10^8 m^3/kg for the broad area.	The RI/FS used the EPA default PEF of 7.3×10^{10} m^3/kg for the local area and a PEF of 2.6×10^{10} m^3/kg for the broad area.
Time spent on the local area and broad area scale	The RCBRA (DOE/RL-2007-21) assumed an exposure time of 13 hours/day spent at the residence (local area), 8 hours spent onsite at work (broad area), and 3 hours offsite (neither local nor broad area) for a total of 24 hours/day.	The RI/FS assumed that an exposure time of 16 hours/day was spent at the residence (local area) and 8 hours/day onsite at work (broad area) for a total of 24 hours/day.
Indoor and outdoor exposure time	The RCBRA (DOE/RL-2007-21) assumed that the resident spent 13 hours/day indoors, 8 hours/day outdoors, and 3 hours/day offsite.	The RI/FS assumed that the resident spent 13 hours/day indoors and 3 hours/day outdoors (local area) and the worker spent 8 hours/day outdoors (broad area).
Gamma shielding factor	The RCBRA (DOE/RL-2007-21) used an external gamma shielding factor of 0.7.	The RI/FS used an external gamma shielding factor of 0.4 based on current guidance.
Radiological decay factors	Decay of radioisotopes over the exposure duration was not accounted for.	Decay of radioisotopes over the exposure duration was incorporated.

EPA = U. S. Enviornmental Protection Agency
PEF = particulate emission factor
RCBRA = River Corridor Baseline Risk Assessment
RI/FS = Remedial Investigation/Feasibility Study

The Casual User scenario was evaluated in the RCBRA (DOE/RL-2007-21, Volume II) as a recreational scenario and was applied on a broad area scale; the casual user spent time enjoying recreational activities (broad area) only in a region as large as an individual ROD OU, and potentially as large as the entire River Corridor. Similar to the Resident Monument Worker, this exposure scenario was used to calculate forward risk estimates. To incorporate the use of this exposure scenario in the RI/FS process, the scenario

was modified to develop a PRG assuming that all of the casual user time was spent on the waste site (local area). This assumption is the only modification made to this exposure scenario; no changes were made to the exposure assumptions used to calculate PRG values. This modification allows a conservative PRG to be developed to confirm that cleanup actions at the waste site will protect casual users.

Some exposure assumptions for the Casual Recreational User scenario were updated based on recent EPA guidance or modified to conform to recommended EPA methodology for calculation of PRGs. Exposure assumptions that were updated based on recent guidance include the incidental soil ingestion rate, the inhalation rate, PEF, time spent on the local area and broad area scale, external gamma shielding factor, and radiological decay. The exposure assumptions that were modified to correlate to standard PRGs equations include soil ingestion rates and use of decay factors. These updates and modifications allow a PRG to be developed to confirm that cleanup actions at the waste site will protect human health and the environment. Table 6-6 summarizes the modifications made to the Casual Recreational User exposure scenario for use as a PRG.

Table 6-6. Summary of Differences in Exposure Assumptions for the Casual Recreational User between the RCBRA and RI/FS Risk Assessment

Parameter	RCBRA Casual User	RI/FS Casual Recreational User
Soil ingestion rate	A soil ingestion rate of 100 mg/day for an adult and 200 mg/day for a child were assumed for this receptor. Soil ingestion at the waste site was assumed proportional to the fraction of waking hours spent at the Site.	A soil ingestion rate of 100 mg/day for an adult and 200 mg/day for a child were assumed for this receptor. All soil ingestion was assumed to occur at the waste site.
Inhalation rate	The RCBRA (DOE/RL-2007-21) assumed an inhalation rate of 1 m^3/hour for an adult and 1 m^3/hour for a child based on EPA recommended short-term exposure values for light activity.	The RI/FS assumed an inhalation rate of 0.83 m^3/hour for an adult, based on an inhalation rate of 20 m^3/day, and 0.417 m^3/hour for a child, based on an inhalation rate of 10 m^3/day (*Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals): Interim* [EPA/540/R-92/003]).
Particulate Emission Factor	The RCBRA (DOE/RL-2007-21) used a PEF of 4.3×10^8 m^3/kg for the broad area.	The RI/FS used the EPA default PEF of 7.3×10^{10} m^3/kg (*Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* [OSWER 9355.4-24]).
Time spent on the local area and the broad area scale	The RCBRA (DOE/RL-2007-21) assumed an exposure time of 6 hours/day is spent onsite, all in the broad area.	The RI/FS assumed an exposure time of 6 hours/day is spent onsite, all in the local area.
Gamma shielding factor	The RCBRA (DOE/RL-2007-21) did not apply a gamma-shielding factor (all exposure is assumed to occur outdoors).	The RI/FS did not apply a gamma-shielding factor (all exposure is assumed to be occurring outdoors).
Radiological decay factors	Decay of radioisotopes over the exposure duration was not accounted for.	Decay of radioisotopes over the exposure duration was incorporated.

EPA = U.S. Environmental Protection Agency
PEF = particulate emission factor
RCBRA = River Corridor Baseline Risk Assessment
RI/FS = Remedial Investigation/Feasbility Study

6.1.4 Other Residential Land Use Scenarios in RCBRA

The RCBRA (DOE/RL-2007-21, Volume II) also evaluated three residential scenarios that describe exposures related to a rural land-use pattern that involves home-produced foods. The Subsistence Farmer scenario envisions a substantial quantity of home-produced foods, but not a diet composed solely of such foods. The two Native American Resident scenarios, however, envision a complete subsistence lifestyle where all foods are grown at the home or (in the case of fish) caught in the Columbia River. Residential receptors are assumed to spend effectively all of their time in the area around a residence located on a remediated waste site to assign all soil-related exposures to that site.

PRGs were not calculated in the RCBRA (DOE/RL-2007-21, Volume II) for these additional residential scenarios. Direct contact and food chain exposure associated with radiological contaminants for unrestricted land use are represented by the Rural Residential scenario described in Section 6.1.2.

DOE, through discussions with the Tribes, has agreed to include quantitative analysis of Native American scenarios in risk assessments supporting RI/FS documents. The two scenarios considered are provided by the CTUIR and the Yakama Nation. The RCBRA (DOE/RL-2007-21, Volume II) presents the risks and hazards calculated for both Native American exposure scenarios from direct contact, external gamma exposure, inhalation, and food chain pathways from remediated waste sites. The groundwater risk assessment presented in Section 6.3 presents the results of both Native American scenarios for potentially complete exposure pathways associated with groundwater. The groundwater risk assessment presents the risks and hazards calculated for groundwater used as a source of drinking water and as a source of steam for sweat lodge (see Section 6.3.8.5.1). The results from the RCBRA for remediated waste sites and the results from the groundwater risk assessment can be summed to obtain a cumulative estimate of risk for all exposure pathways included in the CTUIR and Yakama Nation exposure scenarios. These tribal scenarios have been evaluated and presented in Hanford Site risk assessments to assist interested parties in providing input on remedial alternatives (*Feasibility Study Report for the 200-ZP-1 Groundwater Operable Unit* [DOE/RL-2007-28]), and have not been used for development of PRGs as part of alternatives analyses in the FS.

The results of the local area risk assessment for the residential scenarios indicate that present-day RME cancer risk is frequently greater (11 of 28 remediated sites at the 100-D Source OU and seven of seven remediated sites at the 100-H Source OU for the Subsistence Farmer scenario) than 1×10^{-4} and that RME chemical hazard index (HI) frequently (4 of 28 remediated sites at the 100-D Source OU and seven of seven remediated sites at the 100-H Source OU for the Subsistence Farmer scenario) exceeds the threshold HI of 1. A summary of risks and noncancer hazards associated with the Subsistence Farmer scenario is provided in Table 6-7. Present-day RME cancer risks greater than 1×10^{-4} for the Subsistence Farmer exposure scenario are almost entirely related to one of three factors:

- External irradiation from short-lived radionuclides including europium-152, cesium-137, and cobalt-60
- Exposure to arsenic from ingestion of garden produce
- Exposure to the short-lived radionuclide strontium-90 from ingestion of produce and livestock products

By the year 2075, the RCBRA (DOE/RL-2007-21) calculated the Subsistence Farmer RME cancer risks above 1×10^{-4} are related overwhelmingly to arsenic exposure from produce ingestion. Because the CTUIR Resident and Yakama Resident scenarios use very high (subsistence level) Hanford Site-raised food ingestion rates, strontium-90 still plays a significant role in food-related exposures at year 2075 for

these scenarios. By the year 2150, however, CTUIR Resident and Yakama Resident cancer risks above 1×10^{-4} are dominated by arsenic exposure from ingestion of garden produce.

- The RCBRA (DOE/RL-2007-21, Volume II) Subsistence Farmer cancer risk and chemical HI results were frequently above threshold criteria. The Subsistence Farmer reported cancer risk and chemical HI results above threshold criteria whereas the closeout documentation reported that residual chemical concentrations met or were below threshold criteria. The two major differences were identified between the risk assessment methods used in the RCBRA (DOE/RL-2007-21, Volume II) and the basis of the interim remedial action goals. These differences were as follows: Residential interim action remedial action goals for chemicals are 1996 MTCA Method B direct contact soil cleanup levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]), which is an RME scenario based on incidental soil ingestion and does not address the food exposure pathways historically evaluated for radionuclides.
- The interim action remedial action goal for arsenic is 20 mg/kg, which is an "adjusted" value established by the State of Washington to address a range of natural background levels 2007 MTCA ("Tables" [WAC 173-340-900]).

These differences largely explain why some waste sites that were remediated to meet the interim action RAGs still appear to present high levels of residual risk under the Subsistence Farmer scenario:

One of the primary uncertainties for site-specific results relates to modeled exposure concentrations in foods, particularly garden produce. Further discussion of the potential biases in modeled food chain exposures is provided in the RCBRA (DOE/RL-2007-21). As discussed in Section 5.9.4.2 of the RCBRA (DOE/RL-2007-21), in the case of the noncancer HI results for produce ingestion of mercury, uranium, and copper, a large conservative bias is anticipated because a linear plant uptake model was applied to soil concentrations that are far above naturally occurring levels. In the case of arsenic, produce ingestion provides the largest contribution to total cancer risk, even though the range of site soil concentrations is relatively small. Uncertainty in produce concentrations is attributable to intrinsic variability related to soil conditions, plant species and tissue type, harvest time, and other variables. A review of recommended plant-soil ratios from a number of sources, as described in Section 5.9.2.4 of the RCBRA (DOE/RL-2007-21, Volume II), shows that the range of soil to plant transfer ratios for arsenic (from 0.006 to 1.125) is approximately a factor of 200. The value of 0.53 used in the HHRA, from the RESRAD computer code that has been used to perform dose assessment at the Hanford Site and other DOE facilities, is near the upper end of this range. The high-end values for plant-soil concentrations, many of which were used in the RCBRA (DOE/RL-2007-21, Volume II) to assess exposure through food pathways, may result in a scenario that provides exposures to nonradionuclide contaminants higher than an RME. PRGs identified in this document for nonradiological analytes are based on 2007 MTCA procedures, which do not include food chain pathways.

Table 6-7. Summary of Excess Lifetime Cancer Risks and Noncancer Hazards for the Subsistence Farmer Scenario Reported in the RCBRA

Waste Site Name	Present Day Total Cancer Risk	COPC	Pathway	Present Day Hazard Index	COPC	Pathway
100-D Source OU Waste Sites						
100-D-4	6×10^{-5}	None	--	0.12	None	--

Table 6-7. Summary of Excess Lifetime Cancer Risks and Noncancer Hazards for the Subsistence Farmer Scenario Reported in the RCBRA

Waste Site Name	Present Day Total Cancer Risk	COPC	Pathway	Present Day Hazard Index	COPC	Pathway
100-D-12	--[a]	None	--	--[a]	None	--
100-D-20	2×10^{-4}	Cesium-137	External Irradiation	0.25	None	--
		Europium-152	External Irradiation			
100-D-21	2×10^{-5}	None	--	--[a]	None	--
100-D-22	--[a]	None	--	--[a]	None	--
100-D-48:1	9×10^{-5}	None	--	0.14	None	--
100-D-48:2	2×10^{-4}	Cesium-137	External Irradiation	0.15	None	--
		Europium-152	External Irradiation			
		Cobalt-60	External Irradiation			
100-D-48:3	4×10^{-4}	Cesium-137	External Irradiation	0.17	None	--
		Strontium-90	Milk Ingestion			
		Cesium-137	Milk Ingestion			
100-D-48:4	2×10^{-4}	Cesium-137	External Irradiation	0.21	None	--
		Europium-152	External Irradiation			
		Strontium-90	Milk Ingestion			
100-D-49:2	6×10^{-5}	None	--	0.11	None	--
100-D-49:4	2×10^{-4}	Europium-152	External Irradiation	0.56	None	--
100-D-52	7×10^{-6}	None	--	0.13	None	--
116-D-1A	2×10^{-4}	Cesium-137	External Irradiation	0.16	None	--
		Europium-152	External Irradiation			
		Strontium-90	Milk Ingestion			
		Strontium-90	Produce Ingestion			
116-D-2	2×10^{-5}	None	--	0.14	None	--

Table 6-7. Summary of Excess Lifetime Cancer Risks and Noncancer Hazards for the Subsistence Farmer Scenario Reported in the RCBRA

Waste Site Name	Present Day Total Cancer Risk	COPC	Pathway	Present Day Hazard Index	COPC	Pathway
116-D-4	8×10^{-6}	None	--	0.13	None	--
116-D-7	1×10^{-4}	None	--	0.18	None	--
116-D-9	7×10^{-5}	None	--	0.16	None	--
116-DR-1&2	1×10^{-4}	None	--	0.14	None	--
116-DR-4	3×10^{-5}	None	--	0.15	None	--
116-DR-6	1×10^{-4}	None	--	0.13	None	--
116-DR-7	4×10^{-5}	None	--	0.15	None	--
116-DR-9	7×10^{-4}	Cesium-137	External Irradiation	0.054	None	--
		Cesium-137	Milk Ingestion			
118-DR-2:2	8×10^{-4}	Arsenic	Produce Ingestion	2.9	Arsenic	Produce Ingestion
122-DR-1:2	5×10^{-4}	Arsenic	Produce Ingestion	2.6	Arsenic	Produce Ingestion
1607-D2:1	2×10^{-4}	Arsenic	Produce Ingestion	1.2	Arsenic	Produce Ingestion
1607-D2:3	3×10^{-5}	None	--	0.63	None	--
1607-D2:4	9×10^{-6}	None	--	0.13	None	--
1607-D4	2×10^{-4}	Arsenic	Produce Ingestion	1.4	Arsenic	Produce Ingestion
100-H Source OU Waste Sites						
100-H-5	7×10^{-4}	Arsenic	Produce Ingestion	4.7	Arsenic	Produce Ingestion
					Mercury	Beef Ingestion
100-H-17	7×10^{-4}	Arsenic	Produce Ingestion	3	Arsenic	Produce Ingestion
100-H-21	2×10^{-3}	Arsenic	Produce Ingestion	12	Arsenic	Produce Ingestion
100-H-24	7×10^{-4}	Arsenic	Produce Ingestion	3.6	Arsenic	Produce Ingestion
116-H-1	1×10^{-3}	Arsenic	Produce Ingestion	5.9	Arsenic	Produce Ingestion
116-H-7	1×10^{-3}	Arsenic	Produce Ingestion	4.7	Arsenic	Produce Ingestion

Table 6-7. Summary of Excess Lifetime Cancer Risks and Noncancer Hazards for the Subsistence Farmer Scenario Reported in the RCBRA

Waste Site Name	Present Day Total Cancer Risk	COPC	Pathway	Present Day Hazard Index	COPC	Pathway
1607-H2	1×10^{-3}	Arsenic	Produce Ingestion	69	Mercury	Beef Ingestion
					Mercury	Produce Ingestion

Notes: Risk drivers shown have an associated risk greater than 1×10^{-4}.

No COCs were identified.

Source: RCBRA data from *River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment* (DOE/RL-2007-21), Part 2 (Tables 5-102 and 5-104).

COC = contaminant of concern

COPC = contaminant of potential concern

OU = opearable unit

RCBRA = River Corridor Baseline Risk Assessment

6.2 Soil Risk Assessment

Section 6.1.1 summarized the evaluation of residual risks performed in the RCBRA (DOE/RL-2007-21, Volume II) for waste sites cleaned up under the interim action ROD. Section 6.1.2 described how elements of the RCBRA (DOE/RL-2007-21, Volume II) were updated to reflect current guidance, risk assessment methodologies, and toxicity information to support the FS. Section 6.2 provides the updated soil risk assessment, which implements the updates described in Section 6.1.2.

The following paragraphs describe the 100-D/H Source OU soil risk assessment followed:

- Identify all waste sites with a “no action” or “interim closed out” reclassification status.
- Obtain verification sampling and analysis data for all “no action” and “interim closed out” waste sites that have been remediated through July 2011[4].
- Compute EPCs for each detected analyte measured at a waste site, using the EPA’s ProUCL version 4.00.05 software (ProUCL Version 4.00.05 User Guide (Draft) [EPA/600/R-07/038]).
- Compare EPCs to direct contact RBSLs selected to represent baseline conditions and reasonably anticipated future Hanford Site use.
- Calculate cancer risk and noncancer hazards for each detected analyte.
- Compare cancer risks and noncancer hazards to acceptable state and federal target risk and noncancer thresholds.
- Determine whether the “no action” or “interim closed out” waste site should be carried forward into the FS to select remedial alternatives.

[4] These are waste sites for which interim action cleanups had been completed under interim action RODs and for which the CVPs were completed through July 2011.

This soil risk assessment follows the risk assessment guide (EPA/540/1-89/002). The following sections describe the four-step process. Because this soil risk assessment is intended to complement the analysis performed in the RCBRA (DOE/RL-2007-21, Volume II), where applicable, a brief description is provided to describe the similarities in approach.

6.2.1 Data Analysis

This section describes the sources of data used in the risk assessment (Section 6.2.1.1), describes the data quality assessment (DQA) and data validation process (Section 6.2.1.2), and identifies COPCs in vadose zone material that are accessible for human exposures (Section 6.2.1.3). During the course of this risk assessment, analytes were evaluated to identify COPCs and prioritize those estimated to pose an unacceptable risk and warrant evaluation in the FS.

6.2.1.1 Sources of Analytical Data Used in Risk Assessment

This soil risk assessment includes vadose zone material samples for remediated waste sites with a "no action" or "interim closed out" reclassification status collected within the 100-DR-1, 100-DR-2, 100-HR-1, and 100-HR-2 Source OUs. Waste sites where remediation and verification sampling and analysis were assessed by the end of July 2011 are included in the soil risk assessment.

All samples were collected and analyzed in accordance with the requirements stated in *100 Area Remedial Action Sampling and Analysis Plan* (hereinafter called 100 Area SAP [DOE/RL-96-22]). Data collected under the 100 Area SAP (DOE/RL-96-22) are used to meet the purpose and objectives of the 100 Area RDR/RAWP (DOE/RL-96-17), which describes the design and the implementation of the remedial action processes required by the following:

- *Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington (100 Area Remaining Sites)* (EPA/ROD/R10-99/039)
- *Amendment to the Interim Remedial Action Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington* (EPA/AMD/R10-97/044)
- *Declaration of the Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington* (EPA/541/R-00/121)

Remediation of waste sites in the 100-D/H Source OUs began in 1996. The constituents are identified for each waste site based on process knowledge, site history, and site-specific discussions with the lead regulatory agency. Constituents analyzed include the COPCs for the waste site; as a result different constituents are analyzed at each waste site. Therefore, only constituents reported at each waste site are included in risk calculations. Analytical results for each waste site are included in the associated closeout documentation, which is listed in Appendix C, Table C-1, of the 100-D/H Work Plan (DOE/RL-2008-46-ADD1). Both the 100-D/H Work Plan (DOE/RL-2008-46-ADD1) and the 100 Area RDR/RAWP (DOE/RL-96-17) were reviewed and approved by the Tri-Parties.

Ninety-five 100-D Source OU waste sites have verification sampling data and are included in this soil risk assessment. Twenty-eight of these 100-D Source OU waste sites were evaluated in the RCBRA (DOE/RL-2007-21, Volume II). An additional thirteen 100-D Source OU sites, referred to as associated waste sites, have been remediated, but are included in another waste site's sampling and closeout documentation. Forty-seven 100-H Source OU waste sites have verification sampling and analysis data and are included in this soil risk assessment. Eight of these 36 100-H Source OU waste sites were evaluated in the RCBRA (DOE/RL-2007-21, Volume II). An additional 10 100-H Source OU sites, referred to as consolidated sites, have been remediated but are included in another waste site's sampling

and closeout documentation. A summary of the waste sites, associated decision unit(s), and reclassification status for 100-D Source OU and 100-H Source OU is provided in Tables G-1 and G-2, respectively. Waste site decision units are defined in Section 6.2.2.2. The waste sites listed in Tables G-1 and G-2 are a subset of the waste sites that were listed in Appendix C, Table C-1, of the 100-D/H Work Plan (DOE/RL-2008-46-ADD1). Summaries of the remediated waste sites and consolidated waste sites for the 100-D and 100-H Source OUs is provided in Tables 6-8 and 6-9, respectively.

Table 6-8. Summary of Remediated Waste Sites and Associated Waste Sites in the 100-D Source OUs

Waste Site Totals	Remediated Waste Site	Associated Waste Sites[a]
100-D Source OU		
100-DR-1		
	100-D-1	--
	100-D-18	
	100-D-19	
	100-D-2	
	100-D-20	
	100-D-21	
	100-D-22	
	100-D-24	
	100-D-29	
	100-D-3	
	100-D-31:1[b]	
	100-D-31:10	
	100-D-31:2[b]	
	100-D-31:3	
	100-D-31:4	
	100-D-31:5	
	100-D-31:6	
	100-D-31:7	
	100-D-31:8	
	100-D-31:9	
	100-D-32	
	100-D-4	
	100-D-42[c]	
	100-D-45[c]	

Table 6-8. Summary of Remediated Waste Sites and Associated Waste Sites in the 100-D Source OUs

Waste Site Totals	Remediated Waste Site	Associated Waste Sites[a]	
	100-D-48:1	100-D-49:1	UPR-100-D-4
	100-D-48:2	UPR-100-D-2	UPR-100-D-3
	100-D-48:3	100-D-5	100-D-6
	100-D-48:4	--	
	100-D-49:2		
	100-D-49:3		
	100-D-49:4		
	100-D-50:5		
	100-D-52		
	100-D-56:1		
	100-D-56:2		
	100-D-61		
	100-D-7		
	100-D-70		
	100-D-74		
	100-D-75:3		
	100-D-80:1		
	100-D-82		
	100-D-83:4		
	100-D-84:1		
	100-D-85:1		
	100-D-87		
	100-D-88		
	100-D-9		
	100-D-90		
	116-D-10		
	116-D-1A	116-D-1B	
	116-D-2	--	
	116-D-4		
	116-D-5		
	116-D-6		

Table 6-8. Summary of Remediated Waste Sites and Associated Waste Sites in the 100-D Source OUs

Waste Site Totals	Remediated Waste Site	Associated Waste Sites[a]
	116-D-7	
	116-D-9	
	116-DR-1 & 2	
	116-DR-5	
	116-DR-9	100-D-25
	118-D-6:4	--
	120-D-2	
	126-D-2	
	128-D-2	
	130-D-1	
	132-D-1	
	1607-D2:1	
	1607-D2:2	
	1607-D2:3	
	1607-D2:4	
	1607-D4	
	1607-D5	
	628-3	
	UPR-100-D-5	
100-DR-1 Source OU Totals	**74**	**8**
100-DR-2		
	100-D-12	--
	100-D-13	
	100-D-15	
	100-D-28:1	
	100-D-43[c]	
	100-D-47	
	100-D-94	
	116-D-8	
	116-DR-10	
	116-DR-4	

Table 6-8. Summary of Remediated Waste Sites and Associated Waste Sites in the 100-D Source OUs

Waste Site Totals	Remediated Waste Site	Associated Waste Sites[a]
	116-DR-6	
	116-DR-7	
	116-DR-8	
	118-D-1	
	118-D-4	
	118-D-5	
	118-DR-1	
	--[d]	100-D-46
	118-DR-2:2	--
	122-DR-1:2	100-D-23 100-D-53 100-D-54 100-D-64
	1607-D1	--
	600-30	
100-DR-2 Source OU Totals	**21**	**5**
100-DR-1 and 100-DR-2	**95**	**13**
100-D Area Total	**108**	

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Sample results are consolidated for the 100-D-31:1 and 100-D-31:2 waste sites.

c. Sample results are consolidated for the 100-D-42, 100-D-43, and 100-D-45 waste sites.

d. Consolidated with 116-D-1A (100-DR-1) remediated waste site.

OU = operable unit

Table 6-9. Summary of Remediated Waste Sites and Consolidated Waste Sites in the 100-H Source OUs

Waste Site Totals	Remediated Waste Site	Associated Waste Sitesa
100-HR-1 Source OU		
	100-H-17	100-H-30 116-H-2
	100-H-21	100-H-1 100-H-22
	100-H-24	--
	100-H-28:1	
	100-H-28:6	
	100-H-3	

Table 6-9. Summary of Remediated Waste Sites and Consolidated Waste Sites in the 100-H Source OUs

Waste Site Totals	Remediated Waste Site	Associated Waste Sitesa
	100-H-35	
	100-H-4	
	100-H-41	
	100-H-45	
	100-H-49:2	
	100-H-5	
	100-H-50	
	100-H-51:4	
	100-H-51:5	
	100-H-53	
	100-H-7	
	100-H-8	
	116-H-1	
	116-H-3	
	116-H-5	
	116-H-7	
	116-H-9	
	100-H-11[b]	100-H-10[b]
	100-H-12[b]	100-H-9[b]
	100-H-14[b]	100-H-13[b]
	118-H-6:3[b]	118-H-6:2[b]
	118-H-6:6[b]	100-H-31[b]
	118-H-6:5	
	118-H-6:4	
	1607-H2	--
	1607-H3	
	1607-H4	
100-HR-1 Source OU Totals	**33**	**9**
100-HR-2 Source OU		
	-- [c]	100-H-2
	100-H-37	--

Table 6-9. Summary of Remediated Waste Sites and Consolidated Waste Sites in the 100-H Source OUs

Waste Site Totals	Remediated Waste Site	Associated Waste Sitesa
	100-H-40	
	118-H-1:1	
	118-H-1:2	
	118-H-2	
	118-H-3	
	118-H-4	
	118-H-5	
	128-H-1	
	128-H-2	
	128-H-3	
	1607-H1	
	600-151	
	600-152	
100-HR-2 Source OU Totals	**14**	**1**
100-HR-1 and 100-HR-2 Totals	**47**	**10**
100-H Area Total	**57**	

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Sample results are consolidated for the 118-H-6:2,118-H-6:3,118-H-6:6,100-H-9, 100-H-10,100-H-11,100-H-12,100-H-13,100-H-14, and 100-H-31 waste sites

c. Consolidated with 100-H-17 (100-DR-1)

OU = operable unit

The following sources of analytical data were used in the soil risk assessment:

- All verification sampling and analysis data reside in the HEIS database.
- All closeout verification data used in this soil risk assessment are included in Appendix D of this report.

6.2.1.2 Data Quality Assessment and Data Validation

A 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 Hanford 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 cleanup Hanford Site verification. The cleanup verification sample analytical data and detailed DQA are 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 the analytical data are evaluated, and a portion 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 SAP 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. Data validation was done in accordance with validation procedures as part of data evaluation.

6.2.1.3 Identification of COPCs

For the purposes of this soil risk assessment, a COPC is defined as an analyte suspected of being associated with site-related activities that represent a potential threat to human health and the environment, and whose data are of sufficient quality for use in a quantitative BRA.

All analytes detected at least once in a waste site decision unit for the waste sites included in the soil risk assessment are identified as COPCs. 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 (for example, shallow zone, deep zone, overburden, or staging pile area). Verification sampling and analysis data are collected according to sample design requirements for the type of decision unit. For the purpose of this soil risk assessment, 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 contributions from naturally occurring metals and anthropogenic radioisotopes are discussed in the risk characterization section in accordance with CERCLA Soil Background Comparisons Guidance (EPA 540-R-01-003). The risk characterization will discuss elevated background concentrations and their contribution to Hanford Site risks as well as naturally occurring elements that are not CERCLA hazardous substances, pollutants, and contaminants but exceed the RBSLs.

The RCBRA (DOE/RL-2007-21) identifies a subset of analytes that is excluded from consideration as COPCs by agreement among the Tri-Parties based on relevant Hanford Site data. The following exclusion lists employed in the RCBRA (DOE/RL-2007-21) were also applied to the waste site verification data during the data reduction steps described in Section 6.2.2.2 and listed in Appendix G, Tables G-5 and G-6:

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 of radioactive decay that would have occurred since operations ceased.

Essential nutrients: Essential nutrients that are present at relatively low concentrations and are toxic only at high concentrations need not be considered in a quantitative risk assessment.

Water quality or soil physical property measurements: These analytes were measured 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 (for example, grain size for soils, water hardness for metal effects).

Background radionuclides (potassium-40, radium-226, radium-228, thorium-228, thorium-230, and thorium-232): These background radionuclides were identified by consensus of Tri-Party managers as not directly related to Hanford Site operations or processes.

The RCBRA (DOE/RL-2007-21) includes two additional steps to identify COPCs that the soil risk assessment did not apply:

Evaluate 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" evaluation.

As a result of not applying these last two steps used in the RCBRA (DOE/RL-2007-21) to identify COPCs, more analytes are identified as COPCs in this soil risk assessment than were identified in the RCBRA (DOE/RL-2007-21, Volume II). Identifying all detected analytes (except those on the exclusion list) as COPCs is a more streamlined approach that is consistent with CERCLA Soil Background Comparisons Guidance (EPA 540-R-01-003).

6.2.2 Exposure Point Concentrations

Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites (hereinafter called Calculating UCL for EPCs [OSWER 9285.6-10]) states that, "an exposure point concentration (EPC) is a conservative estimate of the average chemical concentration in an exposure medium." *Supplemental Guidance to RAGS: Calculating the Concentration Term* (hereinafter called RAGS Supplemental Guidance [OSWER Publication 9285.7-081]) states that, "because of the uncertainty associated with estimating the true average concentration at a site, the 95 percent UCL of the arithmetic mean should be used for this variable." Use of the 95 percent UCL of the arithmetic mean yields risk estimates that correspond to an RME. Instances where a value different from a UCL is used as the EPC are clearly stated in this risk assessment. Reasons and/or justifications are also provided.

Calculating UCL for EPCs (OSWER 9285.6-10) further states that, "The EPC is determined for each individual exposure unit within a site. An exposure unit is the area throughout which a receptor moves and encounters an environmental medium for the duration of the exposure. Unless there is site-specific evidence to the contrary, an individual receptor is assumed to be equally exposed to media within all portions of the exposure unit over the time frame of the risk assessment." For this soil risk assessment, the "exposure unit" and the "decision unit" are operationally defined as being the same. As previously described, one or more decision units are included within a waste site, including shallow vadose zone material (0 to 4.6 m [0 to 15 ft] bgs), deep vadose zone material (greater than 4.6 m [15 ft] bgs), overburden material, and staging pile area footprint material.

Statistical Guidance for Ecology Site Managers (Ecology Publication 92-54) has been used to calculate EPCs for all closeout documentation to date. *Statistical Guidance for Ecology Site Managers* (Ecology Publication 92-54) was published in 1992, and this guidance has been superseded by Calculating UCL for EPCs (OSWER 9285.6-10), which was published in 2002. For this soil risk assessment, UCLs were recalculated for all waste sites and decision units to incorporate the updated guidance in Calculating UCL for EPCs (OSWER 9285.6-10). UCLs that incorporate updated guidance use more rigorous statistical methods to estimate exposure concentrations and eliminate the use of the simple substitution method for nondetects (where a proxy value of one-half the detection limit is assigned to all nondetected results). Calculating UCL for EPCs (OSWER 9285.6-10) notes that because of the complicated formulas used to compute UCLs, there is no general rule about which substitution rule will yield an appropriate UCL. The uncertainty associated with the substitution method increases and its appropriateness decreases as the detection limit becomes larger and as the number of nondetects in the dataset increases.

The following sections describe the statistical methodology used for closeout documentation (Section 6.2.2.1) and the statistical methodology used for this soil risk assessment (Section 6.2.2.2). Although both evaluations used the same dataset, the differences in statistical methodologies may result in differences in the EPC values between the closeout documentation and this risk assessment for the same COPCs in a waste site decision unit.

6.2.2.1 Statistical Evaluation Methodology Used for Closeout Documentation

For waste sites closed using a statistical/random sampling design, the primary statistical calculation to support cleanup verification was the 95 percent UCL on the arithmetic mean of the data. Statistical calculations were performed in compliance with *Statistical Guidance for Ecology Site Managers* (Ecology Publication 92-54). This guidance addresses two kinds of data distributions: normal, and lognormal. For normal data, the guidance recommends a UCL on the mean based on the Student's t-statistic. For lognormal data, the guidance recommends the Land method using the H-statistic. This guidance also implements the substitution method where a proxy value of one-half the detection limit is assigned to nondetected results.

Small datasets (n<10) were evaluated in accordance with Section 5.2.1.4 of *Statistical Guidance for Ecology Site Managers* (Ecology Publication 92-54) and a nonparametric distribution was assumed. When a nonradionuclide was detected in fewer than 50 percent of the samples collected and for focused sampling designs, the maximum detected value was used for comparison purposes.

6.2.2.2 Statistical Evaluation Methodology Used for the Soil Risk Assessment

Calculating UCL for EPCs (OSWER 9285.6-10) is the EPA guidance for UCL calculation and ProUCL 4.00.05 serves as the companion software package for this guidance. ProUCL 4.00.05 contains rigorous parametric and nonparametric (including bootstrap methods) statistical methods that can be used on full datasets without nondetects and on datasets with nondetect observations. Both ProUCL and Calculating UCL for EPCs (OSWER 9285.6-10) were used to recalculate the UCLs for the 100-D/H Source OU.

To ensure that waste sites and decision units are grouped correctly and UCLs are accurately recalculated, all waste sites, decision unit groupings, and sample numbers were individually verified against the original closeout documentation. *Waste Site Evaluation Process for the 100-DR-1, 100-DR-2, 100-HR-1, and 100-HR-2 Source Operable Units* (ECF-100DR1-11-0003), which is provided in Appendix G, documents the process used to confirm a complete list of waste sites with a reclassification status of "interim closed out" or "no action" through July 2011. Verification of sample numbers associated with each waste site was confirmed, along with the decision unit grouping with which the sample is associated. This list of samples is used to verify that the sampling results are complete. The analytical data that have undergone this review process become the final dataset used to calculate the UCLs and associated summary statistics used in this risk assessment. Tables G-3 and G-4 (Appendix G) list the sample numbers associated with each waste site decision unit, along with the date the sample was collected, the type of sample design used, and the Washington State plane coordinates of the sample location.

6.2.2.2.1 Waste Site Decision Units

Verification sampling and analysis data that are associated with the samples listed in Tables G-3 and G-4 (Appendix G) are from several different decision units within a waste site, including shallow vadose zone material, deep vadose zone material, overburden material, and staging pile area footprint material. The following describes the basis of each decision unit and briefly describes the sample designs used.

The floor and sidewalls of an excavated waste site are divided into one or more decision units. A sample design is developed for the decision unit. Sample design requirements for each decision unit are described in the 100 Area SAP (DOE/RL-96-22). In practice, the shallow zone decision unit is typically represented

by material from the excavation floor if at or above 4.6 m (15 ft) and any sidewalls from grade level (0 m) to a depth of 4.6 m (0 to 15 ft). The deep zone decision unit is represented by material from the excavation floor (if below 4.6 m [15 ft]) and by any sidewall materials below 4.6 m (15 ft). As needed, decision subunits and an associated sampling design are also established for suspect clean overburden stockpiles (that is, to verify suitability for backfill material) and the footprint of the staging pile area. The layout and orientation of the sampling designs are based on the size, shape, and depth of the site. Sampling of a waste site decision unit to confirm attainment of RAOs was performed according to one of three types of sampling designs: focused sampling design, random or statistical sampling, or a combination of both.

The decision unit naming convention is summarized in Table 6-10.

Table 6-10. Summary and Definition of Decision Unit Types

Decision Unit Name	Depth	Sampling Design Description
Shallow	0 to 4.6 m (0 to 15 ft) bgs	Samples collected using a statistical sampling design
Deep	Greater than 4.6 m (15 ft) bgs	
Overburden	Not applicable	
Staging pile area	Not applicable	
Shallow_Focused	0 to 4.6 m (15 ft) bgs	Samples collected using a focused sampling design
Deep_Focused	Greater than 4.6 m (15 ft) bgs	
Staging Pile Area_Focused	Not applicable	
bgs = below ground surface		

The process used to calculate EPCs for each waste site and decision unit is documented in *Computation of Exposure Point Concentrations for the 100-DR-1, 100-DR-2, 100-HR-1, and 100-HR2 Source Operable Units* (ECF-100DR1-11-0004), which is provided in Appendix G, and the purpose is to document the data processing and reduction steps, methodology, decision logic, assumptions, input files, and output files used to determine the EPCs.

6.2.2.2.2 *Data Processing and Reduction*

This section describes the data processing and reduction steps that are taken prior to the calculation of UCLs. Figures 6-1 and 6-2 show each of the data processing and data reduction steps, and the number of records associated with each step for the 100-D and 100-H Source OUs, respectively.

6.2.2.2.3 *Laboratory and Data Validation Flags*

Analytical data are received from the laboratory with data qualification flags; validation qualifiers are assigned during the data validation process. The following rules are applied to determine how the sample results can be used for calculating UCLs.

- All sample results flagged with a “U” data qualifier or combination of qualifiers that include a “U,” such as a “UJ,” are considered nondetected concentrations.
- All sample results without a “U” data qualifier are considered detected concentrations, including results without a qualifier or with an “E” or a “J” qualifier.

- Sample results that are rejected and flagged with an "R" validation qualifier are not used for calculating UCLs.

where:

U = Analyzed for but not detected above limiting criteria.

J = Estimated value.

E = Reported value is estimated because of interference (inorganics).

R = Do not use. Further review indicates the result is not valid.

6.2.2.2.4 *Analytes Reported by Multiple Analytical Methods*

Often, a sample is analyzed for an analyte using more than one analytical method, resulting in multiple results for the analyte from the same location and sample date. When analytes are reported by more than one analytical method for a sample, the results are processed to select the method that provides the most reliable results. Considerations for determining data to be retained include method-associated sample size, detection frequency, method sensitivity, and detection limits. The most conservative (that is, health-protective) use of these types of data is the goal. Larger sample size, higher detection frequencies, and lower detection limits are given higher priority for method selection.

For example, lead may be analyzed using EPA Method 200.8 (*Methods for the Determination of Metals in Environmental Samples, Supplement I* [EPA-600/R-94/111]) with an EQL of 0.5 mg/kg, or EPA Method 6010 (*Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B* [SW-846], hereinafter called SW 846) with an EQL of 5.0 mg/kg. For a sample with lead concentrations reported by both methods, the results reported by EPA Method 200.8 (*Methods for the Determination of Metals in Environmental Samples, Supplement I* [EPA-600/R-94/111]) are chosen over EPA Method 6010 (SW 846 [SW-846]) because of the more sensitive detection limit.

6.2.2.2.5 *Field Duplicate Results*

Field QC samples (field duplicates) are collected in the field and analyzed by the laboratory as unique samples. The parent sample and field QC samples are collected from the same location (that is, sample node) and same date, resulting in more than one sample per location and date. Because multiple sets of analytical results cannot be used to quantify risk (that is, this would result in multiple-counting of a chemical), the results for the same location and date are reduced to a single result for each reported analyte. The most conservative (that is, health-protective) result is the goal. The following criteria are used to reduce multiple sample results for one location and date to a single result:

- If two or more detections are reported, the maximum concentration is used.
- If one detection and one or more nondetections are reported, the detected concentration is used. If two or more nondetections are reported, the lowest detection limit is used.

6.2.2.2.6 *Identify Analytes for 95 Percent UCL Calculation*

After extracting and processing the dataset, it is further reduced to identify a subset of analytes that require computation of a UCL. Analytes that meet any of the exclusion criteria or that were not detected in any of the samples analyzed with the 100-D/H Source OU are not carried forward into the statistical calculations and EPC selection. The analyte identification steps and the number of records associated with each of the steps are presented on Figure 6-3 for the 100-D Source OU and Figure 6-4 for the 100-H Source OU.

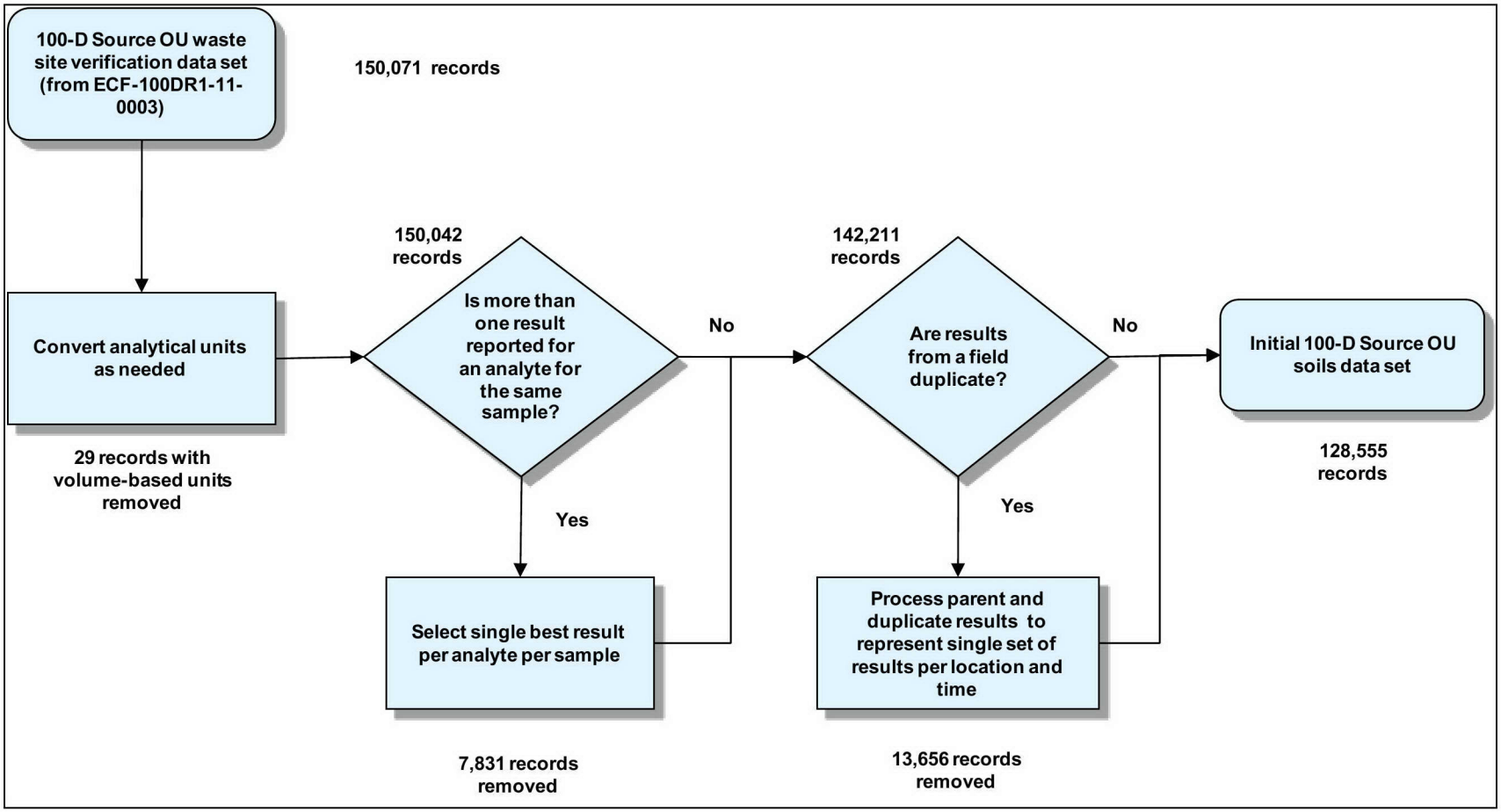

Figure 6-1. Data Processing and Reduction Steps for 100-D Source OU

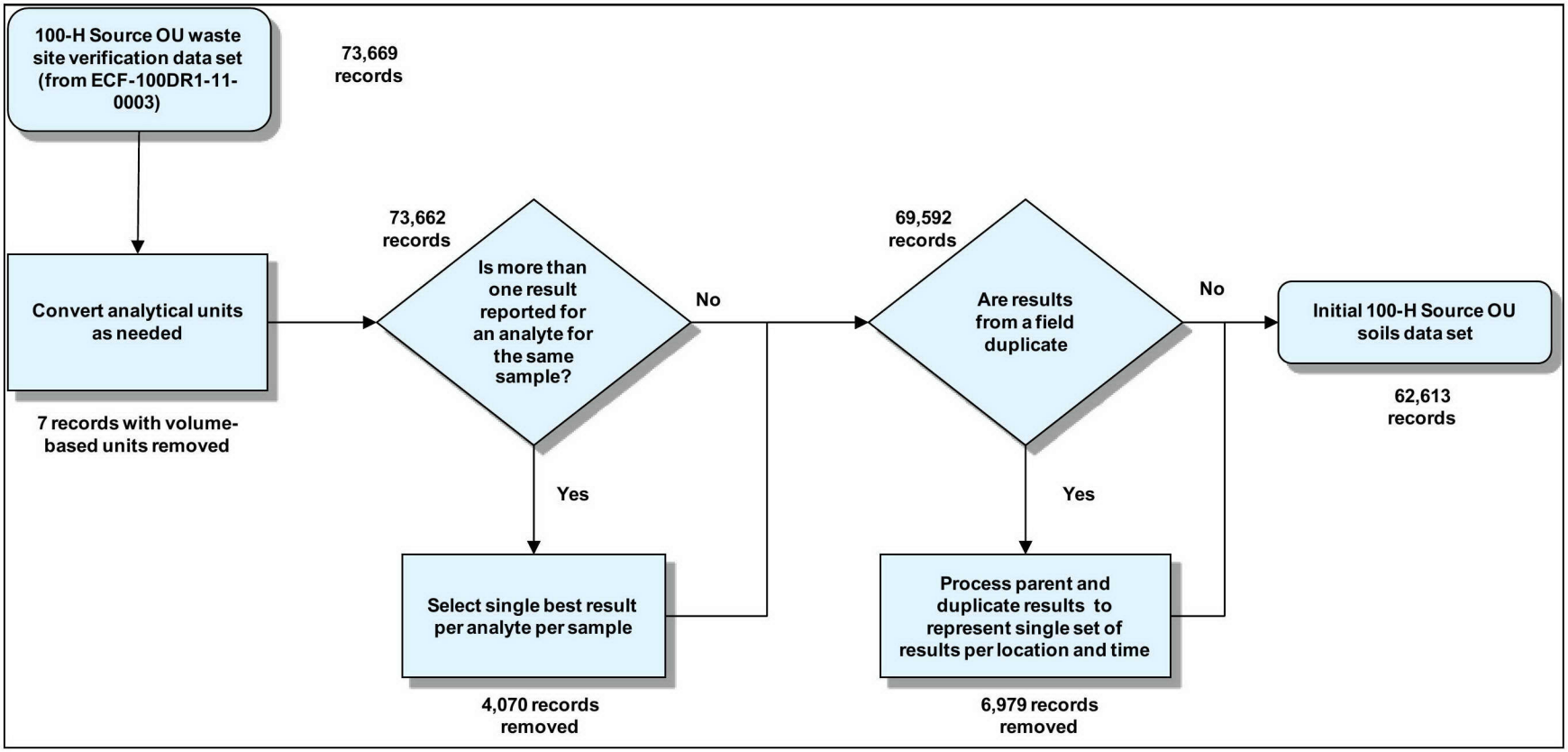

Figure 6-2. Data Processing and Reduction Steps for 100-H Source OU

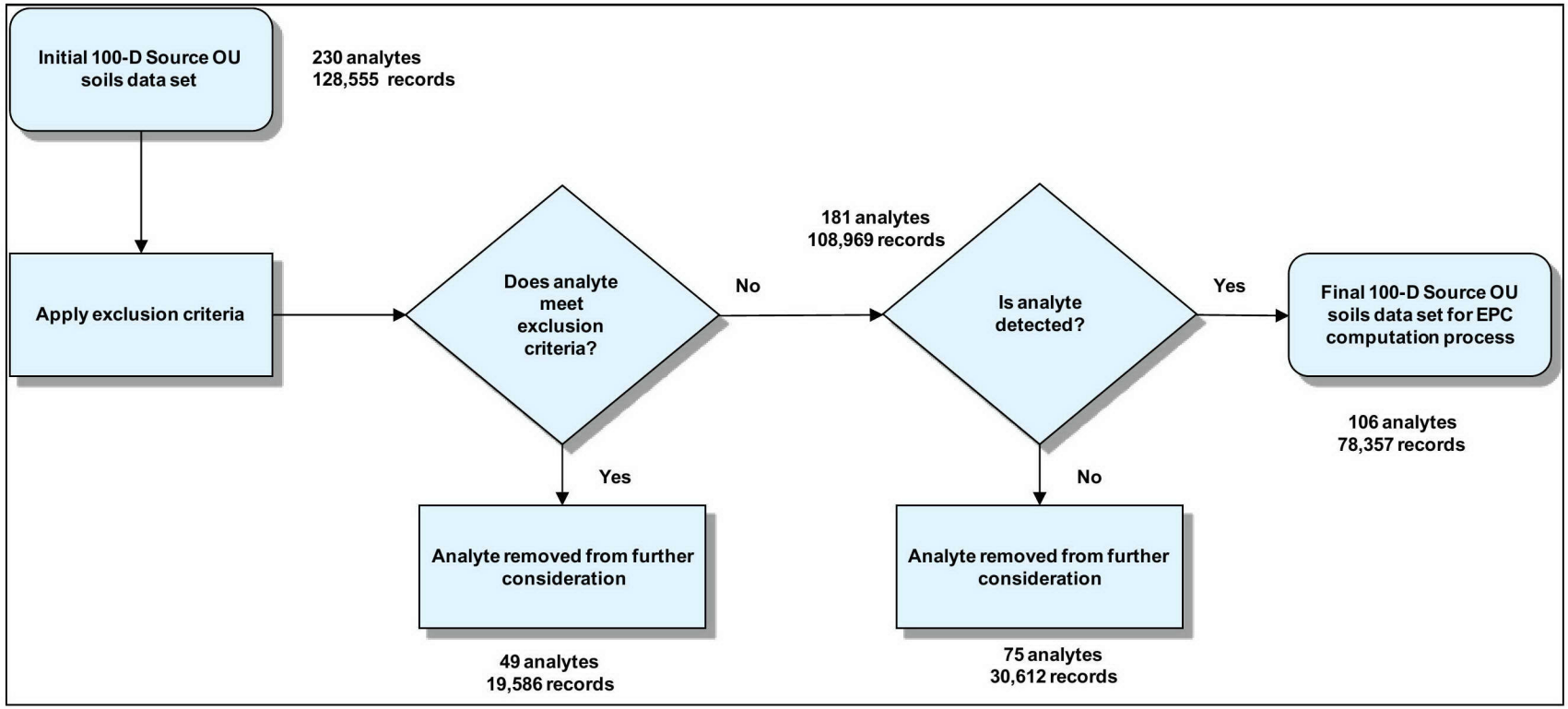

Figure 6-3. Analyte Identification Steps for 100-D Source OU

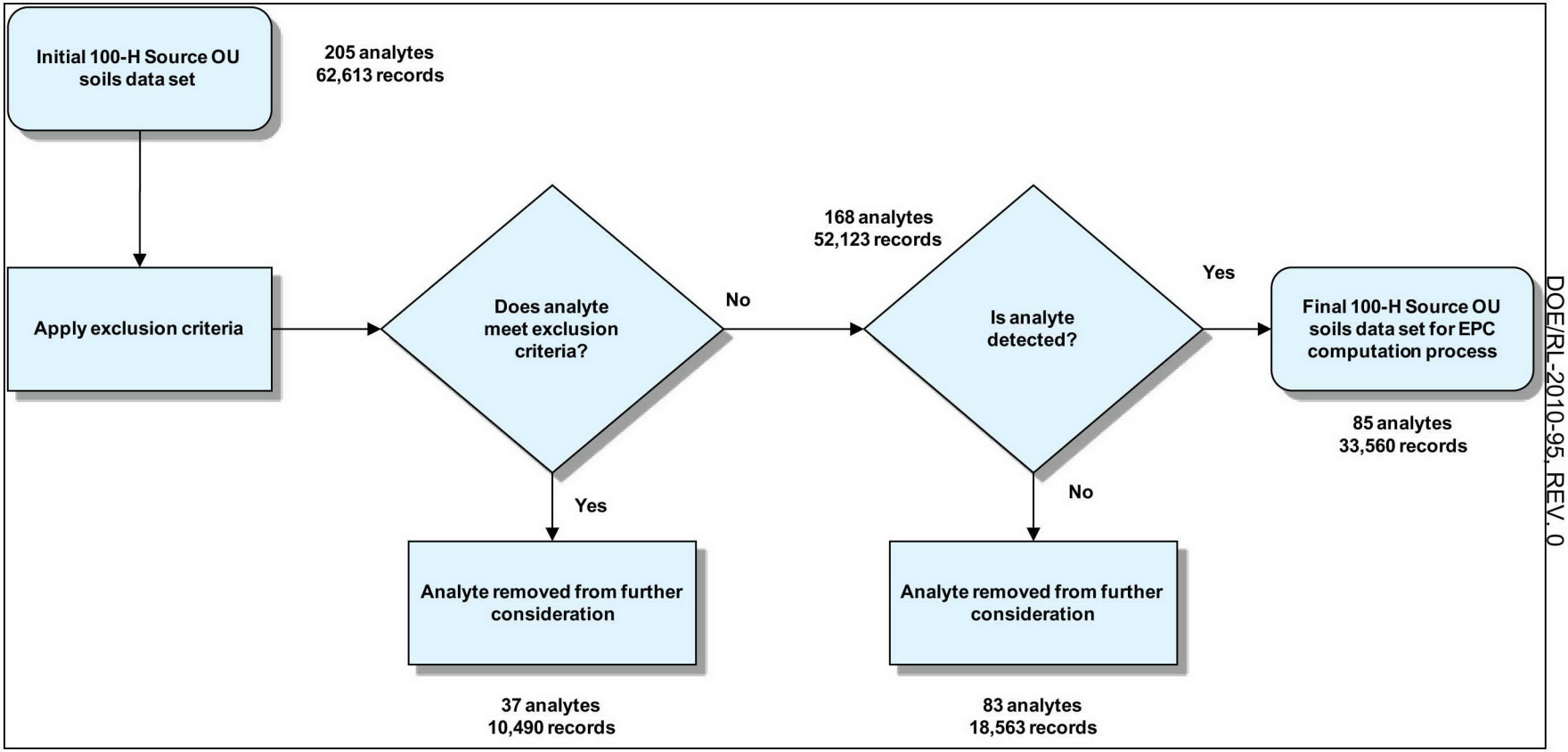

Figure 6-4. Analyte Identification Steps for 100-H Source OU

6.2.2.2.7 *Apply Exclusion Criteria*

The first step used to identify analytes that require a 95 percent UCL calculation is to apply exclusion criteria. Analytes that do not meet the exclusion criteria are carried forward into the next step of the process. Analytes that meet exclusion criteria are eliminated from further consideration. The following were excluded:

- Radionuclides that have half-lives of less than 3 years and that are not significant daughter products
- Background radionuclides that are not directly related to Hanford Site operations or processes (potassium-40, radium-226, radium-228, thorium-228, thorium-230, and thorium-232)
- Essential nutrients (minerals) (calcium, magnesium, potassium, and sodium)
- Analytes without known toxicity information (for example, delta-BHC, endrin ketone, and sulfate)[5]

A total of 49 analytes for the 100-D Source OU and 37 analytes for the 100-H Source OU meet the exclusion criteria and are listed in Tables G-5 and G-6 (Appendix G), respectively. Sampling dates, minimum and maximum detected concentrations, minimum and maximum method detection limits (MDL), and the basis for their exclusion are provided in these tables.

6.2.2.2.8 *Identify Nondetected Analytes*

The next step used to identify analytes that require a 95 percent UCL calculation is to identify nondetected analytes. Analytes that are measured at appropriate sampling locations, have adequate detection limits, and that have not been detected in any of the samples from the 100-D Source OUs or (separately) from the 100-H Source OUs are eliminated from further consideration. Any analyte that is detected at least once in the 100-D Source OU or (separately) at least once in the 100-H Source OU is carried forward to the next step of the process.

A total of 75 analytes were not detected in the 100-D Source OU and 83 analytes were not detected in the 100-H Source OU and are listed in Tables G-7 and G-8 (Appendix G), respectively. The tables also provide sampling dates, total number of samples, and minimum and maximum MDLs.

6.2.2.2.9 *95 Percent UCL Calculation Methodology*

A discussion of waste site decision units was provided earlier in this section. It should be noted that calculated UCLs and EPCs selected for shallow zone and deep zone decision units represent verification data collected from the floor and the sidewall of the excavated waste site. As a result, risks are overstated because the UCL and the EPC do not take credit for the existing clean backfill that covers the remediated waste site.

Analytical data for all analytes that have been detected at least once in each waste site decision unit are extracted from the dataset and subsequently formatted so they can be directly imported into ProUCL where 95 percent UCL calculations and summary statistics are performed.

The following information is obtained from the UCL calculations and summary statistics generated for each waste site decision unit:

- Waste site decision unit name
- Analyte name and Chemical Abstract Service (CAS) Registry number
- Total number of sample results, total number of detects, and total number of nondetects

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[5] Note that this exclusion criterion includes the water quality or soil physical property measurements described in Section 6.2.1.3 of this chapter. The sources of analyte-specific toxicity values and the recommended reference hierarchy is provided in Section 6.2.4.2.

- Minimum and maximum detection limits for each detected analyte (when available)[6]
- Minimum and maximum detected concentrations for each analyte
- Coefficient of variation (CV) for each analyte
- The UCL value, the UCL basis, and comments and/or warning statements for each analyte

For most datasets, ProUCL recommends a single UCL as the decision statistic. When a single decision statistic is recommended, this UCL is selected. However, ProUCL will recommend more than one decision statistic for some datasets. The most conservative (that is, health-protective) result, that is not greater than the maximum observed concentration, is the goal when selecting the UCL to represent the EPC. When more than one decision statistic is given, the following logic is used to select the UCL:

If more than one UCL is recommended as a decision statistic and the UCLs are less than or equal to the maximum observed concentration, then the highest recommended UCL is selected as the decision statistic.

If more than one UCL is recommended as a decision statistic and the UCLs are greater than the maximum observed concentration, then the maximum observed concentration is selected as the decision statistic.

If more than one UCL is recommended as a decision statistic, at least one is less than the maximum observed concentration, and at least one is greater than the maximum observed concentration, then the maximum observed concentration is selected as the decision statistic. There were 12 analytes in 100-D and 8 analytes in 100-H where more than one UCL was recommended and at least one of the UCLs was greater than the maximum observed concentration.

6.2.2.2.10 *Selection of EPCs*

The following logic was used to select the EPC for each detected analyte in a waste site decision unit:

- For samples collected in accordance with a focused sampling design, the maximum detected concentration is selected as the EPC for every detected analyte.
- For samples collected in accordance with a statistical sampling design, the following logic is applied:
  - If a valid 95 percent UCL can be calculated, then the highest potential 95 percent UCL value (if more than one potential UCL value is recommended) is selected.
  - If the recommended 95 percent UCL is greater than the maximum detected concentration, then the maximum detected concentration is selected.
  - If a valid 95 percent UCL cannot be calculated, then the maximum detected concentration is selected.

Selection of the EPC value using the above decision logic is presented on Figure 6-5. A summary of the EPCs for each detected analyte in a given waste site decision unit is provided in Table G-9 for the 100-D Source OU and Table G-10 for the 100-H Source OU (Appendix G).

6.2.2.2.11 *Use of Maximum Detected Concentrations to Estimate the EPC*

The EPC defaults to the maximum detected concentration when the following conditions are met:

- When samples are collected using a focused sampling design

[6] Minimum and maximum detection limits are summarized in the ProUCL output only when a valid UCL can be calculated.

- When a valid 95 percent UCL cannot be calculated because of a limited number of detections (less than 5)
- When a valid 95 percent UCL is greater than the maximum detected concentration

The sampling plan for a focused decision unit was designed to sample the areas of suspected contamination. The results from this type of sampling design can introduce bias into statistical analyses to estimate means, such as calculations of UCLs. RAGS Supplemental Guidance (OSWER Publication 9285.7-081) states "a value other than the 95 percent UCL can be used, provided the risk assessor can document that high coverage of the true population mean occurs (that is, the value equals or exceeds the true population mean with high probability)." The closeout documentation for the focused decision units used the maximum detected concentration to determine whether the remedial action remedial action goal has been attained (Section 3.6.3 of the 100 Area RDR/RAWP [DOE/RL-96-17]). Because of the potential for statistical bias and to maintain consistency with the 100 Area RDR/RAWP (DOE/RL-96-17) the maximum detected concentration is selected as a conservative estimate of the EPC for the focused decision units.

ProUCL has minimum size requirements to compute UCLs. For datasets of at least five results, a UCL is not calculated when there is only one detected result in the dataset. ProUCL notes that in cases where the number of available detected samples is small (fewer than five), the estimation of the EPC term is decided upon on a site-specific basis. ProUCL generates warning messages regarding the potential deficiencies associated with a small dataset. For small datasets with very few detected values (fewer than five) a valid UCL cannot be calculated. For risk assessment purposes, the maximum concentration is used as a conservative representation of the EPC.

Some of the distributional methods employed by ProUCL can produce very high estimates of the UCL (particularly the Land method). Calculating UCL for EPCs (OSWER 9285.6-10) acknowledges that the Land method can produce extremely high values for the UCL when data exhibit high variance and the sample size is small. RAGS Supplemental Guidance (OSWER Publication 9285.7-081) recognizes the problem of extremely high UCLs, and recommends the maximum detected concentration become the default when the calculated UCL exceeds this value. However, when the recommended UCL exceeds the maximum detected concentration, ProUCL advises that an alternative UCL (that is, Chebyshev inequality) be selected instead of the maximum detected concentration for an EPC. When the recommended UCL is greater than the maximum detected result, the maximum detected value is selected as the EPC for the 100-D/H Source OU. ProUCL displays a warning message when the recommended 95 percent UCL of the mean exceeds the observed maximum concentration.

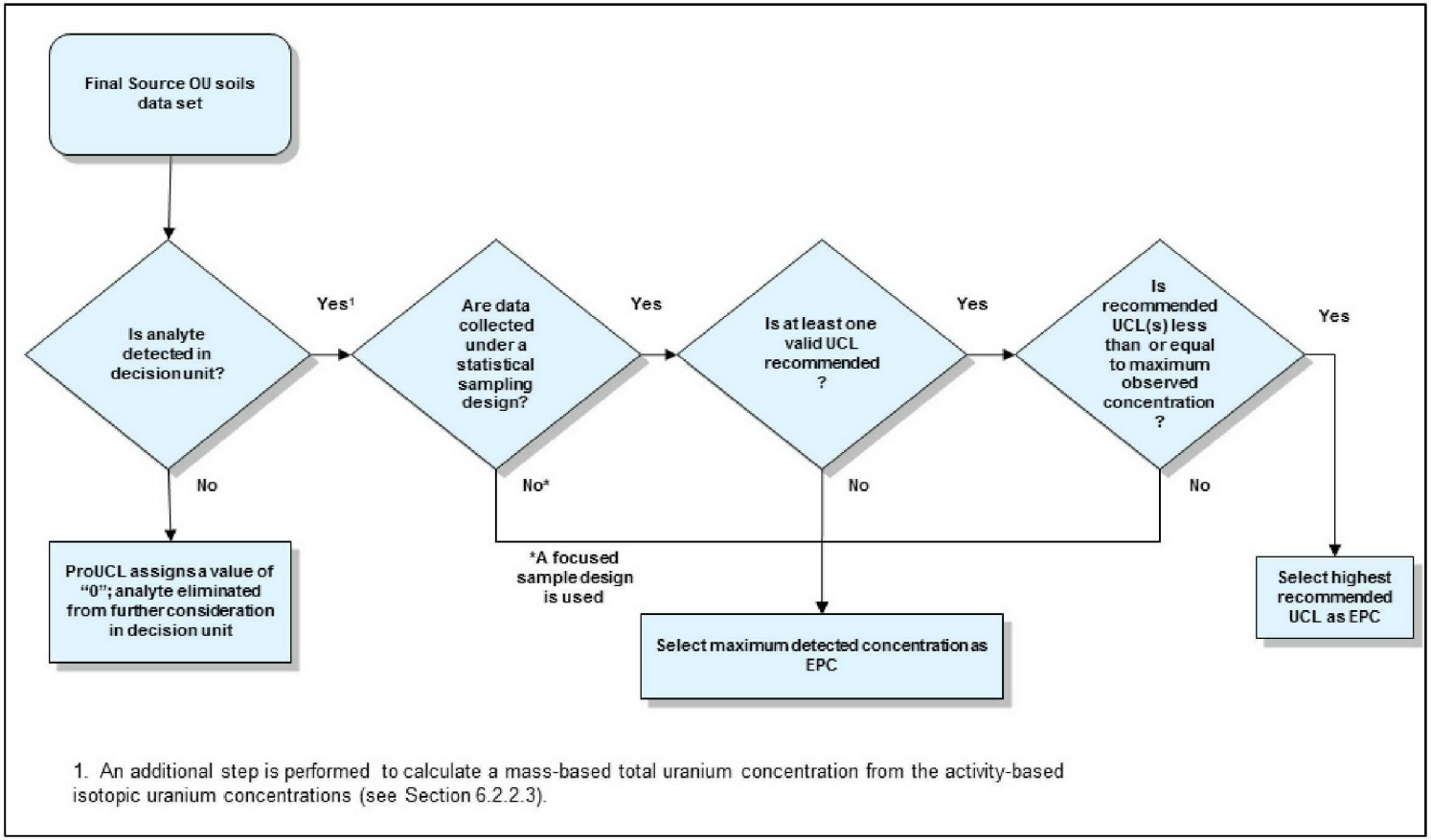

Figure 6-5. Decision Logic for Selection of the EPC Value

6.2.2.3 *Methodology Used to Calculate Total Uranium Concentrations from Isotopic Uranium Concentrations*

Uranium analytical data are reported for all the 100-D/H Source OU waste site decision units as isotopic uranium (reported in units of pCi/g) and not as total uranium (reported in units of µg/kg). Because total uranium (µg/kg) is needed to support the 100-D/H Area Source OU FS, an additional step is performed to calculate a mass-based total uranium concentration (µg/kg) from the activity-based isotopic uranium concentrations (pCi/g) reported for each waste site decision unit. This step entails obtaining the uranium isotope analytical data for each sample, converting the data from activity- to mass-based concentrations, and then summing the converted values for detected concentrations to produce a mass-based total uranium value. When all uranium isotope results are reported as nondetects, they are assigned a zero by ProUCL and are not included in the summation of the mass-based total uranium concentration. The pCi/g to µg/kg conversions and subsequent summations are performed using specific activities for the uranium isotopes and appropriate conversion factors, as shown in the calculation example provided in Table 6-11. As mentioned previously, only uranium isotopes that are detected at least once are included in the summations for calculation of the total uranium concentration. In the Table 6-11 example, U-235 is shown for demonstration purposes because it is not included in the summation. The calculated total uranium values are assigned an analyte name of Total_U_Isotopes in the datasets and then a ProUCL input file (as described in Section 6.2.2.2) containing the Total_U_Isotopes data is produced for each waste site decision unit.

Table 6-11. Example Conversion from Activity- to Mass-Based Concentration (pCi/g to µg/kg) for Uranium Isotopes and Summation to Produce a Mass-Based Total Uranium Concentration (µg/kg)

Uranium Isotope	Measured Activity (pCi isotope/ g soil)[a] (ND or D)	Specific Activity (Bq isotope/ g isotope)[b]	Specific Activity (pCi isotope/ g isotope)[c]	Conversion Factor (µg isotope/ g isotope)	Conversion Factor (g soil/ kg soil)	Calculated Concentration (µg isotope/ kg soil)[d]
U-233/234[e]	0.649 (D)	2.302E+08	6.222E+09	1,000,000	1,000	0.10
U-235	0.031 (ND)	7.995E+04	2.161E+06	1,000,000	1,000	14 (not summed)
U-238	0.338 (D)	1.243E+04	3.359E+05	1,000,000	1,000	1,006
Total Uranium Concentration (Total_U_Isotopes) (µg total uranium/kg soil) =						**1,006**

a. Example analytical data shown for illustration purposes only.

b. *Table of Isotopes* (Firestone and Shirley, 1998).

c. Formula = specific activity (Bq/g) / 3.7E+10 Bq/Ci × 1.0E+12 pCi/Ci.

d. Formula = measured activity (pCi/g) / specific activity (pCi/g) × conversion factor (µg/g) × conversion factor (g/kg).

e. Values presented are for uranium-234; uranium-234 is assumed to be the dominant isotope in undifferentiated uranium-233/234

6.2.3 Exposure Assessment

This section defines the exposure scenarios used for various land use and receptor activities, describes the potential exposure pathways resulting from Hanford Site contaminants, and provides the methodology for calculating the RBSLs for direct contact, based on currently available Hanford Site information.

The conceptual exposure model is formulated according to EPA guidance, taking into consideration information on contaminant sources, release mechanisms, routes of migration, potential exposure points, potential routes of exposure, and potential receptor groups associated with the 100-D/H Source OUs. This results in a set of exposure pathways that reflect an RME.

An exposure pathway can be described as the physical course that a COPC takes from the point of release to a receptor. The route of exposure is the means by which a COPC enters a receptor. For an exposure pathway to be complete, all of the following components must be present:

- A source
- A mechanism of chemical release and transport
- An environmental transport medium
- An exposure point
- An exposure route
- A receptor or exposed population

In the absence of any one of these components, an exposure pathway is considered incomplete; therefore, it creates no risk or hazard[11].

6.2.3.1 Contaminant Sources

The primary sources of contamination in 100-D/H Source OU are three water-cooled nuclear reactors (105-D, 105-DR, and 105-H) and the structures (for example, fuel storage basins) and processes (for example, sodium dichromate process) associated with reactor operations. The reactors were built to irradiate uranium-enriched fuel rods from which plutonium and other special nuclear materials could be extracted. Effluent generated during operations consisted primarily of contaminated reactor cooling water, fuel storage basin water, and decontamination solutions.

Liquid and solid wastes from reactor operations and associated facilities were released to the vadose zone column and the Columbia River. Wastes released to the environment created secondary sources of contamination such as surface impoundments, cribs, ditches, burial grounds, and unplanned release sites. Contaminant sources (that is, facilities and waste sites) are described in Sections 4.2 and 5.3 of this report.

6.2.3.2 Release Mechanisms and Environmental Transport Media

The primary COPC release mechanisms and transport pathways at 100-D and 100-H are discussed in Sections 5.4 and 5.5, and include the following:

- Migration of contaminated liquids through the vadose zone column through infiltration, percolation, or leaching
- Direct contact and external radiation from vadose zone material containing COPCs (receptor contact with shallow vadose zone material replaces release and transport)
- Emission of dusts and vapors during former plant operations
- Generation of dust emanating from shallow vadose zone material to ambient air from wind, or during maintenance or excavation activities occurring at the 100-D/H Source OU
- Volatilization of COPCs emanating from shallow vadose zone material to ambient air at the 100-D/H Source OU

6.2.3.3 Potentially Complete Human Exposure Pathways and Receptors

Based on the current understanding of land use conditions near the 100-D/H Source OU, the most plausible exposure pathways for calculating PRGs and characterizing the human health risks have been

[11] With the exception of external irradiation from radionuclides, environmental contaminants must cross a cellular barrier and enter the body of a receptor for exposure to occur.

identified (represented on Figures G-1 and G-2 in Appendix G). The groundwater risk assessment is provided in Section 6.3.

For the purpose of this soil risk assessment, shallow vadose zone material is represented by samples collected from 0 to 4.6 m (0 to 15 ft) bgs, and deep vadose zone material is represented by samples collected from depths greater than 4.6 m (15 ft) bgs (Section 6.2.2.2, Table 6-10). Groundwater is represented by samples collected from the unconfined aquifer and discussed in Section 6.3.

6.2.3.3.1 *Residential Scenario*

PRGs (also used as RBSLs) developed for the Residential scenario are the numeric values that represent the RAOs presented in Chapter 8. The results of comparing EPCs to the RBSLs in this soil risk assessment will be used to help determine whether additional remedial action is necessary for waste sites where remediation has been completed, and whether the goals and objectives of the interim action RODs have been met, as demonstrated by verification sampling and analysis.

The Residential scenario for radiological and nonradiological analytes is based on two different conceptual exposure models. The exposure pathways for radionuclides include direct contact in addition to dust inhalation, consumption of homegrown foodstuffs (for example, produce, beef, and milk), and the leaching pathway (includes drinking water ingestion and fish ingestion). The exposure pathways for nonradiological analytes in vadose zone material include direct contact from incidental ingestion and inhalation of vapors and dust in ambient air.

The Residential scenarios described in the following paragraphs are consistent with the exposure scenario and ARARs used to develop the interim action remedial action goals for soil presented in the 100 Area RDR/RAWP (DOE/RL-96-17). This exposure scenario is also evaluated in the RCBRA (DOE/RL-2007-21, Volume II) to determine whether cleanup actions completed under the interim action RODs protect human health relative to the range of exposure scenarios evaluated in this risk assessment.

Radiological. Consistent with the 100 Area RDR/RAWP (DOE/RL-96-17), the RESRAD code is used to evaluate exposure to radiological contaminants in vadose zone material. Revisions to this exposure scenario reflect updates in guidance since the 100 Area RDR/RAWP (DOE/RL-96-17) was originally published in 1996. With the exception of changes resulting from updates in guidance, the Residential scenario is the same as that published in the 100 Area RDR/RAWP (DOE/RL-96-17) (see Table 6-4). Exposure assumptions that were updated to reflect current EPA guidance include a decrease in the external gamma shielding factor (increased shielding) and a decrease in the outdoor time fraction. Health protective levels were also updated from a target annual dose rate of 15 mrem/yr to a target risk of 1×10^{-4} to be consistent with guidance recommended in *Radiation Risk Assessment At CERCLA Sites: Q & A (*EPA/540/R/99/006). A detailed description of this exposure scenario is provided in *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* (ECF-HANFORD-10-0429). A summary of the exposure assumptions that were modified as a result of updates to EPA guidance was provided in Table 6-4.

For radiological PRG development, a subsistence farming setting is used. This assumes that each interim remediated waste site decision unit has 1) the potential to be developed into a residence with a basement, 2) vegetable and fruit crops grown in a backyard garden, and 3) a pasture that is used to raise livestock sufficient for meat and milk production. A downgradient well is installed where exposure could potentially occur from contaminants leaching from the vadose zone material to groundwater beneath the residence (that is, the leaching pathway). The resident could potentially come into direct contact with soil from the remediated waste site and potentially inhale dust in ambient air. The resident could potentially

consume crops raised in a backyard garden and consume meat (beef and poultry) and milk from livestock raised on the pasture. Based on established land uses and the proclamation of "Establishment of the Hanford Reach National Monument" (65 FR 37253), it is unlikely that land within the l00-D/H OU will be used for residential purposes.

The Residential scenario evaluates residential pathways that include exposure to shallow vadose zone material from residential yards or groundwater from domestic wells. Potential routes of exposure to shallow vadose zone material evaluated in the RESRAD code include direct external exposure, incidental material ingestion, and inhalation of dust generated from wind or from yard maintenance activities. This scenario also evaluates residential exposure to radiological contaminants through food chain pathways (uptake of contamination from vadose zone material to plants and animals). Food chain pathways include the consumption of fruits and vegetables grown in a backyard garden and consumption of meat and milk from livestock raised on the pasture. From the leaching pathway, this scenario evaluates residential consumption of drinking water from a downgradient well, use of the well for irrigating crops and watering livestock, and residential consumption of fish raised in a pond supplemented with water from the downgradient well.

Nonradiological. The Residential scenario for nonradiological analytes measured in soil is also consistent with the exposure scenario used for the interim action remedial action goals for soil presented in the 100 Area RDR/RAWP (DOE/RL-96-17). The exposure scenario for protection of human health is based on 2007 MTCAMethod B direct contact soil cleanup levels ("Unrestricted Land Use Soil Cleanup Standards" "Method B Soil Cleanup Levels for Unrestricted Land Use" [WAC 173-340-740(3)] and "Cleanup Standards to Protect Air Quality" "Method B Air Cleanup Levels" [WAC 173-340-750(3)]). The 2007 MTCA Method B direct contact soil cleanup levels (WAC 173-340) are based on exposure to a child receptor that includes incidental ingestion, and use residential exposure frequency and duration assumptions. The 2007 MTCA (WAC 173-340) Method B inhalation cleanup levels are based on exposure to child and adult receptors, includes inhalation of vapors and dust in ambient air, and assumes residential exposure frequency and duration assumptions. For arsenic and lead, 2007 MTCA ("Tables" [WAC 173-340-900]), Table 740-1 Method A, soil cleanup level for unrestricted land use of 20 mg/kg and 250 mg/kg were used.

Groundwater. Groundwater within the 100-HR-3 OU is currently contaminated, and withdrawal is prohibited as a result of institutional controls placed on it by DOE through the interim action ROD; however, institutional controls will be evaluated as part of the final remedy. Under current Hanford Site use conditions, no complete human exposure pathways to groundwater are assumed to exist. In addition, groundwater currently discharges to the Columbia River through upwelling and seeps. 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. However, groundwater in this risk analysis is evaluated for drinking water use and undiluted groundwater concentrations are compared to DWSs and aquatic criteria to support the determination of the basis for action and to support the development of PRGs for evaluating remedial alternatives in the FS.

The Residential scenario for radiological and nonradiological analytes measured in groundwater is also consistent with the remedial action goals documented in the interim action RODs and in the 100 Area RDR/RAWP (DOE/RL-96-17). Groundwater concentrations are compared to current maximum contaminant levels (MCL) for radionuclides, which 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 Ra-226, but excluding uranium and radon), and 5 pCi/L combined for Ra-226 and Ra-228. A mass-based concentration MCL has been established for uranium as 30 μg/L. The exposure scenario for protection of human health is based on the 2007 MTCA Method B ("Groundwater Cleanup Standards" "Standard Method B Potable Groundwater Cleanup Levels" [WAC 173-340-720 (4)(b)]). The 2007 MTCA

(WAC 173-340) Standard Method B groundwater cleanup levels are based on exposure to child and adult receptors, include drinking water ingestion and inhalation of vapors, and makes residential exposure frequency and duration assumptions. Resident Monument Worker Scenario

Land use within the River Corridor's 100 and 600 Areas is predominantly conservation/preservation. In 2000, Presidential Proclamation 7319 (*Establishment of the Hanford Reach National Monument* was signed creating the Hanford Reach National Monument, to be managed by USFWS and DOE ("Establishment of the Hanford Reach National Monument" [65 FR 37253]). The Monument was established to protect the biological, historic, and scientific objects contained within. To support continued protection of natural and cultural resources, the proclamation stated that the Monument would not be developed for residential or commercial use in the future ("Establishment of the Hanford Reach National Monument" [65 FR 37253]).

This exposure scenario was included in the subset of occupational scenarios presented in the RCBRA (DOE/RL-2007-21, Volume II). The Resident Monument Worker scenario is a site-specific scenario that envisions a resident employee of the Hanford Reach National Monument. These receptors are assumed to be exposed primarily in an outdoor environment as they lead tours, conduct ecological education, or perform similar activities. When not working, these receptors are envisioned to live in an onsite residence associated with the Monument. By use of a domestic well at their residence, these receptors may also be exposed to groundwater contaminants through domestic water use. Exposure to groundwater as a domestic source of water by the resident Monument worker is not included in the soil PRG value that is calculated for this exposure scenario. The risks from exposure to 100-HR-3 groundwater from use as a domestic source of water can be separately added to provide a total risk from exposure to soil and groundwater.

The Resident Monument Worker scenario for radiological and nonradiological analytes in vadose zone material is based on the same conceptual exposure model. The exposure pathways include direct contact and inhalation of vapors and dust in ambient air. Adults could potentially be exposed to Hanford Site contaminants in shallow vadose zone material at their residence through direct external exposure, incidental ingestion, dermal absorption, and inhalation. During working activities, these adults may also be potentially exposed to contaminants in shallow vadose zone material by direct external exposure, incidental soil ingestion, dermal absorption, and inhalation. No food chain pathways are included in this exposure scenario.

When the total risk for a waste site is less than 1×10^{-4} for radionuclides based on the Residential scenario or 1×10^{-5} for chemicals based on the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold, then protection of the resident Monument worker is achieved. The results of these comparisons can be used in risk management decisions (presented in Section 6.2.5.5) and show that the total risk calculated for the Resident and the Resident Monument Worker scenarios are essentially identical. The Residential PRGs are slightlylower than the Resident Monument Worker PRGs because the Residential exposure scenario includes the food chain pathways.

6.2.3.3.2 *Casual Recreational User Scenario*

As discussed previously, the reasonably anticipated future land use within the River Corridor's 100 and 600 Areas is predominantly conservation/preservation. The casual recreational user is selected as a receptor to represent potential exposures from recreational use along the River Corridor. This exposure scenario was included in the subset of recreational use scenarios presented in the RCBRA (DOE/RL-2007-21, Volume II). 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. These receptors are assumed to be exposed entirely in an outdoor environment. This scenario also assumes that drinking water is obtained from an offsite source.

PRGs are presented in this section for the casual recreational user that represents a reasonably anticipated future land use. Casual recreational user PRG values are developed for radiological and nonradiological contaminants. When the total risk for a waste site is less than 1×10^{-4} based on the Residential scenario or 1×10^{-5} for chemicals based on the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold, then protection of the casual recreational user is achieved. The results of these comparisons (presented in Section 6.2.5.5) can be used in risk management decisions.

The Casual Recreational User scenario for radiological and nonradiological analytes in vadose zone material is based on the same conceptual exposure model. The exposure pathways include direct contact and inhalation of vapors and dust in ambient air. Adults and children could potentially be exposed to Hanford Site contaminants in shallow vadose zone material along the river through direct external exposure, incidental ingestion, dermal absorption, and inhalation of vapors and dust in ambient air.

6.2.3.4 Quantification of Potential Exposures

Quantification of potential exposures in this risk assessment is evaluated through the comparison of EPCs to PRGs (which are also used as RBSLs). *Risk Assessment Guidance for Superfund Volume I – Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals): Interim* (EPA/540/R-92/003), hereinafter called Risk Assessment Guidance Volume I, Part B, provides guidance on using EPA toxicity values and exposure information to calculate PRGs. Once the BRA has been performed, PRGs can be derived using site-specific risks. PRGs developed in the FS will usually be based on site-specific risks and ARARs and not on screening levels. PRGs are obtained from two general sources: concentrations based on ARARs (for example DWS), and concentrations based on risk assessment. It should be recognized that the PRGs that are ARAR-based are also considered risk-based. Exposure assumptions published by the state and EPA and toxicity values published by EPA are used to derive risk-based PRGs.

PRGs based on risk assessment equations include the Resident Monument Worker and the Casual Recreational User scenarios. PRGs for these scenarios are calculated using methodologies published in Risk Assessment Guidance Volume I, Part B (EPA/540/R-92/003) and the Superfund Radionuclide PRG download and calculation web site (EPA, 2010b). Toxicity values and exposure values published by EPA are used to derive risk-based PRGs.

The Residential scenario for chemicals is based on the 2007 MTCA Method B direct contact soil cleanup levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) and 2007 MTCA Method B Inhalation Cleanup Levels ("Method B Air Cleanup Levels" [WAC 173-340-750]). PRGs for soil ingestion are calculated using the equations provided in 2007 MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740(3)]). PRGs for the inhalation pathway are calculated using the equations provided in 2007 MTCA ("Cleanup Standards to Protect Air Quality" "Method B Air Cleanup Levels" [WAC 173-340-750(3)]). Air cleanup levels are converted to soil concentrations using EPA published volatilization factors for analytes that meet the operational definition of a volatile and a PEF for analytes that are not volatile. Method A soil cleanup levels for unrestricted land use, obtained from 2007 MTCA ("Tables" [WAC 173-340-900]), Table 740-1 are used as PRGs for arsenic and lead.

In addition to the guidance listed previously, radionuclide PRGs for the resident are calculated using the RESRAD code. The RESRAD code was used to calculate PRGs for the Residential scenario because of unique exposure pathways. The RESRAD code was used for the Residential scenario because this scenario includes the food chain pathway and the leaching to groundwater pathway. According to *User's Manual for RESRAD Version 6* (ANL/EAD-4), the RESRAD model and computer code were developed as a multifunctional tool to assist in developing cleanup criteria and assessing the dose or risk associated with residual radioactive material.

Table 6-12 summarizes the PRG values for each exposure scenario.

6.2.3.4.1 *Calculation of Residential PRGs using RESRAD*

The radionuclide PRGs for the Residential scenario are calculated using RESRAD, Version 6.5 (ANL, 2009b) model and code according to the guidance specified in *User's Manual for RESRAD Version 6* (ANL/EAD-4). The RESRAD model was used to calculate single radionuclide concentrations that correspond to a target cancer risk level of 1×10^{-4} for the Residential scenario. For the purpose of this soil risk assessment, the single radionuclide concentrations described in this section are used as PRGs for the Residential scenario.

The RESRAD model allows for the use of site-specific chemical and physical parameters to estimate single radionuclide concentrations. The potentially complete exposure pathways considered are direct contact, inhalation pathway, the food chain pathway, and leaching of contaminants in the vadose zone through the vadose zone column to the groundwater table. Exposure routes associated with the direct contact and inhalation pathways include external gamma exposure, incidental ingestion, and inhalation of dust. Exposure routes associated with the food chain exposure pathway include consumption of homegrown produce, meat, and milk. Exposure routes associated with the leaching pathway include crop irrigation, aquatic food consumption, and drinking water ingestion. A detailed description of methodology, inputs, assumptions, and results of the calculations is presented in *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* (ECF-HANFORD-10-0429) in Appendix G.

6.2.3.4.2 *Calculation of Unrestricted Land Use PRGs using 2007 MTCA Equations*

The direct contact nonradiological PRGs for unrestricted land use (that is, the resident) are calculated using equations and input parameters described in 2007 MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740(3)]). The Standard Method B direct contact soil cleanup levels for unrestricted land use are based on ingestion and were calculated for noncarcinogens and carcinogens using equation 740-1 and equation 740-2, respectively. Standard Method B direct contact soil cleanup levels for unrestricted land use are based on an acceptable cancer risk level of 1×10^{-6} for nonradiological carcinogens or a hazard quotient (HQ) of 1 for noncarcinogens.

Reference dose (RfD) and carcinogenic potency factors are determined using the recommended reference hierarchy as described in "Human Health Toxicity Values in Superfund Risk Assessments" (Cook, 2003), hereinafter called Superfund HHT Risk Assessment Values. A detailed description of methodology, inputs, assumptions, and the results of the calculations is presented in *Calculation of Standard Method B Direct Contact Soil Cleanup Levels for Unrestricted Land Use* (ECF-HANFORD-10-0044) (Appendix G).

The inhalation nonradiological PRGs for unrestricted land use (that is, the resident) are calculated using equations and input parameters described in 2007 MTCA ("Cleanup Standards to Protect Air Quality," "Method B Air Cleanup Levels" [WAC 173-340-750(3)]). The Method B air PRGs are calculated for noncarcinogens and carcinogens using equation 750-1 and equation 750-2, respectively.

Air PRGs are converted to soil concentrations using EPA-published volatilization factors for analytes that meet the operational definition of a volatile and a PEF for analytes that are not volatile. Method B soil PRGs for the inhalation pathway are based on an acceptable cancer risk level of 1×10^{-6} for carcinogens or an HQ of 1 for noncarcinogens. Inhalation RfD and inhalation carcinogenic potency factors are determined using the recommended reference hierarchy as described in Superfund Human Health Toxicity Risk Assessment Values (Cook, 2003). A detailed description of methodology, inputs, and

assumptions and the results of the calculations are presented in *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* (ECF-HANFORD-11-0033) in Appendix G.

6.2.3.4.3 Calculation of Resident Monument Worker PRGs for Radiological Analytes using EPA Equations

The radiological PRGs for the resident Monument worker are calculated using equations consistent with those published on the EPA Preliminary Remediation Goals for Radionuclides Web site. Resident Monument worker PRGs are based on an acceptable cancer risk level of 1×10^{-4} for carcinogens. A detailed description of methodology, inputs, and assumptions and the results of the calculations is presented in *Documentation of Radiological Preliminary Remediation Goals in Soil for a Resident Monument Worker Exposure Scenario for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study (RI/FS) Reports* (ECF-HANFORD-11-0142).

6.2.3.4.4 Calculation of Casual Recreational User PRGs for Radiological Analytes using EPA Equations

The radiological PRGs for the casual recreational user are calculated using equations consistent with those published on the EPA Preliminary Remediation Goals for Radionuclides Web site. Casual recreational user radiological PRGs are based on an acceptable cancer risk level of 1×10^{-4} for carcinogens. A detailed description of methodology, inputs, assumptions, and the results of the calculations is presented in *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 (RI/FS) Reports* (ECF-HANFORD-10-0446).

6.2.3.4.5 Calculation of Casual Recreational User PRGs for Nonradiological Analytes using EPA Equations

The nonradiological PRGs for the casual recreational user are calculated using equations consistent with those published on "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (hereinafter called Regional Screening Levels [EPA, 2013a]). Casual recreational user nonradiological PRGs are based on an acceptable cancer risk level of 1×10^{-6} for carcinogens or an HQ of 1 for noncarcinogens. RfD and carcinogenic potency factors are determined using the recommended reference hierarchy as described in Superfund HHT Risk Assessment Values (Cook, 2003). A detailed description of methodology, inputs and assumptions and the results of the calculations are presented in *Calculation of Nonradiological Preliminary Remediation Goals in Soil for a Casual Recreational User Scenario for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study (RI/FS) Reports* (ECF-HANFORD-10-0445).

6.2.4 Toxicity Assessment

This toxicity assessment evaluates the relationship between the magnitude of exposure to a contaminant at the 100-D/H Source OU and the likelihood of adverse health effects to potentially exposed populations. This assessment provides, where possible, a numerical estimate of the increased likelihood of adverse effects associated with contaminant exposure. The toxicity assessment contains two steps—hazard characterization and dose-response evaluation—as discussed in the following sections.

6.2.4.1 Hazard Characterization

Hazard characterization identifies the types of toxic effects that a chemical can exert. For the toxicity assessment, chemicals can be divided into two broad groups—noncarcinogens and carcinogens—based on their effects on human health.

Table 6-12. Summary of Risk-based Screening Levels for the 100-D/H Source OU

Analyte	90th Percentile Background	2007 MTCA Method A Soil PRG	Residential PRG	2007 MTCA Method B Direct Contact Soil PRG (Carcinogen)	2007 MTCA Method B Direct Contact PRG (Noncarcinogen)	2007 MTCA Method B Inhalation Soil PRG (Carcinogen)	2007 MTCA Method B Inhalation Soil PRG (Noncarcinogen)	Casual Recreational User PRG (Carcinogen)	Casual Recreational User PRG (Noncarcinogen)	Resident Monument Worker PRG (Carcinogen)
Radionuclides (pCi/g)										
Americium-241	--	--	155	--	--	--	--	2,570	--	275
Carbon-14	--	--	81	--	--	--	--	328,000	--	52,000
Cesium-137	1.1	--	4.4	--	--	--	--	100	--	6.2
Cobalt-60	0.0084	--	3.1	--	--	--	--	63	--	3.3
Europium-152	--	--	3.7	--	--	--	--	66	--	3.8
Europium-154	0.033	--	4.4	--	--	--	--	78	--	4.8
Europium-155	0.054	--	327	--	--	--	--	5,870	--	354
Neptunium-237	--	--	8.9	--	--	--	--	202	--	15
Nickel-63	--	--	608	--	--	--	--	575,000	--	91,600
Plutonium-238	0.0038	--	236	--	--	--	--	3,820	--	605
Plutonium-239/240	0.025	--	203	--	--	--	--	3,340	--	539
Technetium-99	--	--	1.5	--	--	--	--	114,000	--	17,300
Total beta radiostrontium	0.18	--	2.3	--	--	--	--	5,060	--	518
Tritium	--	--	623	--	--	--	--	15,400	--	1,270,000
Uranium-233/234	1.1	--	133	--	--	--	--	5,810	--	931
Uranium-234	1.1	--	133	--	--	--	--	5,810	--	931
Uranium-235	0.11	--	16	--	--	--	--	295	--	22
Uranium-238	1.1	--	54	--	--	--	--	1,090	--	93
Metals (mg/kg)										
Aluminum	11,800	--	--	--	80,000	--	>1,000,000	--	912,000	--
Antimony	0.13	--	--	--	32	--	--	--	365	--
Arsenic	6.5	20	--	0.67	24	42,400	500,000	4.5	253	--
Barium	132	--	--	--	16,000	--	>1,000,000	--	182,000	--
Beryllium	1.5	--	--	--	160	76,000	667,000	>1,000,000	1,820	--
Boron	3.9	--	--	--	16,000	--	>1,000,000	--	182,000	--
Cadmium	0.56	--	--	--	8	101,000	667,000	>1,000,000	821	--
Chromium	19	--	--	--	120,000	--	--	--	>1,000,000	--
Cobalt	16	--	--	--	24	20,300	200,000	920,000	274	--
Copper	22	--	--	--	3,200	--	--	--	36,500	--
Cr(VI)	--	--	--	--	240	2,170	>1,000,000	98,600	2,740	--
Iron	32,600	--	--	--	56,000	--	--	--	639,000	--
Lead	10	250	--	--	--	--	--	--	--	--
Lithium	13	--	--	--	160	--	--	--	1,830	--
Manganese	512	--	--	--	11,200	--	>1,000,000	--	128,000	--
Mercury	0.013	--	--	--	24	--	>1,000,000	--	274	--

Table 6-12. Summary of Risk-based Screening Levels for the 100-D/H Source OU

Analyte	90th Percentile Background	2007 MTCA Method A Soil PRG	Residential PRG	2007 MTCA Method B Direct Contact Soil PRG (Carcinogen)	2007 MTCA Method B Direct Contact PRG (Noncarcinogen)	2007 MTCA Method B Inhalation Soil PRG (Carcinogen)	2007 MTCA Method B Inhalation Soil PRG (Noncarcinogen)	Casual Recreational User PRG (Carcinogen)	Casual Recreational User PRG (Noncarcinogen)	Resident Monument Worker PRG (Carcinogen)
Molybdenum	0.47	--	--	--	400	--	--	--	4,560	--
Nickel	19	--	--	--	1,600	701,000	>1,000,000	>1,000,000	18,200	--
Selenium	0.78	--	--	--	400	--	>1,000,000	--	4,560	--
Silver	0.17	--	--	--	400	--	--	--	4,560	--
Strontium	--	--	--	--	48,000	--	--	--	548,000	--
Tin	--	--	--	--	48,000	--	--	--	548,000	--
Total_U_Isotopes	3.2	--	--	--	240	--	>1,000,000	--	2,740	--
Uranium	3.2	--	--	--	240	--	>1,000,000	--	2,740	--
Vanadium	85	--	--	--	400	--	--	--	4,560	--
Zinc	68	--	--	--	24,000	--	--	--	274,000	--
Polyaromatic Hydrocarbons (mg/kg)										
Acenaphthene	--	--	--	--	4,800	--	--	--	40,100	--
Anthracene	--	--	--	--	24,000	--	--	--	201,000	--
Benzo(a)anthracene	--	--	--	1.4	--	>1,000,000	--	1.7	--	--
Benzo(a)pyrene	--	--	--	0.14	--	166,000	--	0.17	--	--
Benzo(b)fluoranthene	--	--	--	1.4	--	>1,000,000	--	1.7	--	--
Benzo(k)fluoranthene	--	--	--	1.4	--	>1,000,000	--	1.7	--	--
Chrysene	--	--	--	14	--	>1,000,000	--	17	--	--
Dibenz[a,h]anthracene	--	--	--	1.4	--	>1,000,000	--	1.7	--	--
Fluoranthene	--	--	--	--	3,200	--	--	--	26,800	--
Fluorene	--	--	--	--	3,200	--	--	--	26,800	--
Indeno(1,2,3-cd)pyrene	--	--	--	1.4	--	>1,000,000	--	1.7	--	--
Pyrene	--	--	--	--	2,400	--	--	--	20,100	--
Polychlorinated Biphenyls (mg/kg)										
Aroclor-1242	--	--	--	0.50	--	320,000	--	2.6	--	--
Aroclor-1248	--	--	--	0.50	--	319,963	--	2.6	--	--
Aroclor-1254	--	--	--	0.50	1.6	320,000	--	2.6	13	--
Aroclor-1260	--	--	--	0.50	--	320,000	--	2.6	--	--
Anions (mg/kg)										
Fluoride	2.8	--	--	--	4,800	--	>1,000,000	--	54,700	--
Nitrate	52	--	--	--	568,000	--	--	--	>1,000,000	--
Nitrite	--	--	--	--	24,000	--	--	--	274,000	--
Nitrogen in Nitrate	--	--	--	--	128,000	--	--	--	>1,000,000	--
Nitrogen in Nitrite	--	--	--	--	8,000	--	--	--	91,300	--
Nitrogen in Nitrite and Nitrate	--	--	--	--	128,000	--	--	--	>1,000,000	--

Table 6-12. Summary of Risk-based Screening Levels for the 100-D/H Source OU

Analyte	90th Percentile Background	2007 MTCA Method A Soil PRG	Residential PRG	2007 MTCA Method B Direct Contact Soil PRG (Carcinogen)	2007 MTCA Method B Direct Contact PRG (Noncarcinogen)	2007 MTCA Method B Inhalation Soil PRG (Carcinogen)	2007 MTCA Method B Inhalation Soil PRG (Noncarcinogen)	Casual Recreational User PRG (Carcinogen)	Casual Recreational User PRG (Noncarcinogen)	Resident Monument Worker PRG (Carcinogen)
Other Organics (mg/kg)										
1,1-Dichloroethene	--	--	--	--	4,000	--	102	--	8,773	--
1,2-Dichlorobenzene	--	--	--	--	7,200	--	546	--	34,000	--
2-(2-methyl-4-chlorophenoxy) propionic acid	--	--	--	--	80	--	--	--	913	--
2,4,5-Trichlorophenol	--	--	--	--	8,000	--	--	--	71,300	--
2,4-DB(4-(2,4-Dichlorophenoxy)butanoic acid)	--	--	--	--	640	--	--	--	7,300	--
2,4-Dichlorophenol	--	--	--	--	240	--	--	--	2,140	--
2,4-Dinitrophenol	--	--	--	--	160	--	--	--	1,426	--
2-Butanone	--	--	--	--	48,000	--	28,700	--	464,000	--
2-Chloronaphthalene	--	--	--	--	6,400	--	--	--	73,000	--
2-Hexanone	--	--	--	--	400	--	160	--	3,599	--
2-Methylnaphthalene	--	--	--	--	320	--	--	--	2,680	--
4,4'-DDD (Dichlorodiphenyldichloroethane)	--	--	--	4.2	--	>1,000,000	--	24	--	--
4,4'-DDE (Dichlorodiphenyldichloroethylene)	--	--	--	2.9	--	>1,000,000	--	17	--	--
4,4'-DDT (Dichlorodiphenyltrichloroethane)	--	--	--	2.9	40	>1,000,000	--	20	421	--
Acetone	--	--	--	--	72,000	--	190,000	--	789,000	--
Aldrin	--	--	--	0.059	2.4	0.12	--	0.32	21	--
Alpha-BHC	--	--	--	0.16	640	101,322	--	0.90	5,703	--
Alpha-Chlordane	--	--	--	2.9	40	>1,000,000	>1,000,000	19	410	--
beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	--	--	--	0.56	--	344,000	--	3.2	--	--
Bis(2-ethylhexyl) phthalate	--	--	--	71	1,600	>1,000,000	--	405	14,300	--
Butylbenzylphthalate	--	--	--	526	16,000	--	--	2,980	143,000	--
Carbazole	--	--	--	50	--	--	--	283	--	--
Chlordane	--	--	--	2.9	40	>1,000,000	>1,000,000	19	410	--
Chloroform	--	--	--	32	800	0.24	100	11	4,908	--
Dibenzofuran	--	--	--	--	80	--	--	--	713	--
Dieldrin	--	--	--	0.063	4.0	39,600	--	0.35	36	--
Diethylphthalate	--	--	--	--	64,000	--	--	--	570,313	--
Di-n-butylphthalate	--	--	--	--	8,000	--	--	--	71,300	--
Dinoseb(2-secButyl-4,6-dinitrophenol)	--	--	--	--	80	--	--	--	713	--
Endosulfan I	--	--	--	--	480	--	--	--	4,280	--
Endosulfan II	--	--	--	--	480	--	--	--	4,280	--
Ethylbenzene	--	--	--	91	8,000	2.3	1,045	90	50,140	--

Table 6-12. Summary of Risk-based Screening Levels for the 100-D/H Source OU

Analyte	90th Percentile Background	2007 MTCA Method A Soil PRG	Residential PRG	2007 MTCA Method B Direct Contact Soil PRG (Carcinogen)	2007 MTCA Method B Direct Contact PRG (Noncarcinogen)	2007 MTCA Method B Inhalation Soil PRG (Carcinogen)	2007 MTCA Method B Inhalation Soil PRG (Noncarcinogen)	Casual Recreational User PRG (Carcinogen)	Casual Recreational User PRG (Noncarcinogen)	Resident Monument Worker PRG (Carcinogen)
Gamma-BHC (Lindane)	--	--	--	0.91	24	588,319	--	6.0	246	--
Heptachlor epoxide	--	--	--	0.11	1.0	70,100	--	0.62	9.3	--
Isophorone	--	--	--	1,053	16,000	--	50,482	5,962	139,000	--
Methoxychlor	--	--	--	--	400	--	--	--	3,560	--
Methylene chloride	--	--	--	500	4,800	528	580	3,230	5,030	--
Naphthalene	--	--	--	--	1,600	1.4	25	62	2,240	--
Phenol	--	--	--	--	24,000	--	11,614	--	182,000	--
Toluene	--	--	--	--	6,400	--	4,770	--	63,800	--
Total petroleum hydrocarbons - diesel range	--	2,000	--	--	--	--	--	--	--	--
Total petroleum hydrocarbons - diesel range extended to C36	--	--	--	--	--	--	--	--	--	--
Total petroleum hydrocarbons - gasoline range	--	30	--	--	--	--	--	--	--	--
Total petroleum hydrocarbons - motor oil (high boiling)	--	2,000	--	--	--	--	--	--	--	--
Xylenes (total)	--	--	--	--	16,000	--	103	--	10,346	--

MTCA = Model Toxics Control Act
OU = operable unit
PRG = preliminary remeditation goal

Carcinogens are those contaminants that are known or suspected causes of cancer following exposure. Noncarcinogenic compounds are associated with a wide variety of systemic effects, such as liver toxicity or developmental effects. Some contaminants (for example, arsenic) are capable of eliciting both carcinogenic and noncarcinogenic responses; therefore, these contaminants are evaluated for both effects.

For cancer effects, EPA has developed a carcinogen classification system (*Guidelines for Carcinogen Risk Assessment* [EPA/630/P-03/001F]) that uses a weight of evidence approach for classifying the likelihood that a chemical is a human carcinogen. Information considered in developing the classification includes human studies of the association between cancer incidence and exposure, as well as long-term animal studies under controlled laboratory conditions. Other supporting evidence considered includes short-term tests for genotoxicity, metabolic and pharmacokinetic properties, toxicological effects other than cancer, structure-activity relationships, and physical and chemical properties of the chemical.

For noncancer effects, toxicity values are derived based on the critical toxic endpoint (that is, the most sensitive adverse effect following exposure). Table G-11 (Appendix G) lists the COPCs detected at the 100-D/H Source OU area that have been identified as having documented systemic effects.

6.2.4.1.1 *Dose-response Evaluation*

The magnitude of toxicity of a contaminant depends on the dose to a receptor. Dose refers to exposure to a contaminant concentration over a specified period. Human exposures are generally classified as acute (typically less than 2 weeks), subchronic (about 2 weeks to 7 years), or chronic (7 years to a lifetime). This HHRA specifically addresses chronic exposure. Acute exposures and risks are evaluated only when chronic exposure estimates pose a high risk. A dose-response curve describes the relationship between the degree of exposure (i.e., dose) and the incidence of the adverse effects (that is, response) in the exposed population. EPA uses this dose-response information to establish toxicity values for particular chemicals, as described in the following sections.

Reference Doses for Noncancer Effects. The toxicity value describing the dose-response relationship for noncancer effects is the RfD value. For noncarcinogenic effects, the body's protective mechanisms must be overcome before an adverse effect is manifested. If exposure is high enough and these protective mechanisms (or thresholds) are exceeded, adverse health effects can occur. EPA attempts to identify the upper bound of this tolerance range in the development of noncancer toxicity values. EPA uses the apparent toxic threshold value, in conjunction with uncertainty factors based on the strength of the toxicological evidence, to derive an RfD value. EPA defines an RfD value as follows:

In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfD is generally expressed in units of mg/kg-day.

Available chronic RfD values for the oral and inhalation exposure routes are used to calculate PRGs. Because EPA has not derived toxicity values specific to skin contact, dermal slope factors and RfD values were derived from oral toxicity factors in accordance with EPA guidance. The RfD values for the contaminants evaluated in the 100-D/H Source OU are summarized in Table G-11 (Appendix G).

Slope Factors for Cancer Effects. The dose-response relationship for cancer effects is expressed as a cancer slope factor that converts estimated intake directly to excess lifetime cancer risk (ELCR). Slope factors are expressed in units of risk per level of exposure (or intake). The data used for estimating the dose-response relationship are taken from lifetime animal studies or human occupational or epidemiological studies where excess cancer risk has been associated with exposure to the chemical. However, because risk at low intake levels cannot be directly measured in animal or human epidemiological studies, a number of mathematical models and procedures have been developed to

extrapolate from the high doses used in the studies to the low doses typically associated with environmental exposures. The model choice leads to uncertainty associated with the carcinogenic response at very low levels of exposure. EPA assumes linearity at low doses when uncertainty exists about the mechanism of action of a carcinogen and when information suggesting nonlinearity is absent.

It is assumed, therefore, that if a cancer response occurs at the dose levels used in the study, then there is some probability that a response will occur at all lower exposure levels (that is, a dose-response relationship with no threshold is assumed). Moreover, the dose-response slope chosen is usually the 95 percent UCL on the mean on the actual dose-response curve observed in the laboratory studies. As a result, uncertainty and conservatism are built into the EPA risk extrapolation approach. EPA has stated that cancer risks estimated by this method produce estimates that "provide a rough but plausible upper limit of risk." The cancer slope factors used in this assessment are summarized in Table G-11 (Appendix G).

6.2.4.2 Toxicity Values

The analyte-specific toxicity values presented in Table G-11 (Appendix G) are determined using the following recommended reference hierarchy as described in Superfund HHT Risk Assessment Values (Cook, 2003):

- Tier 1—The EPA Integrated Risk Information System (IRIS) database
- Tier 2—The EPA Provisional Peer Reviewed Toxicity Values
- Tier 3—Other Toxicity Values

6.2.4.2.1 *Tier 1—IRIS*

The preferred source of toxicity data is EPA's IRIS database. Expert toxicologists at EPA have derived the values in this database and the values have undergone a thorough review and validation both within and outside EPA. If a toxicity value is available in IRIS, that value is preferred to any other value.

6.2.4.2.2 *Tier 2—Provisional Peer Reviewed Toxicity Values*

If a toxicity value is not available in IRIS, the next source is EPA's Provisional Peer Reviewed Toxicity Values. This source includes toxicity values that have been developed by the Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center. This database is not available to the public, but is accessible to EPA risk assessors via EPA's intranet. These values are also published at Regional Screening Levels (EPA, 2013a).

6.2.4.2.3 *Tier 3—Other Toxicity Values*

Tier 3 includes additional EPA and non-EPA sources of toxicity information, including the following:

- The California Environmental Protection Agency's (CalEPA) Toxicity Criteria Database contains toxicity values that are peer-reviewed and address both cancer and noncancer effects.
- Agency for Toxic Substances and Disease Registry database Minimal Risk Levels for Hazardous Substances are peer-reviewed estimates of the daily human exposure to hazardous substances that is likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure.
- Toxicity values in *Health Effects Assessment Summary Tables: FY 1997 Update* (EPA 540-R-97-036), hereinafter called HEAST.

When Tier 1, Tier 2, or Tier 3 toxicity values are not available for a COPC, the toxicity values from the National Center for Environmental Assessment are used. These values can be found in the Risk Assessment Information System (ORNL, 2010).

A derived RfD for nitrate was calculated from the RfD reported in IRIS (1.6 mg/kg-day) for nitrate as nitrogen (NO3-N) using the mass fraction of nitrogen in nitrate. The mass fraction of nitrogen in nitrate = mol wt N/mol wt NO_3^- = (14 g/mol)/(62 g/mol) = 0.226. The derived RfD for nitrate = (1.6 mg NO_3 - N/kg-day) × (1 mg NO_3^-/0.226 mg NO_3-N) = 7.1 mg NO_3-/kg-day.

A derived RfD for nitrite was calculated from the RfD reported in IRIS (0.1 mg/kg-day) for nitrite as nitrogen (NO_2-N) using the mass fraction of nitrogen in nitrite. The mass fraction of nitrogen in nitrite = mol wt N/mol wt NO_2^- = (14 g/mol)/(46 g/mol) = 0.304. The derived RfD for nitrite = (0.1 mg NO_2-N/kg-day) × (1 mg NO_2^-/0.304 mg NO_2-N) = 0.3 mg NO_2^-/kg-day.

Toxic equivalence factors were used to calculate toxicity values for dioxins, furans, and carcinogenic PAHs as described in 2007 MTCA ("Human Health Risk Assessment Procedures," hereinafter called HHRA Procedures [WAC 173-340-708(8)(D)(iii)(A)]).

For Cr(VI), the current assessment considers cancer effects only for inhalation exposures. Note that an oral RfD and a reference concentration are available for assessment of noncancer effects. An oral cancer slope factor has recently been published by the New Jersey Department of Environmental Protection (NJDEP). The oral cancer slope factor derived by NJDEP is 0.5 $(mg/kg\text{-}day)^{-1}$, 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 were used to calculate the 2007 MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) level, the soil concentration would decrease from 240 to 2.0 mg/kg. Assessing only inhalation cancer effects from Cr(VI) has the potential to under-estimate cancer risk.

The analyte-specific toxicity values, decay constants, and half-life presented in Table G-11 (Appendix G) are determined using the recommended values from the HEAST Radionuclides Table.

6.2.5 Risk Characterization

Risk characterization is completed through the comparison of the EPC to the RBSL, and comparison of total site cancer risk and site noncancer hazard index to their respective thresholds. These steps are used to determine whether the post-remediation soil concentrations protect human health. It is also used to determine whether current material 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 RME for both current and future land use.

Although this risk assessment produces numerical estimates of risk, it should be recognized that these numbers might 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.

For the purpose of this risk characterization step, 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 regulatory agencies. 2007 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 this 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.

6.2.5.1 Cancer Risk Estimation Method

To estimate the cancer risks from exposure to an individual nonradiological carcinogen from all exposure routes considered, the following equation is used:

$$Risk_I = \frac{EPC_{soil}}{RBSL_{carcinogen}} \times TR$$

where:

$Risk_I$ = ELCR for individual chemical or radioisotope (unitless)

EPC_{soil} = EPC in soil (µg/kg or pCi/g)

$RBSL_{carcinogen}$ = Soil RBSL based on 10^{-6} carcinogenic effect for chemical (µg/kg) or 10^{-4} carcinogenic effect for radioisotope (pCi/g)

TR = Target ELCR of 10^{-6} for individual hazardous substance or 10^{-4} for individual radioisotope

To estimate the cancer risks from exposure to multiple carcinogens from all exposure routes considered, the following equation is used. The following equation is consistent with that published in "Regional Screening Values for Chemical Contaminants at Superfund Sites" (2013a).

$$Risk_T = \sum_i \frac{EPC_{soil}}{RBSL_{carcinogen}} \times TR$$

where:

$Risk_T$ = Total ELCR for all chemicals and radioisotopes

EPC_{soil} = EPC in soil (µg/kg or pCi/g)

$RBSL_{carcinogen}$ = Soil RBSL based on 10^{-6} carcinogenic effect for chemical (µg/kg) or 10^{-4} carcinogenic effect for radioisotope (pCi/g)

TR = Target ELCR of 10^{-6} for individual hazardous substance or 10^{-4} for individual radioisotope

i = The sum of the ratios for the ith chemical

6.2.5.2 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 (that is, its RfD). The ratio of the chronic daily intake divided by RfD is the HQ. To estimate the HQ from all exposure routes considered for an individual hazardous substance, the following equation is used:

$$HQ = \frac{EPC_{soil}}{RBSL_{noncarcinogen}}$$

where:

HQ = HQ for individual chemical

EPC_{soil} = EPC in soil (µg/kg)

$RBSL_{noncarcinogen}$ = RBSL based on HQ=1 noncarcinogenic effects (μg/kg)

To estimate the HI from all exposure routes considered for multiple hazardous substances, the following equation is used. The following equation is consistent with that published in Regional Screening Levels (2014).

$$HI_T = \sum_i \frac{EPC_{soil}}{RBSL_{noncarcinogen}}$$

where:

HI_T = Total HI for all chemicals

EPC_{soil} = Exposure point concentration in soil (μg/kg)

$RBSL_{noncarcinogen}$ = RBSL based on HQ=1 noncarcinogenic effects (μg/kg)

i = The sum of the ratios for the ith chemical

6.2.5.3 Comparisons of Lead and Arsenic to 2007 MTCA A Soil Cleanup Levels

Potential risks from lead concentrations were evaluated using a different method than what is conventionally used for other carcinogens and noncarcinogens (as described in previous sections). For direct contact pathways, the EPCs for lead were compared to the 2007 MTCA ("Tables" [WAC 173-340-900], Table 740-1), Method A soil cleanup level for Unrestricted Land Use of 250 mg/kg.

The Method A cleanup level is based on EPA's Integrated Exposure Uptake Biokinetic (IEUBK) model, which is available on the EPA website. The IEUBK model is designed to calculate the probability of blood-lead concentrations for children between 6 months and 84 months (that is, up to 7 years) of age who have been exposed to lead through various sources (for example, air, water, soil, dust, and in utero contributions from the mother) to exceed a specific blood lead concentration.

Additionally, arsenic EPCs were compared to the 2007 MTCA ("Tables" [WAC 173-340-900], Table 740-1), Method A soil cleanup level for Unrestricted Land Use of 20 mg/kg.

6.2.5.4 Consideration of Background in Risk Assessment

CERCLA Soil Background Comparisons Guidance (EPA 540-R-01-003) provides national policy considerations for application of background data in risk assessment and remedy selection. This policy recommends an approach that addresses site-specific background issues in the risk characterization. CERCLA Soil Background Comparisons Guidance (EPA 540-R-01-003) indicates the following:

- COPCs that have both release-related and background-related sources should be included in the risk assessment. When concentrations of naturally occurring elements at a site exceed risk-based screening levels, that information should be discussed qualitatively in the risk characterization.
- CERCLA Soil Background Comparisons Guidance (EPA 540-R-01-003) defines background constituents as the following: anthropogenic—natural and artificial substances present in the environment as a result of human activities (not specifically related to the CERCLA release in question), and naturally occurring-substances present in the environment in forms that have not been influenced by human activity.

6.2.5.4.1 Sources of Background Concentrations

The 90th percentile and maximum background concentrations for the Hanford Site have been developed for both inorganic chemicals and radionuclides and are considered representative of both naturally

occurring and anthropogenic substances. The maximum inorganic background concentrations used in this evaluation are identified as the "overall maximum concentrations" in the Non-Rad Soil Background document (DOE/RL-92-24), Summary Table 1, and the 90th percentile inorganic background concentrations are identified as the "lognormal distribution 90th percentiles" in the Non-Rad Soil Background document (DOE/RL-92-24), Summary Table 2. The exceptions to this are described in the following paragraph. Two types of sampling were conducted to determine the inorganic background values: systematic random sampling, and judgment sampling. The overall maximum concentrations were determined by considering the analytical results from both systematic random samples and judgmental samples. The 90th percentile values were calculated using the analytical results from the systematic random samples only.

The letter *Issues Associated with Establishing Soil Cleanup Levels for Arsenic* published by the Department of Ecology Toxics Cleanup Program on June 11, 2013, indicates that the Method A soil cleanup level of 20 mg/kg can be used to define natural background levels when developing Method B soil cleanup levels for the Hanford Site..

The Hanford Site background values for antimony, boron, cadmium, lithium, mercury, molybdenum, selenium, silver, and thallium are documented in *Soil Background Data for Interim Use at the Hanford Site* (ECF-HANFORD-11-0038). Boron was not analyzed for in the Non-Rad Soil Background document (DOE/RL-92-24) and the analytical data associated with the remaining analytes in the Non-Rad Soil Background document (DOE/RL-92-24) are considered unusable for statistical analyses because of elevated MDLs. The background concentration values documented in *Soil Background Data for Interim Use at the Hanford Site* (ECF-HANFORD-11-0038) reference *A Review of Metal Concentrations Measured in Surface Soil Samples Collected On and Around the Hanford Site* (PNNL-18577), hereinafter called Review of Metal Concentrations. The ECF documents a review of the datasets from the Non-Rad Soil Background document (DOE/RL-92-24) and Review of Metal Concentrations (PNNL-18577), which indicates the data are comparable and issues associated with elevated detection limits were eliminated as a result of improvements in analytical methods used for Review of Metal Concentrations (PNNL-18577). It is noted that *Soil Background Data for Interim Use at the Hanford Site* (ECF-HANFORD-11-0038) recalculates the percentile values based on using a nonparametric (Kaplan-Meier) method, consistent with the methodology used in the Non-Rad Soil Background document (DOE/RL-92-24). Review of Metal Concentrations (PNNL-18577) calculated the 90th percentile values based on an assumption of normally distributed data.

The background concentration values documented in *Soil Background Data for Interim Use at the Hanford Site* (ECF-HANFORD-11-0038) for selenium reference *Natural Background Soil Metals Concentrations in Washington State* (Ecology Publication 94-115) because neither the Non-Rad Soil Background document (DOE/RL-92-24) nor Review of Metal Concentrations (PNNL-18577) had adequate analytical results.

Radionuclide background values (lognormal 90th percentile and maximum) are identified in the Rad Soil Background document (DOE/RL-96-12), Table 5-1. The background values for naturally occurring radionuclides were determined primarily by analyzing a subset of the inorganic systematic random samples from the vadose zone (upper 30 cm [76 in.] of the soil column). The background values for the anthropogenic radionuclides were determined from analytical results from surface sampling (upper 2.5 cm [1 in.] of the soil column).

The composition of background samples described in the Non-Rad Soil Background document (DOE/RL-92-24), Rad Soil Background document (DOE/RL-96-12), and Review of Metal Concentrations (PNNL-18577) is representative of the sedimentary facies in the vadose zone at the 100-D/H Source OU. These background data are recommended for use in environmental restoration activities on the Hanford Site to maintain consistency between projects, and they have been peer reviewed

for technical credibility. Table G-12 (Appendix G) lists the maximum and 90th percentile background concentration values for inorganic chemicals and radionuclides.

6.2.5.4.2 *Comparison of Site and Background Risk Contributions*

Understanding the contribution to risk from naturally occurring elements is important because remedial action goals are not set at concentrations below natural background levels under CERCLA. Similarly, 2007 MTCA ("Overview of Cleanup Standards" [WAC 173-340-700(6)(d)]) states that:

> *In some cases, cleanup levels calculated using the methods specified in this chapter are less than natural background levels or levels that can be reliably measured. In those situations, the cleanup level shall be established at a concentration equal to the practical quantitation limit or natural background concentration, whichever is higher.*

CERCLA Soil Background Comparisons Guidance (EPA 540-R-01-003) states:

When background concentrations are high relative to the concentrations of released hazardous substances, pollutants, and contaminants, a comparison of site and background concentrations may help risk managers make decisions concerning appropriate remedial actions. The contribution of background concentrations to risks associated with CERCLA releases may be important for refining specific RAGs [remedial action goals] for contaminants of concern that warrant remedial action.

The 90th percentile value is used as a fixed benchmark concentration for determining which contaminants should be evaluated for purposes of background risk. To assist in risk management decisions concerning appropriate remedial actions, a comparison of background risks to risks from CERCLA releases is provided using the approach described in the following text:

EPCs from each decision unit are compared to the background value for metals and radionuclides listed in Table G-12 (Appendix G). A comparison of EPCs to the lognormal 90th percentile value for each decision unit is provided in Table G-13 (Appendix G) for the 100-D Source OU and Table G-14 (Appendix G) for the 100-H Source OU. Risk estimates are calculated as follows:

- If the EPC is less than or equal to the background value, then a risk estimate or an HQ is not calculated.
- If the EPC is greater than the background value, then a risk estimate or an HQ is calculated.
- If a background value is not available for an analyte, then a risk estimate or an HQ is calculated.
- The total ELCR is summed for all analytes with EPCs greater than their background value.
- The HI is summed for all analytes with EPCs greater than their respective background value.

6.2.5.5 *Summary of Risk Estimates by Exposure Scenario*

This section summarizes the risk estimates for each of the exposure scenarios considered for the 100-D/H Source OU.

6.2.5.5.1 *Residential Scenario*

PRGs developed for the Residential scenario are the numeric values that represent the RAOs presented in Chapter 8. PRGs are established to help determine the need for remedial action at unremediated waste sites. The PRGs are also used to compare EPCs to the RBSLs in this soil risk assessment that will be used to help determine whether additional remedial action is necessary for waste sites where remediation has been completed, and whether the goals and objectives of the interim action RODs have been met, as

demonstrated by verification sampling and analysis. A complete description of the Residential exposure scenario is provided in Section 6.2.3.3.1.

For completeness in analysis, all risk estimates for each remediated waste site decision unit are provided in Appendix G. The risk estimates, which include all COPCs regardless of their EPCs relative to background concentrations, are presented in Tables G-15 through G-23 (100-D Residential scenario) and Tables G-34 to G-42 (100-H Residential scenario).

Appendix G also includes risk estimates for each remediated waste site decision unit, which include only those COPCs with EPCs greater than background values or that do not have a background value. These risk estimates are presented in Tables G-24 to G-33 (100-D Residential scenario) and Tables G-43 to G-52 (100-H Residential scenario). Only these risk estimates without background contributions are summarized and discussed in the risk characterization because this information is used for decisions concerning appropriate remedial actions.

100-D Source OU. Risk estimates were calculated for each decision unit within a remediated waste site including shallow vadose zone material, deep vadose zone material, overburden material, and staging pile area footprint material. The results without background contribution for the Residential scenario are presented in Tables G-24 to G-26 (Appendix G).

An overall summary of the total risk estimates and noncancer hazards (if applicable) for the residential scenario from each of the remediated waste sites is provided in Tables 6-13 and Table 6-14 for shallow zone material, Table 6-15 and Table 6-16 for overburden material, Table 6-17 and Table 6-18 for staging piles, and Table 6-19 for the deep zone. These tables list the OU that each remediated waste site resides in, the reclassification status, the remediated waste site, the associated waste site (if applicable), the decision unit reported with an exceedance (if applicable), the total ELCR and the risk driver and percent contribution (if applicable), and the hazard index and the noncancer hazard driver and percent contribution (if applicable).

Shallow Zone. A total of 92 remediated waste sites are reported with CVP/RSVP data associated with the shallow zone in the 100-D Source OU. The following lists the sample designs that were applied to the remediated waste sites evaluated:

- Twenty remediated waste sites were sampled using a focused sampling design.
- Forty-seven remediated waste sites were sampled using a statistical sampling design (with three sites having two statistically distinct decision units).
- Twenty-five remediated waste sites were sampled using both a statistical and a focused sampling design (with two sites having one focused and three statistically distinct decision units; three sites having one focused and two statistically distinct decision units and two sites with two focused decision units and one statistical decision unit).

Radionuclide Results. As presented in Table 6-13, the potential total ELCR is greater than or equal to the upper risk threshold of 1×10^{-4} at nine remediated waste sites, is within the target risk range of 10^{-4} to 10^{-6} at 27 remediated waste sites, and is less than the lower risk threshold of 1×10^{-6} at three remediated waste sites. Risks were not reported at 19 remediated waste sites because radiological COPC concentrations were less than background. Radiological COPCs were not reported at 34 remediated waste sites.

Table 6-13. Summary of Total Risks from Radionuclides for the 100-DR-1 and 100-DR-2 Shallow Zone Waste Sites for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution
100-DR-1 OU					
Interim Closed Out	116-DR-9	100-D-25	Shallow	2.6×10^{-4} $< 1 \times 10^{-4}$ (2038)	Cesium-137 (2.3×10^{-4} – 89%)
	100-D-42, 100-D-43, 100-D-45	--	Shallow Focused	1.2×10^{-4} $< 1 \times 10^{-4}$ (2012)	Cobalt-60 (3.9×10^{-5} – 34%) Nickel-63 (7.6×10^{-5} – 66%)
	100-D-48:3	100-D-5 100-D-6	Shallow	1.2×10^{-4} $< 1 \times 10^{-4}$ (2009)	Strontium-90 (1.2×10^{-4} – 97%)
	118-D-6:4	--	Shallow 2	1.2×10^{-4} $< 1 \times 10^{-4}$ (2022)	Cesium-137 (6.5×10^{-5} – 53%) Europium-152 (3.9×10^{-5} – 31%) Strontium-90 (1.6×10^{-5} – 13%)
	100-D-48:1	100-D-49:1 UPR-100-D-4	None	1×10^{-4} to 1×10^{-6}	None
	100-D-48:2	UPR-100-D-2 UPR-100-D-3			
	116-D-1A	100-D-46 116-D-1B			
	100-D-20 100-D-22 100-D-4 100-D-48:4 100-D-49:2 100-D-49:4 100-D-52 116-D-5 116-D-7 116-D-9 116-DR-1&2 116-DR-5 128-D-2 132-D-1 1607-D2:3 1607-D2:4	--			
	100-D-29 100-D-32 1607-D2:1	--	None	$< 1 \times 10^{-6}$	None

Table 6-13. Summary of Total Risks from Radionuclides for the 100-DR-1 and 100-DR-2 Shallow Zone Waste Sites for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution
	100-D-21 100-D-31:1, 100-D-31:2 100-D-31:10 100-D-31:3 100-D-31:4 100-D-31:7 100-D-31:8 100-D-31:9 100-D-49:3 116-D-10 116-D-2 116-D-4	--	None	No COPCs reported above background	None
	100-D-1 100-D-2 100-D-31:5 100-D-31:6 100-D-56:1 100-D-56:2 100-D-61 100-D-7 100-D-9 120-D-2 126-D-2 130-D-1 1607-D2:2 1607-D4 1607-D5 628-3	--	None	No COPCs reported	None
No Action	100-D-24 100-D-3 UPR-100-D-5	--	None	No COPCs reported above background	None

Table 6-13. Summary of Total Risks from Radionuclides for the 100-DR-1 and 100-DR-2 Shallow Zone Waste Sites for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution
	100-D-50:5 100-D-70 100-D-74 100-D-75:3 100-D-80:1 100-D-82 100-D-83:4 100-D-84:1 100-D-85:1 100-D-87 100-D-88 100-D-90	--	None	No COPCs reported	None
100-DR-2					
Interim Closed Out	--[c]	100-D-43	Shallow Focused	1.2×10^{-4} $< 1 \times 10^{-4}$ (2012)	Cobalt-60 (3.9×10^{-5} – 34%) Nickel-63 (7.6×10^{-5} – 66%)
	--[d]	100-D-46	None	1×10^{-4} to 1×10^{-6}	None
	118-DR-2:2	--	Shallow	2.2×10^{-4} $< 1 \times 10^{-4}$ (>100,000 years)	Technetium-99 (1.6×10^{-4} – 74%) Strontium-90 (3.9×10^{-5} – 18%)
	116-D-8		Shallow Focused 2	1.7×10^{-4} $< 1 \times 10^{-4}$ (2035)	Cesium-137 (1.7×10^{-4} –100%)
	100-D-47		Shallow Focused	1.0×10^{-4} $< 1 \times 10^{-4}$ (2009)	Europium-152 (4.2×10^{-5} – 40%) Strontium-90 (5.2×10^{-5} – 50%)
	116-DR-10 116-DR-6 116-DR-7 116-DR-8 118-D-1 118-D-4 118-D-5 118-DR-1	--	None	1×10^{-4} to 1×10^{-6}	None
	100-D-13	--	None	No COPCs reported above background	None
	116-DR-4				

Table 6-13. Summary of Total Risks from Radionuclides for the 100-DR-1 and 100-DR-2 Shallow Zone Waste Sites for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution
	122-DR-1:2	100-D-23 100-D-53 100-D-54 100-D-64			
	100-D-12 100-D-15 100-D-28:1 1607-D1 600-30		None	No COPCs reported	None
No Action	100-D-94	--	None	No COPCs reported	None

Note: Results summarized from Table G-24, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-D Source OU Waste Site Decision Units Without Background Contribution (Appendix G).

The following three waste sites do not report shallow zone sample data: 100-D-18, 100-D-19, and 116-D-6.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from radiological COPCs.

c. Remediated waste site 100-D-43 (100-DR-2 OU) is associated with remediated waste sites 100-D-42 and 100-D-45 (100-DR-1 OU).

d. Remediated waste site 100-D-46 (100-DR-2 OU) is associated with remediated waste site 116-D-1A (100-DR-1).

COPC = contaminats of potential concern

ELCR = excess lifetime cancer risk

OU = operable unit

Table 6-14. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-DR-1 and 100-DR-2 Shallow Zone Waste Sites for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution	Hazard Index	Noncancer Hazard Driver and % Contribution
100-DR-1 OU							
Interim Closed Out	100-D-31:4	--	Shallow	1.7×10^{-5}	Benzo(a)pyrene (1.4×10^{-5} – 81%) Benzo(b)fluoranthene (1.2×10^{-6} – 7%)	<1	None

Table 6-14. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-DR-1 and 100-DR-2 Shallow Zone Waste Sites for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution	Hazard Index	Noncancer Hazard Driver and % Contribution
	1607-D5		Shallow	5.2×10^{-6}	Benzo(a)anthracene (1.4×10^{-6} – 28%) Benzo(a)pyrene (3.0×10^{-6} – 57%)		
	1607-D2:2		Shallow	1.2×10^{-6}	Aroclor-1254 (8.9×10^{-7} – 74%) Aroclor-1260 (3.1×10^{-7} – 26%)		
	100-D-1 100-D-31:1, 100-D-31:2 100-D-31:10 100-D-31:3 100-D-31:6 100-D-31:7 100-D-31:8 100-D-31:9 100-D-4 100-D-42, 100-D-43, 100-D-45 100-D-49:4 100-D-61 100-D-7 100-D-9 116-D-5 116-DR-5 118-D-6:4 126-D-2 128-D-2 130-D-1 132-D-1 1607-D2:3 1607-D4 628-3	--	None	$< 1 \times 10^{-6}$	None	<1	None

Table 6-14. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-DR-1 and 100-DR-2 Shallow Zone Waste Sites for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution	Hazard Index	Noncancer Hazard Driver and % Contribution
	100-D-2 100-D-29 100-D-31:5 100-D-32 100-D-56:1 100-D-56:2 116-D-10 120-D-2	--	None	No COPCs reported above background	None	<1	None
	1607-D2:1					No COPCs reported above background	None
	100-D-20	--	None	No COPCs reported	None	No COPCs reported	None
	100-D-21						None
	100-D-22						None
	100-D-48:1	100-D-49:1 UPR-100-D-4				<1	None
	100-D-48:2	UPR-100-D-2 UPR-100-D-3				No COPCs reported	None
	100-D-48:3	100-D-5 100-D-6				<1	None
	100-D-48:4	--					

Table 6-14. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-DR-1 and 100-DR-2 Shallow Zone Waste Sites for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution	Hazard Index	Noncancer Hazard Driver and % Contribution
	100-D-49:2 100-D-49:3					No COPCs reported	None
	100-D-52					No COPCs reported above background	
	116-D-1A	100-D-46 116-D-1B				<1	None
	116-D-2 116-D-4	--				No COPCs reported	None
	116-D-7					<1	None
	116-D-9 116-DR-1&2					No COPCs reported	None
	116-DR-9	100-D-25				<1	None
	1607-D2:4	--				No COPCs reported above background	None
No Action							
	100-D-24 100-D-74 100-D-84:1 100-D-87 100-D-88 100-D-70	--	None	$< 1 \times 10^{-6}$	None	<1	None
	100-D-82					No COPCs reported above background	None

Table 6-14. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-DR-1 and 100-DR-2 Shallow Zone Waste Sites for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution	Hazard Index	Noncancer Hazard Driver and % Contribution
	100-D-50:5 100-D-85:1	--	None	No COPCs reported above background	None	No COPCs reported above background	None
	100-D-75:3 100-D-83:4 UPR-100-D-5					<1	None
	100-D-3 100-D-80:1 100-D-90	--	None	No COPCs reported	None	No COPCs reported	None
100-DR-2							
Interim Closed Out	--[c]	100-D-43	None	$< 1 \times 10^{-6}$	None	<1	None
	--[d]	100-D-46	None	No COPCs reported	None	<1	None
	100-D-13 100-D-15 100-D-28:1 116-D-8 116-DR-10 116-DR-8 118-DR-1 118-DR-2:2	--	None	$< 1 \times 10^{-6}$	None	<1	None

Table 6-14. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-DR-1 and 100-DR-2 Shallow Zone Waste Sites for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution	Hazard Index	Noncancer Hazard Driver and % Contribution
	122-DR-1:2	100-D-23 100-D-53 100-D-54 100-D-64					
	1607-D1 600-30	--					
	100-D-47 118-D-1 118-D-4 118-D-5	--	None	No COPCs reported above background	None	<1	None
			None	No COPCs reported	None		
	100-D-12 116-DR-4 116-DR-6 116-DR-7					No COPCs reported	None
No Action	100-D-94	--	None	No COPCs reported above background	None	<1	None

Note: Results summarized from Table G-24, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-D Source OU Waste Site Decision Units Without Background Contribution (Appendix G).

The following three waste sites do not report shallow zone sample data: 100-D-18, 100-D-19, and 116-D-6.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from nonradiological carcinogenic COPCs.

c. Remediated waste site 100-D-43 (100-DR-2 OU) is associated with remediated waste sites 100-D-42 and 100-D-45 (100-DR-1 OU).

d. Remediated waste site 100-D-46 (100-DR-2 OU) is associated with remediated waste site 116-D-1A (100-DR-1).

ELCR = excess lifetime cancer risk

OU = operable unit

Table 6-15. Summary of Total Risks from Radionuclides for the 100-DR-1 and 100-DR-2 Overburden Material for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution
100-DR-1 OU					
Interim Closed Out	100-D-48:3	100-D-5 100-D-6	None	1×10^{-4} to 1×10^{-6}	None
	100-D-48:2	UPR-100-D-2 UPR-100-D-3	None		
	100-D-31:10 100-D-31:3, 100-D-31:4 100-D-31:8 100-D-4 116-D-5 116-DR-5 1607-D2:3	--	None		
	100-D-29	--	None	$< 1 \times 10^{-6}$	
	100-D-31:1, 100-D-31:2 100-D-31:7 100-D-31:9 100-D-32	--	None	No COPCs reported above background	
	100-D-31:5 100-D-31:6 100-D-42, 100-D-43, 100-D-45 100-D-56:1 100-D-56:2 126-D-2	--	None	No COPCs reported	
No Action	UPR-100-D-5	--	None	1×10^{-4} to 1×10^{-6}	
100-DR-2					
Interim Closed Out	100-D-47 116-DR-8 118-D-5	--	None	1×10^{-4} to 1×10^{-6}	None
	118-D-1	--	None	$< 1 \times 10^{-6}$	
	116-DR-10 118-D-4	--	None	No COPCs reported above background	

Table 6-15. Summary of Total Risks from Radionuclides for the 100-DR-1 and 100-DR-2 Overburden Material for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution
	100-D-28:1		None	No COPCs reported	

Note: Results summarized from Table G-24, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-D Source OU Waste Site Decision Units Without Background Contribution (Appendix G).

Remediated waste site 100-D-43 (100-DR-2 OU) is associated with remediated waste sites 100-D-42 and 100-D-45 (100-DR-1 OU).

Remediated waste site 100-D-46 (100-DR-2 OU) is associated with remediated waste site 116-D-1A (100-DR-1).

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from radiological COPCs.

ELCR = excess lifetime cancer risk

OU = operable unit

Table 6-16. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-DR-1 and 100-DR-2 Overburden for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution	Hazard Index	Noncancer Hazard Driver and % Contribution
100-DR-1 OU							
Interim Closed Out	100-D-31:3, 100-D-31:4	--	None	1.2×10^{-6}	None	<1	None
	100-D-31:1, 100-D-31:2 100-D-31:10 100-D-31:6 100-D-31:7 100-D-31:8 100-D-31:9 116-D-5 116-DR-5 126-D-2	--	None	$< 1 \times 10^{-6}$	None	<1	None

Table 6-16. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-DR-1 and 100-DR-2 Overburden for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution	Hazard Index	Noncancer Hazard Driver and % Contribution
	100-D-48:2	UPR-100-D-2 UPR-100-D-3	None	No COPCs reported	None	<1	None
	100-D-48:3	100-D-5 100-D-6				No COPCs reported above background	
	1607-D2:3	--					
Interim Closed Out	100-D-29 100-D-31:5 100-D-32 100-D-42, 100-D-43, 100-D-45 100-D-56:1 100-D-56:2	--	None	No COPCs reported above background	None	<1	None
	100-D-4	--	None	No COPCs reported	None	<1	None
No Action	UPR-100-D-5	--	None	$< 1 \times 10^{-6}$	None	<1	None
100-DR-2							
Interim Closed Out	100-D-28:1	--	None	1.9×10^{-6}	None	<1	None

Table 6-16. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-DR-1 and 100-DR-2 Overburden for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution	Hazard Index	Noncancer Hazard Driver and % Contribution
	116-DR-10 116-DR-8 118-D-1	--		$< 1 \times 10^{-6}$	None		
	100-D-47 118-D-4 118-D-5	--		No COPCs reported above background	None		

Note: Results summarized from Table G-24, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-D Source OU Waste Site Decision Units Without Background Contribution (Appendix G).

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from nonradiological carcinogenic COPCs.

COPC = contiminant of potential concern

ELCR = excess lifetime cancer risk

OU = operable unit

Table 6-17. Summary of Total Risks from Radionuclides for the 100-DR-1 and 100-DR-2 Staging Piles for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution
100-DR-1 OU					
Interim Closed Out	116-D-10	--	None	1×10^{-4} to 1×10^{-6}	None
	116-DR-5 132-D-1			$< 1 \times 10^{-6}$	
	100-D-7 116-D-5			No COPCs reported above background	
	100-D-56:2 130-D-1 628-3			No COPCs reported	
100-DR-2					
Interim Closed Out	118-D-1	--	None	$< 1 \times 10^{-6}$	None
	100-D-28:1 1607-D1			No COPCs reported	

Note: Results summarized from Table G-24, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-D Source OU Waste Site Decision Units Without Background Contribution (Appendix G).

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from radiological COPCs.

COPC = contaminant of potential concern

ELCR = excess lifetime cancer risk

OU = operable unit

Table 6-18. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-DR-1 and 100-DR-2 Staging Piles for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution	Hazard Index	Noncancer Hazard Driver and % Contribution
100-DR-1 OU							
Interim Closed Out	132-D-1	--	None	1.8×10^{-6}	Benzo(a)pyrene (1.3×10^{-6} – 69%)	<1	None
	100-D-56:2 100-D-7 116-D-5 116-DR-5 130-D-1 628-3	--	None	$< 1 \times 10^{-6}$	None	<1	None
	116-D-10	--	None	No COPCs reported above background	None	<1	None
100-DR-2							
Interim Closed Out	100-D-28:1 118-D-1 1607-D1	--	None	$< 1 \times 10^{-6}$	None	<1	None

Note: Results summarized from Table G-24, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-D Source OU Waste Site Decision Units Without Background Contribution (Appendix G).

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from nonradiological carcinogenic COPCs.

COPC = contaminant of potential concern

ELCR = excess lifetime cancer risk

OU = operable unit

Table 6-19. Summary of Total Risks from Radionuclides for the 100-DR-1 and 100-DR-2 Deep Zone Waste Sites for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution
100-DR-1					
Interim Closed Out	116-D-1A	100-D-46 116-D-1B	Deep	1.6×10^{-2} $< 1.0 \times 10^{-4}$ (2203)	Cesium-137 (9.3×10^{-3} – 58%) Cobalt-60 (2.5×10^{-4} – 1.6%) Europium-152 (5.3×10^{-3} – 33%) Europium-154 (3.6×10^{-4} – 2.2%) Strontium-90 (9.3×10^{-4} – 5.8%)
	116-D-7	--	Deep	9.7×10^{-3} $< 1.0 \times 10^{-4}$ (2125)	Cesium-137 (7.1×10^{-4} – 7.3%) Cobalt-60 (7.4×10^{-4} – 7.6%) Europium-152 (7.3×10^{-3} – 75%) Europium-154 (8.3×10^{-4} – 8.6%) Nickel-63 (1.2×10^{-4} – 1.2%)
	116-DR-1&2		Deep	6.7×10^{-3} $< 1.0 \times 10^{-4}$ (2148)	Cesium-137 (1.7×10^{-3} – 25%) Cobalt-60 (1.1×10^{-4} – 1.7%) Europium-152 (3.4×10^{-3} – 51%) Europium-154 (1.8×10^{-4} – 2.7%) Strontium-90 (1.3×10^{-3} – 19%)
	118-D-6:4		Deep Focused	2.5×10^{-3} $< 1.0 \times 10^{-4}$ (2143)	Cesium-137 (1.9×10^{-3} – 77%) Europium-152 (4.7×10^{-4} – 19%)
	100-D-48:1	100-D-49:1 UPR-100-D-4	Deep	2.8×10^{-3} $< 1.0 \times 10^{-4}$ (2093)	Cesium-137 (6.8×10^{-4} – 24%) Cobalt-60 (2.6×10^{-4} – 9.2%) Europium-152 (1.8×10^{-3} – 62%) Europium-154 (1.1×10^{-4} – 3.9%)
	100-D-49:2	--	Deep	2.5×10^{-3} $< 1.0 \times 10^{-4}$ (2117)	Cesium-137 (1.4×10^{-3} – 57%) Cobalt-60 (2.5×10^{-4} – 10%) Europium-152 (6.7×10^{-4} – 27%)
	116-DR-9	100-D-25	Deep	1.2×10^{-3} $< 1.0 \times 10^{-4}$ (2064)	Cesium-137 (2.4×10^{-4} – 21%) Europium-152 (7.0×10^{-4} – 61%)
	100-D-18	--	Deep	7.5×10^{-4} $< 1.0 \times 10^{-4}$ (2066)	Cesium-137 (4.1×10^{-4} – 54%) Europium-152 (2.7×10^{-4} – 36%)
	100-D-49:4		Deep	3.3×10^{-4} $< 1.0 \times 10^{-4}$ (2027)	Cesium-137 (4.8×10^{-5} – 14%) Europium-152 (2.3×10^{-4} – 69%)
	100-D-48:2	UPR-100-D-2 UPR-100-D-3	Deep	3.0×10^{-4} $< 1.0 \times 10^{-4}$ (2034)	Cesium-137 (1.1×10^{-4} – 36%) Europium-152 (8.8×10^{-5} – 29%) Strontium-90 (7.8×10^{-5} – 26%)

Table 6-19. Summary of Total Risks from Radionuclides for the 100-DR-1 and 100-DR-2 Deep Zone Waste Sites for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution
	100-D-48:3	100-D-5 100-D-6	Deep	2.0×10^{-4} $< 1.0 \times 10^{-4}$ (2028)	Cesium-137 (6.1×10^{-5} – 30%) Strontium-90 (1.2×10^{-4} – 60%)
	100-D-19	--	Deep Focused	1.4×10^{-4} $< 1.0 \times 10^{-4}$ (2042)	Nickel-63 (1.3×10^{-4} – >99%)
	116-D-5 116-D-6	--	None	1×10^{-4} to 1×10^{-6}	None
100-DR-2					
Interim Closed Out	--[c]	100-D-46	Deep	1.6×10^{-2} $< 1.0 \times 10^{-4}$ (2203)	Cesium-137 (9.3×10^{-3} – 58%) Cobalt-60 (2.5×10^{-4} – 1.6%) Europium-152 (5.3×10^{-3} – 33%) Europium-154 (3.6×10^{-4} – 2.2%) Strontium-90 (9.3×10^{-4} – 5.8%)
	116-DR-6	--	Deep	6.3×10^{-4} $< 1.0 \times 10^{-4}$ (2048)	Cesium-137 (1.5×10^{-4} – 23%) Europium-152 (3.9×10^{-4} – 62%)
	118-DR-2:2		Deep	6.8×10^{-4} $< 1.0 \times 10^{-4}$ (2140)	Cesium-137 (2.7×10^{-4} – 37%) Cobalt-60 (1.4×10^{-4} – 19%) Europium-152 (1.6×10^{-4} – 22%)
	118-D-1	--	Deep	$< 1 \times 10^{-6}$	None
	122-DR-1:2	100-D-23 100-D-53 100-D-54 100-D-64	None	No COPCs reported above background	None

Note: Results summarized from Table G-24, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-D Source OU Waste Site Decision Units Without Background Contribution (Appendix G).

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from radiological COPCs.

c. Remediated waste site 100-D-46 (100-DR-2 OU) is associated with remediated waste site 116-D-1A (100-DR-1).

COPC = contaminant of potential concern

ELCR = excess lifetime cancer risk

OU = operable unit

Nine remediated waste sites report concentrations of Hanford Site-related COPCs that are equal to or exceed the upper range of the target threshold for the Residential scenario. The cancer risk levels for the Residential scenario are as follows:

- The 116-DR-9 waste site (shallow decision unit) reports a total ELCR of 2.6×10^{-4}. The primary contributor to risk is cesium-137 (2.3×10^{-4}; 89 percent contribution). The EPC of cesium-137 is 10 pCi/g, which is greater than the residential RBSL of 4.4 pCi/g and is also greater than the direct exposure remedial action goal of 6.2 pCi/g, published in the 100 Area RDR/RAWP (DOE/RL-96-17). Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2038.

- The 118-DR-2:2 waste site (shallow decision unit) reports a total ELCR of 2.2×10^{-4}. The primary contributors to risk include technetium-99 (1.6×10^{-4}; 74 percent contribution) and strontium-90 (3.9×10^{-5}; 18 percent contribution). The EPC of technetium-99 is 2.4 pCi/g, which is greater than the residential RBSL of 1.5 pCi/g. However, the EPC is less than the current direct exposure remedial action goal of 5.8 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). Activities of all radionuclides will not decay to a total ELCR of less than 1.0×10^{-4} within a reasonable timeframe as a result of the presence of technetium-99.

- The 116-D-8 (shallow focused 2 decision unit) reports a total ELCR of 1.7×10^{-4}. The primary contributor to risk is cesium-137 (1.7×10^{-4}; 100 percent contribution). The EPC of cesium-137 is 7.6 pCi/g, which is greater than the residential RBSL of 4.4 pCi/g and is also greater the current direct exposure remedial action goal of 6.2 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2035.

- The 100-D-42, 100-D-43, 100-D-45 waste sites (shallow focused decision unit) report a total ELCR of 1.2×10^{-4}. The primary contributors to risk include cobalt-60 (3.9×10^{-5}; 34 percent contribution) and nickel-63 (Ni-63) (7.6×10^{-5}; 66 percent contribution). Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2012.

- The 100-D-48:3 waste site (shallow decision unit) reports a total ELCR of 1.2×10^{-4}. The primary contributor to risk is strontium-90 (1.2×10^{-4}; 97 percent contribution). The EPC of strontium-90 is 2.7 pCi/g, which is slightly greater than the residential RBSL of 2.3 pCi/g. However, the EPC is less than the current direct exposure remedial action goal of 4.5 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). Activities of all radionuclides have decayed to a total ELCR of less than 1.0×10^{-4} in year 2009.

- The 118-D-6:4 waste site (shallow 2 decision unit) reports a total ELCR of 1.2×10^{-4}. The primary contributors to risk are cesium-137 (6.5×10^{-5}; 53 percent contribution), europium-152 (3.9×10^{-5}; 31 percent contribution), and strontium-90 (1.6×10^{-5}; 13 percent contribution). Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2022.

- The 100-D-47 waste site (shallow focused decision unit) reports a total ELCR of 1.0×10^{-4}. The primary contributors to risk include europium-152 (4.2×10^{-5}; 40 percent contribution) and strontium-90 (5.2×10^{-5}; 50 percent contribution). Activities of all radionuclides have decayed to a total ELCR of less than 1.0×10^{-4} in year 2009.

Nonradiological Results (Direct Contact). As presented in Table 6-14, the potential cumulative ELCR is greater than the 1×10^{-6} for three remediated waste sites and is less than the 1×10^{-6} for 45 remediated waste sites. Risks were not reported at 19 remediated waste sites because nonradiological carcinogenic COPCs were less than background. Nonradiological carcinogenic COPCs were not reported at 25 remediated waste sites.

As presented in Table 6-14, two remediated waste sites report individual carcinogens greater than the WAC 173-340-740 acceptable cancer risk level of 1×10^{-6}, one of these two remediated waste sites are greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}. The cancer risk levels for the residential scenario are as follows:

- The 100-D-31:4 waste site (shallow decision unit) reports a cumulative nonradiological ELCR of 1.7×10^{-5}. The primary contributors to risk include benzo[a]pyrene (1.4×10^{-5}; 81 percent contribution) and benzo[b]fluoranthene (1.2×10^{-6}; 6.8 percent contribution).
- The 1607-D5 waste site (shallow decision unit) reports a cumulative nonradiological ELCR of 5.2×10^{-6}. The primary contributors to risk include benzo[a]anthracene (1.4×10^{-6}; 28 percent contribution) and benzo[a]pyrene (3.0×10^{-6}; 57 percent contribution).

For the 100-D-31:4 remediated waste site (shallow decision unit), the EPCs for benzo(a)pyrene (1.9 mg/kg) and benzo(b)fluoranthene (1.6 mg/kg) are greater than their risk-based screening level. A summary of the benzo(a)pyrene and benzo(b)fluoranthene results follows:

- The EPC for benzo(a)pyrene is based on the maximum detected concentration. Twelve soil samples were collected from the shallow decision unit and analyzed for benzo(a)pyrene. Benzo(a)pyrene was detected in three of 12 samples, measured concentrations range between 0.24 and 1.9 mg/kg (all three results are greater than the risk based screening level of 0.14 mg/kg).
- The EPC for benzo(b)fluoranthene is based on the maximum detected concentration. Twelve soil samples were collected from the shallow decision unit and analyzed for benzo(b)fluoranthene. Benzo(a)fluoranthene was detected in three of 12 samples, measured concentrations range between 0.01 and 1.6 mg/kg (one result greater than the risk based screening level of 1.4 mg/kg).

As presented in Table 6-14, the potential HI from noncancer effects from direct contact without background contribution is less than the EPA target HI of 1 and the 2007 MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) target HI of 1 for 69 of 92 remediated waste sites. An HI was not reported for 19 remediated waste sites because COPC concentrations were less than background. Nonradiological COPCs were not reported at four remediated waste sites.

As presented in Table G-26 (Appendix G), all lead and arsenic EPCs are less than their respective Method A soil cleanup levels of 250 mg/kg and 20 mg/kg for unrestricted land use.

Nonradiological Results (Inhalation). As presented in Table G-28 (Appendix G), the potential cumulative ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs without background contribution ranges from 3.3×10^{-16} to 7.7×10^{-8}. The potential cumulative ELCR is less than the 2007 MTCA "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) Method B risk value of 1×10^{-6} for individual carcinogens for 65 remediated waste sites. Risks were not reported at eight remediated waste sites because COPC concentrations were less than background. Nonradiological carcinogenic COPCs were not reported at 19 remediated waste sites.

As presented in Table G-28 (Appendix G), the potential HI is less than the EPA target HI of 1 and the 2007 MTCA "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) Method B target HI of 1 for 65 remediated waste sites. An HI was not reported for 23 remediated waste sites because COPC concentrations were less than background. Nonradiological COPCs were not reported at four remediated waste sites.

Overburden. A total of 32 remediated waste sites are reported with CVP/RSVP data associated with overburden material in the 100-D Source OU. The following sample designs were applied to the remediated waste sites evaluated:

- Thirty-one remediated waste sites were sampled using a statistical sampling design (include one site with two statistically distinct decision units.
- One remediated waste site was sampled using both a statistical and a focused sampling design and was subdivided into two focused decision units and two statistical decision units.

Radionuclide Results. As presented in Table 6-15, the potential total ELCR is within the target risk range of 10^{-4} to 10^{-6} for overburden material associated with 14 remediated waste sites and less than the lower target risk threshold of 1×10^{-6} for overburden material associated with two remediated waste sites. Risks were not reported at seven remediated waste sites because radiological COPCs concentrations were less than background. Radiological COPCs were not reported at nine remediated waste sites.

Nonradiological Results (Direct Contact). As presented in Table 6-16, the potential cumulative ELCR is greater than 1×10^{-6} for overburden material associated with three remediated waste sites and is less than 1×10^{-6} for overburden material associated with 14 remediated waste sites. Risks were not reported in overburden material associated with 11 remediated waste sites because nonradiological carcinogenic COPCs were less than background. Risks were not reported in overburden material associated with four remediated waste sites because no COPCs were reported. Although overburden material associated with three remediated waste sites report a total ELCR greater than 1×10^{-6}; there were no individual carcinogens reported with risks greater than the target risk level of $1 \times 10^{-}$.

As presented in Table 6-16, the potential HI for direct contact from noncancer effects without background contribution is less than the EPA target HI of 1 and the 2007 MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) target HI of 1 for overburden material associated with 30 remediated waste sites. Hazards were not reported in overburden material associated with two remediated waste sites because nonradiological carcinogenic COPCs were less than background.

As presented in Table G-26 (Appendix G), all lead and arsenic EPCs are less than their respective Method A soil cleanup levels of 250 mg/kg and 20 mg/kg for unrestricted land use.

Nonradiological Results (Inhalation). As presented in Table G-30 (Appendix G), the potential cumulative ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs without background contribution ranges from 1.9×10^{-14} to 3.5×10^{-8}. The potential cumulative ELCR is less than the 2007 MTCA ("Cleanup Standards to Protect Air Quality" [WAC 173-340-750]) Method B risk threshold of 1×10^{-6} for individual carcinogens for overburden material associated with 21 remediated waste sites. Risks were not reported at eight remediated waste sites because nonradiological carcinogenic COPCs were less than background. Nonradiological carcinogenic COPCs were not reported in three remediated waste sites.

As presented in Table G-30 (Appendix G), the potential HI is less than the EPA target HI of 1 and the 2007 MTCA ("Cleanup Standards to Protect Air Quality" [WAC 173-340-750]) Method B target HI of 1 for overburden material associated with 26 remediated waste sites. Risks were not reported at six remediated waste sites because nonradiological carcinogenic COPCs were less than background.

Staging Pile Area. A total of 11 remediated waste sites are reported with CVP/RSVP data associated with staging pile areas in the 100-D Source OU. The following sample designs were applied to the remediated waste sites evaluated:

- Nine remediated waste sites were sampled using a statistical sampling design.
- One remediated waste site was sampled using a focused sampling design.
- One remediated waste site was sampled using both a statistical and a focused sampling design and was subdivided into two distinct statistical decision units.

Radionuclide Results. As presented in Table 6-17, the potential total ELCR is within the target risk range of 10^{-4} to 10^{-6} for staging pile material associated with one remediated waste site and less than the lower risk threshold of 1×10^{-6} for staging pile material associated with three remediated waste sites. Risks were not reported in staging pile material associated with two remediated waste sites because radiological COPC concentrations were less than background. Radiological COPCs were not reported at five remediated waste sites.

Nonradiological Results (Direct Contact). As presented in Table 6-18, the potential cumulative ELCR from direct contact for all nonradiological carcinogenic COPCs without background contribution is greater than 1×10^{-6} for staging pile material associated with one remediated waste site and is less than 1×10^{-6} for staging pile material associated with nine remediated waste sites. Risks were not reported at one remediated waste site because nonradiological carcinogenic COPC concentrations were less than background.

As presented in Table 6-18, staging pile material associated with one remediated waste site reports individual carcinogens greater than the WAC 173-340-740 acceptable cancer risk level of 1×10^{-6}; however, it is less than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}. The cancer risk levels for the residential scenario are as follows:

- The 132-D-1 (staging pile area decision unit) reports a cumulative ELCR of 1.8×10^{-6}. The primary contributor to risk is benzo[a]pyrene (1.3×10^{-6}; 69 percent contribution).

As presented in Table 6-18, the potential HI for direct contact from noncancer effects without background contribution is less than the EPA target HI of 1 and the 2007 MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) target HI of 1 for staging pile material associated with the 11 remediated waste sites.

As presented in Table G-26 (Appendix G), all lead and arsenic EPCs are less than their respective Method A soil cleanup levels of 250 and 20 mg/kg for unrestricted land use.

Nonradiological Results (Inhalation). As presented in Table G-32 (Appendix G), the potential cumulative ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs without background contribution ranges from 9.0×10^{-16} to 2.8×10^{-10}. The potential cumulative ELCR is less than the 2007 MTCA ("Cleanup Standards to Protect Air Quality" [WAC 173-340-750]) Method B risk value of 1×10^{-6} for individual carcinogens for staging pile material associated with the 11 remediated waste sites.

As presented in Table G-32 (Appendix G), the potential HI is less than the EPA target HI of 1 and the 2007 MTCA ("Cleanup Standards to Protect Air Quality" [WAC 173-340-750]) Method B target HI of 1 for staging pile material associated with nine remediated waste sites. HIs were not reported for two remediated waste sites because COPC concentrations were less than background.

Deep Zone. Deep vadose zone samples were evaluated to identify remediated waste sites where exposure to residual contamination could present a potential risk from an inadvertent exposure through deep excavation activities. While this exposure would be industrial in nature, the RBSLs (developed for the Residential

exposure scenario) were used for convenience as screening values to identify such sites in order to allow institutional controls to be established to control access to deep contamination.

A total of 18 remediated waste sites are reported with CVP/RSVP data associated with the deep zone in the 100-D Source OU. The following lists the sample designs that were applied to the remediated waste sites evaluated:

- One remediated waste site was sampled using a focused sampling design.
- Sixteen remediated waste sites were sampled using a statistical sampling design.
- One remediated waste site was sampled using both a statistical and a focused sampling design.

The remaining 77 remediated waste sites were not excavated deeper than 4.6 m (15 ft) bgs and are not discussed in this section.

Radionuclide Results. As presented in Table 6-19, the total ELCR is greater than the upper risk threshold of 1×10^{-4} at 14 remediated waste sites; is within the target risk range of 10^{-4} to 10^{-6} at two remediated waste site; and is less than the lower risk threshold of 1×10^{-6} at one remediated waste site. Risks were not reported at one remediated waste site because COPC concentrations were less than background.

100-H Source OU. Risk estimates were calculated for each decision unit within a remediated waste site including shallow vadose zone material, deep vadose zone material, overburden material, and staging pile area footprint material. The results for the Residential scenario are presented in Tables G-43 to G-52 (Appendix G).

An overall summary of the total risk estimates and noncancer hazards (if applicable) for the residential scenario from each of the remediated waste sites is provided in Table 6-20 and Table 6-21 for shallow zone material, Table 6-22 and Table 6-23 for overburden material, Table 6-24 and Table 6-25 for staging piles, and Table 6-26 for the deep zone. These tables list the OU that each remediated waste site resides in, the reclassification status, the remediated waste site, the associated waste site (if applicable), the decision unit reported with an exceedance (if applicable), the total ELCR and the risk driver and percent contribution (if applicable), and the hazard index and the noncancer hazard driver and percent contribution (if applicable).

Shallow Zone. A total of 42 remediated waste sites are reported with CVP/RSVP data associated with the shallow zone in the 100-H Source OU. The following lists the sample designs that were applied to the sites evaluated:

- Fifteen remediated waste sites were sampled using a focused sampling design.
- Seventeen remediated waste sites were sampled using a statistical sampling design (with one site having two statistically distinct decision units and three sites having three statistically distinct decision units).
- Ten remediated waste sites were sampled using both a statistical and a focused sampling design (with two sites having one focused and two statistically distinct decision units and one site having one focused and three statistically distinct decision units).

Radionuclide Results. As presented in Table 6-20, the potential total ELCR from all radiological COPCs without background contribution is greater than the upper risk threshold of 1×10^{-4} for two remediated waste sites, is within the target risk range of 10^{-4} to 10^{-6} for 16 remediated waste sites, and less than the lower risk threshold of 1×10^{-6} for two remediated waste sites. Risks were not reported at five remediated

waste sites because radiological COPC concentrations were less than background. Radiological COPCs were not reported at 17 remediated waste sites.

Two remediated waste sites report concentration of Hanford Site-related COPCs that exceed the upper range of the threshold for the Residential scenario. The cancer risk levels for the Residential scenario are as follows:

- The 116-H-5 waste site (shallow decision unit) reports a total ELCR of 1.1×10^{-4}. The primary contributor to risk is strontium-90 (1.1×10^{-4}; 96 percent contribution). The EPC of strontium-90 is 2.4 pCi/g, which is greater than the residential RBSL of 2.3 pCi/g. However, the EPC is less than the current direct exposure remedial action goal of 4.5 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2016.

- The 118-H-1:1waste site (shallow 2 decision unit) reports a total ELCR of 1.2×10^{-4}. The primary contributor to risk is strontium-90 (1.0×10^{-4}; 87 percent contribution). The EPC of strontium-90 is 2.3 pCi/g, which is equal to the residential RBSL of 2.3 pCi/g. However, the EPC is less than the current direct exposure remedial action goal of 4.5 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2016.

Nonradiological Results (Direct Contact). As presented in Table 6-21, the potential cumulative ELCR is greater than 1×10^{-6} for five remediated waste sites and is less than 1×10^{-6} for 20 remediated waste sites. Risks were not reported at 18 remediated waste sites because nonradiological carcinogenic COPC concentrations were less than background.

As presented in Table 6-21, five remediated waste sites report individual carcinogens greater than the 2007 MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) acceptable cancer risk level of 1×10^{-6}, two of the remediated waste sites are greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}. The cancer risk levels for the residential scenario are as follows:

- 100-H-41 (shallow focused decision unit) reports a cumulative nonradiological ELCR of9.8×10^{-6}. The primary contributor to risk is benzo(a)pyrene (7.1×10^{-6}; 73 percent contribution).

- 116-H-7 (shallow decision unit) reports a cumulative nonradiological ELCR of 1.3×10^{-6}. The primary contributor to risk is aroclor-1260 (1.3×10^{-6}; 100 percent contribution).

- 118-H-6:5 (shallow 1 decision unit) reports a cumulative nonradiological ELCR of 6.0×10^{-5}. The primary contributor to risk is arsenic (6.0×10^{-5}; > 99 percent contribution).

- 1607-H4 (shallow decision unit) reports a cumulative nonradiological ELCR of 3.8×10^{-6}. The primary contributor to risk is benzo(a)pyrene (2.8×10^{-6}; 74 percent contribution).

- 600-151 (shallow 2 decision unit) reports a cumulative nonradiological ELCR of 9.0×10^{-5}. The primary contributor to risk is arsenic (8.9×10^{-5}; >99 percent contribution).

Table 6-20. Summary of Total Risks from Radionuclides for the 100-HR-1 and 100-HR-2 Shallow Zone Waste Sites for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution
100-HR-1					
Interim Closed Out	116-H-5	--	Shallow	1.1×10^{-4} $< 1.0 \times 10^{-4}$ (2016)	Strontium-90 (1.1×10^{-4} – 96%)
	100-H-17	100-H-30 116-H-2	None	1×10^{-4} to 1×10^{-6}	None
	100-H-21	100-H-1 100-H-22			
	100-H-4 100-H-5 116-H-1 116-H-3 116-H-7 118-H-6:5	--			
	116-H-9	--	None	$< 1 \times 10^{-6}$	None
	118-H-6:4 1607-H2 1607-H4	--	None	No COPCs reported above background	None
	100-H-24 100-H-3 100-H-41 1607-H3	--	None	No COPCs rported	None
No Action	100-H-49:2	--	None	1×10^{-4} to 1×10^{-6}	None
	100-H-35 100-H-53	--	None	No COPCs reported above background	None
	100-H-28:1 100-H-28:6 100-H-45 100-H-50 100-H-51:4 100-H-51:5 100-H-7 100-H-8	--	None	No COPCs reported	None

Table 6-20. Summary of Total Risks from Radionuclides for the 100-HR-1 and 100-HR-2 Shallow Zone Waste Sites for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution
100-HR-2					
Interim Closed Out	--[c]	100-H-2	None	1×10^{-4} to 1×10^{-6}	None
	118-H-1:1	--	Shallow 2	1.2×10^{-4} $< 1.0 \times 10^{-4}$ (2016)	Strontium-90 (1.0×10^{-4} – 87%)
	100-H-37 118-H-2 118-H-3 118-H-4 118-H-5 1607-H1 600-152	--	None	1×10^{-4} to 1×10^{-6}	None
	118-H-1:2	--	None	$< 1 \times 10^{-6}$	None
	128-H-1 600-151	--	None	No COPCs reported	None
No Action	100-H-40 128-H-2 128-H-3	--	None	No COPCs reported	None

Note: Results summarized from Table G-43, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-H Source OU Waste Site Decision Units Without Background Contribution (Appendix G).

The following five waste sites do not report shallow zone sample data: 100-H-11, 100-H-12, 100-H-14, 118-H-6:3, and 118-H-6:6.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from radiological COPCs.

c. Remediated waste site 100-H-2 (100-HR-2 OU) is associated with remediated waste site 100-H-17 (100-HR-1).

COPC = contaminant of potential concern

ELCR = excess lifetime cancer risk

OU = operable unit

Table 6-21. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-HR-1 and 100-HR-2 Shallow Zone Waste Sites for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution	Hazard Index	Noncancer Hazard Driver and % Contribution
100-HR-1							
Interim Closed Out	118-H-6:5	--	Shallow 1	6.0×10^{-5}	Arsenic (6.0×10^{-5} – >99%)	1.7	Arsenic (HQ = 1.7 – >99%)
	100-H-41		Shallow Focused	9.8×10^{-6}	Benzo(a)pyrene (7.1×10^{-6} – 73%)	<1	None
	1607-H4		Shallow	3.8×10^{-6}	Benzo(a)pyrene (2.8×10^{-6} – 74%)		
	116-H-7		Shallow	1.3×10^{-6}	Aroclor-1260 (1.3×10^{-6} – 100%)		
	100-H-3 100-H-4 116-H-5 116-H-9 1607-H2 1607-H3	--	None	$< 1 \times 10^{-6}$	None	<1	None
	100-H-17	100-H-30 116-H-2--	None	No COPCs reported above background	None	<1	None
	100-H-21	100-H-1 100-H-22					
	100-H-5 116-H-1	--					
	100-H-24 116-H-3 118-H-6:4					No COPCs reported above background	None
No Action	100-H-28:1 100-H-49:2 100-H-51:4 100-H-51:5 100-H-53	--	None	$< 1 \times 10^{-6}$	None	<1	None
	100-H-28:6 100-H-35 100-H-45 100-H-50 100-H-7 100-H-8	--	None	No COPCs reported above background	None	<1	None

Table 6-21. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-HR-1 and 100-HR-2 Shallow Zone Waste Sites for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution	Hazard Index	Noncancer Hazard Driver and % Contribution
100-HR-2							
Interim Closed Out	--[c]	100-H-2	None	No COPCs reported above background	None	<1	None
	600-151	--	Shallow 2	9.0×10^{-5}	Arsenic (8.9×10^{-5} – >99%)	2.5	Arsenic (HQ = 2.5 – >99%)
	118-H-1:1 118-H-1:2 118-H-3 128-H-1 1607-H1 600-152	--	None	$< 1 \times 10^{-6}$	None	<1	None
	100-H-37 118-H-2 118-H-4 118-H-5	--	None	No COPCs reported above background	None	<1	None
No Action	100-H-40 128-H-2 128-H-3	--	None	$< 1 \times 10^{-6}$	None	<1	None

Note: Results summarized from Table G-43, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-H Source OU Waste Site Decision Units Without Background Contribution (Appendix G).

The following five waste sites do not report shallow zone sample data: 100-H-11, 100-H-12, 100-H-14, 118-H-6:3, and 118-H-6:6.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from nonradiological carcinogenic COPCs.

c. Remediated waste site 100-H-2 (100-HR-2 OU) is associated with remediated waste site 100-H-17 (100-HR-1).

COPC = contaminant of potential concern

ELCR = excess lifetime cancer risk

OU = operable unit

Arsenic is a primary contributor to risk at two of the five remediated waste sites. Arsenic concentrations at 118-H-6:5 and 600-151 are both greater than the2007 WAC 173-340 Method A cleanup level of 20 mg/kg.

Although aroclor-1260 at 116-H-7 (shallow decision unit) and benzo(a)pyrene at 100-H-4 (shallow decision unit) and 1607-H4 (shallow decision unit) are greater than the acceptable risk threshold value of 1×10^{-6} for individual carcinogens, they are not greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}.

As presented in Table 6-21, the potential HI for direct contact from noncancer effects without background contributions is greater than the target HI of 1 at two remediated waste sites and is less than the target HI at 38 remediated waste sites. An HI was not reported for two remediated waste sites because nonradiological COPC concentrations were less than background.

Two remediated waste sites report a HI greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1. The HI for the residential scenario is as follows:

- 118-H-6:5 (shallow 1 decision unit) reports an HI of 1.7. The primary contributor to the HI is arsenic (HQ = 1.7; > 99 percent contribution).
- 600-151 (shallow 2 decision unit) reports an HI of 2.5. The primary contributor to the HI is arsenic (HQ = 2.5; >99 percent contribution).

A comparison of arsenic and lead EPCs to their respective Method A soil cleanup level of 20 mg/kg and 250 mg/kg, respectively, is provided in Table G-45. Except for arsenic EPCs reported at remediated waste sites 118-H-6:5 and 600-151, all arsenic EPCs are less than the Method A soil cleanup level of 20 mg/kg for unrestricted land use. Except for lead EPCs reported at remediated waste site 600-151, all lead EPCs are less than the Method A soil cleanup level of 250 mg/kg.

The following paragraphs provide a discussion of arsenic concentrations measured at the 118-H-6:5 and 600-151 remediated waste sites.

For 118-H-6:5 remediated waste site, the arsenic EPCs for the shallow 1 decision unit (39.6 mg/kg) and the shallow focused decision unit (27 mg/kg) are greater than the remedial action goal of 20 mg/kg published in the 100 Area RDR/RAWP (DOE/RL-96-17). A summary of the arsenic results for the 118-H-6:5 remediated waste site follows:

- Twelve soil samples were collected from the shallow 1 decision unit and analyzed for arsenic. Arsenic concentrations range between 6.52 and 66.2 mg/kg (six results greater than the Method A soil cleanup level of 20 mg/kg). Arsenic concentrations greater than the Method A cleanup level range between 23.5 and 66.2 mg/kg.
- Two soil samples were collected and analyzed from the shallow focused decision unit. Arsenic concentrations from this decision unit range between 17 and 27 mg/kg (one result greater than the Method A soil cleanup level of 20 mg/kg).

Table 6-22. Summary of Total Risks from Radionuclides for the 100-HR-1 and 100-HR-2 Overburden Material for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution
100-HR-1					
Interim Closed Out	100-H-21	100-H-1 100-H-22	None	1×10^{-4} to 1×10^{-6}	None
	116-H-5 118-H-6:4	--		1×10^{-4} to 1×10^{-6}	
	116-H-7 1607-H2			No COPCs reported above background	
	1607-H3			No COPCs reported	
100-HR-2					
Interim Closed Out	118-H-1:1 1607-H1	--	None	1×10^{-4} to 1×10^{-6}	None
	128-H-1			No COPCs reported	

Note: Results summarized from Table G-43, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-H Source OU Waste Site Decision Units Without Background Contribution (Appendix G).

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from radiological COPCs.

COPC = contaminant of potential concern

ELCR = excess lifetime cancer risk

OU = operable unit

Table 6-23. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-HR-1 and 100-HR-2 Overburden Material for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution	Hazard Index	Noncancer Hazard Driver and % Contribution
100-HR-1							
Interim Closed Out	1607-H2	--	Overburden	1.2×10^{-6}	None	<1	None
	116-H-5 116-H-7 1607-H3		None	$< 1 \times 10^{-6}$			
	100-H-21	100-H-1 100-H-22	None	No COPCs reported above background	None	<1	None
	118-H-6:4	--					
100-HR-2							
Interim Closed Out	128-H-1		Overburden	6.1×10^{-5}	Arsenic (6.1×10^{-5} – >99%)	1.7	Arsenic (HQ = 1.7 – >99%)
	118-H-1:1 1607-H1	--	None	$< 1 \times 10^{-6}$	None	<1	None

Note: Results summarized from Table G-43, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-H Source OU Waste Site Decision Units Without Background Contribution (Appendix G).

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from nonradiological carcinogenic COPCs.

COPC = contaminant of potential concern

ELCR = excess lifetime cancer risk

OU = operable unit

Table 6-24. Summary of Total Risks from Radionuclides for the 100-HR-1 and 100-HR-2 Staging Piles for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution
100-HR-1					
Interim Closed Out	116-H-5	--	None	1×10^{-4} to 1×10^{-6}	None
100-HR-2					
Interim Closed Out	118-H-4	--	None	No COPCs reported above background	None
	118-H-1:1			1×10^{-4} to 1×10^{-6}	
	128-H-1			No COPCs reported	

Note: Results summarized from Table G-43, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-H Source OU Waste Site Decision Units Without Background Contribution (Appendix G).

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from radiological COPCs.

COPC = contaminant of potential concern

ELCR = excess lifetime cancer risk

OU = operable unit

Table 6-25. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-HR-1 and 100-HR-2 Staging Piles for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution	Hazard Index	Noncancer Hazard Driver and % Contribution
100-HR-1							
Interim Closed Out	116-H-5	--	Staging Pile Area	$< 1 \times 10^{-6}$	None	<1	None
100-HR-2							
Interim Closed Out	128-H-1	--	Staging Pile Area 2	8.1×10^{-5}	Arsenic (8.1×10^{-5} – >99%)	2.3	Arsenic (HQ = 2.3 – 100%)
	118-H-1:1		None	$< 1 \times 10^{-6}$	None	<1	None
	118-H-4			No COPCs reported above background			

Note: Results summarized from Table G-43, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-H Source OU Waste Site Decision Units Without Background Contribution (Appendix G).

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from nonradiological carcinogenic COPCs.

COPC = contaminant of potential concern

ELCR = excess lifetime cancer risk

OU = operable unit

Table 6-26. Summary of Total Risks from Radionuclides for the 100-HR-1 and 100-HR-2 Deep Zone Waste Sites for the Residential Scenario

Classification Status	Remediated Waste Site	Associated Waste Sites[a]	Decision Unit with Exceedance	Total ELCR[b]	Risk Driver and % Contribution
100-HR-1					
Interim Closed Out	116-H-1	--	Deep	3.0×10^{-3} $< 1.0 \times 10^{-4}$ (2110)	Cesium-137 (1.1×10^{-3} - 36%) Europium-152 (1.6×10^{-3} - 53%) Europium-154 (1.5×10^{-4} - 5%) Strontium-90 (1.2×10^{-4} - 4%)
	116-H-7		Deep	2.8×10^{-3} $< 1.0 \times 10^{-4}$ (2098)	Cesium-137 (5.0×10^{-4} - 18%) Cobalt-60 (2.1×10^{-4} - 7%) Europium-152 (1.8×10^{-3} - 62%) Europium-154 (2.0×10^{-4} - 7%) Strontium-90 (1.1×10^{-4} - 4%)
	116-H-3		Deep	9.4×10^{-4} $< 1.0 \times 10^{-4}$ (2056)	Cesium-137 (2.3×10^{-4} - 25%) Europium-152 (6.3×10^{-4} - 67%)
	118-H-6:2,:3,:6, 100-H-9,10,11,12,13,14,31	100-H-10 100-H-13 100-H-31 100-H-9 118-H-6:2	Deep 3	8.7×10^{-4} $< 1.0 \times 10^{-4}$ (2108)	Cesium-137 (4.4×10^{-4} - 51%) Strontium-90 (2.8×10^{-4} - 32%)
	100-H-21	100-H-1 100-H-22	Deep	1.9×10^{-4} $< 1.0 \times 10^{-4}$ (2019)	Cesium-137 (1.0×10^{-4} - 52%) Europium-152 (5.9×10^{-5} - 31%)
	116-H-5	--	None	1×10^{-4} to 1×10^{-6}	None
	100-H-5		None	No COPCs reported above background	None
	1607-H2	--	None	No COPCs reported	None
No deep zone decision units reported in 100-HR-2 Operable Unit					

Note: Results summarized from Table G-43, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-H Source OU Waste Site Decision Units Without Background Contribution (Appendix G).

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from radiological COPCs.

COPC = contaminant of potential concern

ELCR = excess lifetime cancer risk

OU = operable unit

For 600-151 remediated waste site, the arsenic EPCs for the shallow 1 (31.8 mg/kg), shallow 2 (59.6 mg/kg), and shallow 3 (54 mg/kg) decision units are greater than the remedial action goal of 20 mg/kg published in the 100 Area RDR/RAWP (DOE/RL-96-17). A summary of the arsenic results for the 600-151 remediated waste site follows:

- Eighteen soil samples were collected from the shallow 1 decision unit and analyzed for arsenic. Arsenic concentrations range between 3.2 and 74.4 mg/kg (four results greater than the Method A soil cleanup level of 20 mg/kg). Arsenic concentrations greater than the Method A cleanup level range between 21.6 and 74.4 mg/kg.
- Twelve soil samples were collected from the shallow 2 decision unit and analyzed for arsenic. Arsenic concentrations range between 7 and 104 mg/kg (nine results greater than the Method A soil cleanup level of 20 mg/kg). Arsenic concentrations greater than the Method A cleanup level range between 22.4 and 104 mg/kg.
- Thirteen soil samples were collected from the shallow 3 decision unit and analyzed for arsenic. Arsenic concentrations range between 8.7 and 68.3 mg/kg (eight results greater than the Method A soil cleanup level of 20 mg/kg). Arsenic concentrations greater than the Method A cleanup level range between 26 and 68 mg/kg.

For 600-151 remediated waste site, the lead EPCs for the shallow 2 (267 mg/kg) and shallow 3 (276 mg/kg) decision units are greater than the remedial action goal of 250 mg/kg published in the 100 Area RDR/RAWP (DOE/RL-96-17). A summary of the lead results for the 600-151 remediated waste site follows:

- Twelve soil samples were collected from the shallow 2 decision unit and analyzed for lead. Lead concentrations range between 12 and 518 mg/kg (three results greater than the Method A soil cleanup level of 250 mg/kg). Lead concentrations greater than the Method A cleanup level range between 286 and 518 mg/kg.
- Thirteen soil samples were collected from the shallow 3 decision unit and analyzed for lead. Lead concentrations range between 6.7 and 641 mg/kg (two results greater than the Method A soil cleanup level of 250 mg/kg). Lead concentrations greater than the Method A cleanup level are 408 and 641 mg/kg.

Nonradiological Results (Inhalation). As presented in Table G-47 (Appendix G), the potential cumulative ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs without background contribution ranges from 6.3×10^{-14} to 4.6×10^{-7}. The potential cumulative ELCR is less than the 2007 MTCA ("Cleanup Standards to Protect Air Quality" [WAC 173-340-750]) Method B risk value of 1×10^{-6} for individual carcinogens for 37 remediated waste sites. Risks were not reported at five remediated waste sites because nonradiological carcinogenic COPC concentrations were less than background.

As presented in Table G-47 (Appendix G), the potential HI from the inhalation pathway from noncancer effects without background contributions is less than the EPA target HI of 1 and the 2007 MTCA ("Cleanup Standards to Protect Air Quality" [WAC 173-340-750]) Method B target HI of 1 for 38 remediated waste sites. An HI was not reported for four remediated waste sites because nonradiological COPC concentrations were less than background.

Overburden. Nine remediated waste sites are reported with CVP/RSVP data associated with overburden in the 100-H Source OU. All nine remediated waste sites were sampled using a statistical sampling design.

Radiological Results. As presented in Table 6-22 (Appendix G), the potential total ELCR from all radiological COPCs without background contribution is within the target risk range of 10^{-4} to 10^{-6} for overburden material associated with five remediated waste sites. Risks were not reported in overburden material associated with two remediated waste sites because radiological COPC concentrations were less than background. Radiological COPCs were not reported in overburden material associated with two remediated waste sites.

Nonradiological Results (Direct Contact). As presented in Table 6-23, the potential cumulative ELCR from direct contact for all nonradiological carcinogenic COPCs without background contribution is greater than 1×10^{-6} for overburden material associated with two remediated waste sites and is less than 1×10^{-6} for overburden material associated with five remediated waste sites. Risks were not reported in overburden material associated with two remediated waste sites because nonradiological carcinogenic COPC concentrations were less than background.

As presented in Table 6-23, overburden material associated with two remediated waste sites report individual carcinogens greater than the WAC 173-340-740 acceptable cancer risk level of 1×10^{-6}, one is also greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}. The cancer risk levels for the residential scenario are as follows:

- 128-H-1 (overburden) reports a cumulative nonradiological ELCR of 6.1×10^{-5}. The primary contributor to risk is arsenic (6.1×10^{-5}; > 99 percent contribution).

Arsenic is the primary contributor to risk in overburden material from the 128-H-1 remediated waste site.

As presented in Table 6-23, the potential HI for direct contact from noncancer effects without background contribution is greater than the target HI of 1 in overburden material from one remediated waste site and is less than the target HI in overburden material from eight remediated waste sites.

Overburden material associated with the 128-H-1 waste site reports a HI greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1. The HI for the residential scenario is as follows:

- 128-H-1 (overburden) reports an HI of 1.7. The primary contributor to the HI is arsenic (HQ = 1.7; > 99 percent contribution).

Table G-45 provides a comparison of arsenic and lead EPCs to their Method A soil cleanup levels of 20 mg/kg and 250 mg/kg, respectively. Arsenic (40.5 mg/kg) and lead (254 mg/kg) EPCs reported in overburden material associated with remediated waste site 128-H-1 were greater than these Method A soil cleanup level values of 20 mg/kg and 250 mg/kg, respectively. Arsenic and lead EPCs in overburden material associated with all other remediated waste sites are less than the Method A soil cleanup levels. A summary of the arsenic and lead results in overburden material associated with the 128-H-1 remediated waste site follows:

- Twelve soil samples were collected from the overburden material and analyzed for arsenic. Arsenic concentrations range between 15.1 and 56.8 mg/kg (nine of 12 arsenic results are greater than the Method A soil cleanup level of 20 mg/kg). Arsenic concentrations greater than the Method A cleanup level range between 23.5 and 56.8 mg/kg.
- Twelve soil samples were collected from the overburden material and analyzed for lead. Lead concentrations range between 73.6 and 406 mg/kg (four of 12 lead results are greater than the Method A soil cleanup level of 250 mg/kg). Lead concentrations greater than the Method A cleanup level range between 278 and 406 mg/kg.

Nonradiological Results (Inhalation). As presented in Table G-49 (Appendix G), the potential cumulative ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs without background contribution ranges from 5.9×10^{-11} to 7.7×10^{-8}. The potential cumulative ELCR is less than the 2007 MTCA ("Cleanup Standards to Protect Air Quality" [WAC 173-340-750]) Method B risk value of 1×10^{-6} for individual carcinogens for overburden material associated with the nine remediated waste sites.

As presented in Table G-49 (Appendix G), the potential HI for the inhalation pathway from noncancer effects without background contributions is less than the EPA target HI of 1 and the 2007 MTCA ("Cleanup Standards to Protect Air Quality" [WAC 173-340-750]) Method B target HI of 1 for overburden material associated with the nine remediated waste sites.

Staging Pile Area. Four remediated waste sites are reported with CVP/RSVP data associated with a staging pile area in the 100-H Source OU. The four remediated waste sites were sampled using a statistical sampling design, with one site having two statistically distinct decision units.

Radiological Results. As presented in Table 6-24, the potential total ELCR from all radiological COPCs without background contribution are within the target risk range of 10^{-4} to 10^{-6} for staging piles associated with two remediated waste sites. Risks were not reported for one staging pile associated with one remediated waste site because radiological COPC concentrations were less than background. Radiological COPCs were not reported at one staging pile area associated with one remediated waste site.

Nonradiological Results (Direct Contact). As presented in Table 6-25, the potential cumulative ELCR from direct contact for all nonradiological carcinogenic COPCs without background contributions is greater than 1×10^{-6} for staging pile material associated with one remediated waste site and is less than 1×10^{-6} for staging pile material associated with two remediated waste sites. Risks were not reported in staging pile material associated with one remediated waste site because nonradiological carcinogenic COPC concentrations were less than background.

As reported in Table 6-25, staging pile material associated with one remediated waste site reports individual carcinogens greater than the WAC 173-340-740 acceptable cancer risk level of 1×10^{-6}, and is also greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}. The cancer risk levels for the residential scenario are as follows:

- 128-H-1 (staging pile area footprint 2) reports a cumulative nonradiological ELCR of 8.1×10^{-5}. The primary contributor to risk is arsenic (8.1×10^{-5}; > 99 percent contribution).

Arsenic is the primary contributor to risk in staging pile material from the 128-H-1 remediated waste site.

As presented in Table 6-25, the potential HI for direct contact from noncancer effects without background contribution is greater than the target HI of 1 in staging pile material from one remediated waste site and is less than the target HI in staging pile material from three remediated waste sites.

Staging pile area material associated with the 128-H-1 waste site reports a HI greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1. The HI for the residential scenario is as follows:

- 128-H-1 (staging pile area 2) reports an HI of 2.3. The primary contributor to the HI is arsenic (HQ = 2.3; > 99 percent contribution).

A comparison of arsenic and lead EPCs to their respective Method A soil cleanup level of 20 mg/kg and 250 mg/kg, respectively is provided in Table G-45. Except for the arsenic (40.5 mg/kg) EPC reported in staging pile material associated with remediated waste site 128-H-1, all arsenic and lead EPCs are less

than the Method A soil cleanup level of 20 mg/kg and 250 mg/kg respectively, for unrestricted land use. A summary of the arsenic results in staging pile material associated with the 128-H-1 remediated waste site follows:

- Twelve soil samples were collected from the staging pile area 2 decision unit and analyzed for arsenic. Arsenic concentrations range between 12.9 and 97.7 mg/kg (nine results greater than the Method A soil cleanup level of 20 mg/kg). Arsenic concentrations greater than the Method A cleanup level range between 24.8 and 97.7 mg/kg.

Nonradiological Results (Inhalation). As presented in Table G-51 (Appendix G), the potential cumulative ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs without background contribution ranges from 1.6×10^{-14} to 1.3×10^{-9}. The total cumulative ELCR is less than the 2007 MTCA ("Cleanup Standards to Protect Air Quality" [WAC 173-340-750]) Method B risk value of 1×10^{-6} for individual carcinogens for staging piles associated with the four remediated waste sites.

As presented in Table G-51 (Appendix G), the potential HI for the inhalation pathway from noncancer effects without background contributions is less than the EPA target HI of 1 and the 2007 MTCA ("Cleanup Standards to Protect Air Quality" [WAC 173-340-750]) Method B target HI of 1 for staging piles associated with four remediated waste sites.

Deep Zone. Deep vadose zone samples were evaluated to identify remediated waste sites where exposure to residual contamination could present a potential risk from an inadvertent exposure through deep excavation activities. While industrial in nature, the RBSLs (developed for the Residential exposure scenario) were used for convenience as screening values to identify such sites in order to allow institutional controls to be established to control access to deep contamination.

Twelve remediated waste sites are reported with CVP/RSVP data associated with the deep zone in the 100-H Source OU:

- Five remediated waste sites were sampled using a statistical sampling design.
- One remediated waste site was sampled using a focused sampling design.
- One remediated waste site was sampled using both a statistical and a focused sampling design (consisting of three statistical decision units and two focused decision units).

The remaining 35 remediated waste sites were not excavated deeper than 4.6 m (15 ft) bgs and are not discussed in this section. The Residential scenario results for the deep vadose zone are summarized by decision unit in Table G-52 (Appendix G).

Radiological Results. As presented in Table 6-26, the total ELCR is greater than the upper risk threshold of 1×10^{-4} for nine remediated waste sites and is within the target risk range of 10^{-4} to 10^{-6} for one remediated waste site. Risks were not reported at one remediated waste site because radiological COPC concentrations were less than background. Radiological COPCs were not reported at one remediated waste site.

6.2.5.5.2 *Resident Monument Worker Scenario*

PRGs developed for the Resident Monument Worker scenario represent reasonably anticipated future land use. The results of this comparison are used to confirm that cleanup actions will protect the reasonably anticipated future land uses that DOE and the USFWS anticipate for the River Corridor. The Resident Monument Worker scenario is described in Section 6.2.3.3.

For completeness in analysis, all risk estimates for each remediated waste site decision unit are provided in Appendix G. The risk estimates, which includes all radiological COPCs regardless of their EPCs relative to the background concentration are presented in Tables G-53 through G-56 (100-D Resident Monument Worker scenario) and Tables G-64 through G-67 (100-H Resident Monument Worker scenario).

Appendix G also includes risk estimates for each remediated waste site decision unit, which include only those radiological COPCs with EPCs greater than background values or that do not have a background value in Tables G-57 through G-60 (100-D Resident Monument Worker scenario in Appendix G) and Tables G-68 through G-71 (100-H Resident Monument Worker scenario in Appendix G). Only these results are discussed in the risk characterization because it is this information that is used for decisions concerning appropriate remedial actions.

100-D Source OU. Risk estimates were calculated for the shallow vadose zone material, overburden material, and staging pile area material decision units within a remediated waste site. Risk estimates were not calculated for the deep zone decision units because the direct contact exposure pathway is incomplete. The results for the Resident Monument Worker scenario are presented in Table G-57 (Appendix G).

An overall summary of the cumulative risk estimates for the resident Monument worker scenario for each of the remediated waste sites evaluated is provided in Table G-61 for the shallow zone, Table G-62 for overburden material, and Table G-63 for staging piles. These tables list the OU that each remediated waste site resides in, the reclassification status, the remediated waste site, the associated waste site (if applicable), the decision unit reported with an exceedance (if applicable), the total ELCR, and the risk driver and percent contribution (if applicable).

Shallow Zone. As presented in Table G-61, the total ELCR for radionuclides is greater than the upper risk threshold of 1×10^{-4} at two remediated waste sites, is within the target risk range of 10^{-4} to 10^{-6} at 29 remediated waste sites, and is less than the lower risk threshold of 1×10^{-6} at eight remediated waste sites. Risks were not reported at 21 remediated waste sites because radiological COPC concentrations were less than background. Radiological COPCs were not reported at 32 remediated waste sites. Following are the results of the Resident Monument Worker scenario compared to the Residential scenario.

Nine remediated waste sites report concentrations of Hanford Site-related COPCs that are equal to or exceed the upper range of the target threshold for the Residential scenario (see Table 6-13). Whereas only two remediated waste sites report concentrations of Hanford Site-related COPCs that exceed the upper range of the target threshold for the resident Monument worker scenario. Following are the cancer risk levels for the resident Monument worker scenario:

- The 116-D-8 waste site (shallow focused 2 decision unit) reports a total ELCR of 1.2×10^{-4} for the resident Monument worker. The primary contributor to risk is cesium-137 (1.2×10^{-4}; 100 percent contribution).
- The 116-DR-9 waste site (shallow decision unit) reports a total ELCR of 1.8×10^{-4} for the resident Monument worker. The primary contributors to risk include cesium-137 (1.6×10^{-4}; 92 percent contribution) and europium-152 (1.1×10^{-5}; 6.5 percent contribution).

Nonradiological Results (Direct Contact and Inhalation). As described in Section 6.2.3.3, the 2007 MTCA Method B Soil Cleanup Levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) are the PRG values used to achieve protection of the resident Monument worker. Table 6-14 provides the results for the residential scenario.

Overburden. As presented in Table G-62, the total ELCR for radionuclides is within the target risk range of 10^{-4} to 10^{-6} for overburden material associated with six remediated waste sites and less than the lower

risk threshold of 1×10^{-6} for overburden material associated with ten remediated waste sites. Risks were not reported for seven remediated waste sites because radiological COPC concentrations were less than background. Radiological COPCs were not reported at nine remediated waste sites.

Results for the Residential scenario are similar to the Resident Monument Worker scenario, as overburden material associated with remediated waste sites did not exceed the upper risk threshold of 1×10^{-4}.

Nonradiological Results (Direct Contact and Inhalation). As described in Section 6.2.3.3, the 2007 MTCA Method B Soil Cleanup Levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) are the PRG values used to achieve protection of the resident Monument worker. Table 6-16 provides the results for the residential scenario.

Staging Pile Area. As presented in Table G-63, the total ELCR for radionuclides is less than the lower target threshold of 1×10^{-6} for staging pile area material associated with four remediated waste sites. Risks were not reported at two remediated waste sites because radiological COPC concentrations were less than background. Radiological COPCs were not reported at five remediated waste sites.

Results for the Residential scenario are similar to the Resident Monument Worker scenario, as staging piles associated with remediated waste sites did not exceed the upper risk threshold of 1×10^{-4}.

Nonradiological Results (Direct Contact and Inhalation). As described in Section 6.2.3.3, the 2007 MTCA Method B Soil Cleanup Levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) are the PRG values used to achieve protection of the resident Monument worker. Table 6-18 provides the results for the residential scenario.

100-H Source OU. Risk estimates were calculated for the shallow vadose zone material, overburden material, and staging pile area material decision units within a remediated waste site. Risk estimates were not calculated for the deep zone decision units because the direct contact exposure pathway is incomplete (that is, samples are collected from depths greater than 4.6 [15 ft] bgs). The results without background contribution for the Resident Monument Worker scenario results are presented in Table G-68 (Appendix G).

An overall summary of the cumulative risk estimates for the resident Monument worker scenario from each of the remediated waste sites evaluated is provided in Table G-72 for the shallow zone material, Table G-73 for overburden materials, and Table G-74 for staging piles. These tables list the OU that each remediated waste site resides in, the reclassification status, the remediated waste site, the associated waste site (if applicable), the decision unit reported with an exceedance (if applicable), the total ELCR, and the risk driver and percent contribution (if applicable).

Shallow Zone. As presented in Table G-72, the potential total ELCR for radionuclides is within the target risk range of 10^{-4} to 10^{-6} for ten remediated waste sites and less than the lower risk threshold value of 1×10^{-6} for ten remediated waste sites. Risks were not reported at five remediated waste sites because COPC concentrations were less than background. Radiological COPCs were not reported at 17 remediated waste sites. Following are the results of the Resident Monument Worker scenario compared to the Residential scenario.

Two remediated waste sites report concentrations of Hanford Site-related COPCs that exceed the upper risk threshold of 1×10^{-4} for the Residential scenario (see Table 6-20). Whereas, shallow zone remediated waste sites do not exceed the upper risk threshold of 1×10^{-4} for the Resident Monument Worker scenario.

Nonradiological Results (Direct Contact and Inhalation). As described in Section 6.2.3.3, the 2007 MTCA Method B Soil Cleanup Levels ("Unrestricted Land Use Soil Cleanup Standards"

[WAC 173-340-740]) are the PRG values used to achieve protection of the resident Monument worker. Table 6-21 provides the results for the residential scenario.

Overburden. As presented in Table G-73, the total ELCR for radionuclides is within the target risk range of 10^{-4} to 10^{-6} for overburden material associated with two remediated waste sites and is less than the lower risk threshold of 1×10^{-6} for overburden material associated with three remediated waste sites. Risks were not reported at two remediated waste sites because radiological COPC concentrations were less than background. Radiological COPCs were not reported at two remediated waste sites.

Results for the Residential scenario are similar to the Resident Monument Worker scenario, as overburden material associated with remediated waste sites did not exceed the upper risk threshold of 1×10^{-4}.

Nonradiological Results (Direct Contact and Inhalation). As described in Section 6.2.3.3, the 2007 MTCA Method B Soil Cleanup Levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) are the PRG values used to achieve protection of the resident Monument worker. Table 6-23 provides the results for the residential scenario

Staging Pile Area. As presented in Table G-74, the total ELCR is within the target risk range of 10^{-4} to 10^{-6} for staging pile area material associated with one remediated waste site and is less than the lower risk threshold of 1×10^{-6} for staging pile area material associated with one remediated waste site. Risks were not reported in staging pile material associated with one remediated waste site because radiological COPC concentrations were less than background. Radiological COPCs were not reported in staging pile material associated with one remediated waste site.

Results for the Residential scenario are similar to the Resident Monument Worker scenario, as staging piles associated with remediated waste sites did not exceed the upper risk threshold of 1×10^{-4}.

Nonradiological Results (Direct Contact and Inhalation). As described in Section 6.2.3.3, the 2007 MTCA Method B Soil Cleanup Levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) are the PRG values used to achieve protection of the resident Monument worker. Table 6-25 provides the results for the residential scenario.

6.2.5.5.3 *Casual Recreational User Scenario*

PRGs developed for the Casual Recreational User scenario represent reasonably anticipated future land use. The results of this comparison are used to confirm that cleanup actions are protective of the reasonably anticipated future land uses that DOE and USFWS anticipate for the River Corridor. The Casual Recreational User scenario is described in Section 6.2.3.3.

For completeness in analysis, risk estimates for each remediated waste site decision unit are provided in Appendix G, which includes all COPCs regardless of their EPCs relative to the background values. The risk estimates are provided in Tables G-75 through G-78 (100-D Casual Recreational User scenario) and Tables G-89 through G-92 (100-H Casual Recreational User scenario).

Appendix G also includes risk estimates for each remediated waste site decision unit, which include only those COPCs with EPCs greater than background values or that do not have a background value, in Tables G-79 through G-82 (100-D Casual Recreational User scenario) and Tables G-93 through G-96 (100-H Casual Recreational User scenario). Only these results are discussed in the risk characterization because it is this information that is used for decisions concerning appropriate remedial actions.

100-D Source OU. Risk estimates were calculated for the shallow vadose zone material, overburden material, and staging pile area material decision units within a remediated waste site. Risk estimates were not calculated for the deep zone decision unit because the direct contact exposure pathway is incomplete

(that is, samples are collected from depths greater than 4.6 m [15 ft] bgs). The results for the Casual Recreational User scenario are presented in Table G-79 (Appendix G).

An overall summary of the cumulative risk estimates and noncancer hazards for the casual recreational user scenario for each of the remediated waste sites evaluated is provided in Tables G-83 and G-84 for shallow zone material, Tables G-85 and G-86 for overburden material, and Tables G-87 and G-88 for staging piles. These tables list the OU that each remediated waste site resides in, the reclassification status, the remediated waste site, the associated waste site (if applicable), the decision unit reported with an exceedance (if applicable), the total ELCR, and the risk driver and percent contribution (if applicable).

Shallow Zone. As presented in Table G-83, the total ELCR for radionuclides is within the target risk range of 10^{-4} to 10^{-6} at 14 remediated waste sites and is less than 1×10^{-6} at 25 remediated waste sites. Risks were not reported at 21 remediated waste sites because radiological COPC concentrations were less than background. Radiological COPCs were not reported at 32 remediated waste sites. Following are the results of the Casual Recreational User scenario compared to the Residential scenario.

Nine remediated waste sites report concentrations of Hanford Site-related COPCs (radionuclides) that are equal to or exceed the upper range of the target threshold for the Residential scenario (see Table 6-13). Whereas shallow zone remediated waste sites did not exceed the upper range of the target threshold for the Casual Recreational User scenario (see Appendix G, Table G-83).

As presented in Table G-84, the potential cumulative ELCR for nonradionuclides is within the target risk range of 10^{-4} to 10^{-6} for two remediated waste sites and less than 1×10^{-6} for 63 remediated waste sites. Risks were not reported at eight remediated waste sites because nonradiological carcinogenic COPC concentrations were less than background. Nonradiological carcinogenic COPCs were not reported at 19 decision units. Following are the results of the Casual Recreational User scenario compared to the Residential scenario.

For the Residential scenario, two remediated waste sites report individual carcinogens greater than the WAC 173-340-740 acceptable cancer risk level of 1×10^{-6}, one of these two remediated waste sites are greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5} (see Table 6-14). For the Casual Recreational User scenario, one remediated waste site (100-D-31:4) is greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}.

As presented in Table G-84, the potential HI from direct contact for noncancer effects without background contribution is less than the EPA target HI of 1 for 69 remediated waste sites. An HI was not reported at 19 remediated waste sites because nonradiological COPC concentrations were less than background. Nonradiological COPCs were not detected at four remediated waste sites. The results of the Casual Recreational User scenario compared to the Residential scenario follow.

Noncancer hazards for the Residential scenario are similar to the Casual Recreational User scenario as shallow remediated waste sites were less than the EPA target HI of 1 and the 2007 MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) target HI of 1.

Overburden. As presented in Table G-85,the total ELCR from all radiological COPCs without background contribution is within the target risk range of 10^{-4} to 10^{-6} for overburden material associated with two remediated waste sites and is less than the lower risk threshold of 1×10^{-6} for overburden material associated with 14 remediated waste sites. Risks were not reported at 11 remediated waste sites because radiological COPC concentrations were less than background. Radiological COPCs were not

reported at five remediated waste sites. Following are the results of the Casual Recreational User scenario compared to the Residential scenario.

Results for the Residential scenario are similar to the Casual Recreational User scenario, as overburden material associated with remediated waste sites did not exceed the upper risk threshold of 1×10^{-4}.

As presented in Table G-86, the total ELCR for nonradionuclides from direct contact for all nonradiological carcinogenic COPCs without background contribution is within the target risk range of 10^{-4} to 10^{-6} for overburden material associated with one remediated waste site and is less than 1×10^{-6} for overburden material associated with 20 remediated waste sites. Risks were not reported for overburden material associated with eight remediated waste sites because nonradiological carcinogenic COPC concentrations were less than background. Risks were not reported for overburden material associated with three remediated waste sites because nonradiological carcinogenic COPCs were not reported. Following are results of the Casual Recreational User scenario compared to the Residential scenario.

For the Residential scenario, overburden material associated with three remediated waste sites report a total ELCR greater than 1×10^{-6}; however, there were no individual carcinogens reported with risks greater than the target risk level of 1×10^{-6}. For the Casual Recreational User scenario, overburden material associated with one remediated waste site reports a total ELCR greater than 1×10^{-6}; similarly, there were no individual carcinogens reported with risks greater than the target risk level of 1×10^{-6}.

As presented in Table G-86, the potential HI from direct contact for noncancer effects without background contribution is less than the EPA target HI of 1 for overburden material associated with 30 remediated waste sites. An HI was not reported for overburden material associated with two remediated waste sites because COPC concentrations were less than background. Following are results of the Casual Recreational User scenario compared to the Residential scenario.

Noncancer hazards for the Residential scenario are similar to the Casual Recreational User scenario as shallow remediated waste sites were less than the EPA target HI of 1 and the 2007 MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) target HI of 1.

Staging Pile Area. As presented in Table G-87, the potential total ELCR from direct contact for all radiological COPCs without background contribution is less than the lower target risk threshold value of 1×10^{-6} for staging pile area material associated with four remediated waste sites. Risks were not reported in staging pile material associated with two remediated waste sites because radiological COPC concentrations were less than background. Radiological COPCs were not reported in staging pile area material associated with five remediated waste sites. Following are results of the Casual Recreational User scenario compared to the Residential scenario.

Results for the Residential scenario are similar to the Casual Recreational User scenario for radionuclides, as staging piles associated with remediated waste sites did not exceed the upper risk threshold of 1×10^{-4}.

As presented in Table G-88, the potential cumulative ELCR from direct contact for all nonradiological carcinogenic COPCs without background contribution is within the target risk range of 10^{-4} to 10^{-6} for staging pile area material associated with one remediated waste site and is less than 1×10^{-6} for staging pile material associated with 10 remediated waste sites. Following are results of the Casual Recreational User scenario compared to the Residential scenario.

For the Residential scenario, staging pile material associated with one remediated waste site reports individual carcinogens greater than the WAC 173-340-740 acceptable cancer risk level of 1×10^{-6}; however, it is less than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5} (see Table 6-18). For the Casual

Recreational User scenario, staging pile material associated with one remediate waste site reports a total ELCR greater than 1×10^{-6}; similarly there were no individual carcinogens reported with risks greater than the target risk level of 1×10^{-6}.

As presented in Table G-88, the potential HI from direct contact for noncancer effects without background contribution is less than the EPA target HI of 1 for the staging pile area material associated with 11 remediated waste sites. Following are results of the Casual Recreational User scenario compared to the Residential scenario.

Noncancer hazards for the Residential scenario are similar to the Casual Recreational User scenario as shallow remediated waste sites were less than the EPA target HI of 1 and the 2007 MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) target HI of 1.

100-H Source OU. Risk estimates were calculated for the shallow, overburden, and staging pile area decision units within a remediated waste site. Risk estimates were not calculated for the deep zone decision unit because the direct contact exposure pathway is incomplete (that is, samples are collected from depths greater than 4.6 m [15 ft] bgs). The results for the Casual Recreational User scenario are summarized by decision unit in Tables G-93 (Appendix G).

An overall summary of the total risk estimates and noncancer hazards (if applicable) for the casual recreational user scenario from each of the remediated waste sites evaluated are provided in Tables G-97 and G-98 for shallow zone material, Tables G-99 and G-100 for overburden material, and Tables G-101 and G-102 for staging piles. These tables list the OU that each remediated waste site resides in, the reclassification status, the remediated waste site, the associated waste site (if applicable), the decision unit reported with an exceedance (if applicable), the total ELCR and the risk driver and percent contribution (if applicable), and the hazard index and the hazard driver and percent contribution (if applicable).

Shallow Zone. As presented in Table G-97, the total ELCR from all radiological COPCs without background contribution is within the target risk range of 10^{-4} to 10^{-6} at four remediated waste sites and is less than 1×10^{-6} at 16 remediated waste sites. Risks were not reported at five remediated waste sites because radiological COPC concentrations were less than background. Radiological COPCs were not reported at 17 remediated waste sites. Following are results of the Casual Recreational User scenario compared to the Residential scenario.

Two remediated waste sites report concentrations of Hanford Site-related COPCs that exceed the upper risk threshold of 1×10^{-4} for the Residential scenario (see Table 6-20). Whereas, shallow zone remediated waste sites do not exceed the upper risk threshold of 1×10^{-4} for the Casual Recreational User scenario.

As presented in Table G-98, the total ELCR from all nonradiological COPCs without background contribution is within the target risk range of 10^{-4} to 10^{-6} for four remediated waste sites and less than 1×10^{-6} for 27 remediated waste sites. Risks were not reported at 11 remediated waste sites because nonradiological carcinogenic COPC concentrations were less than background. Following are results of the Casual Recreational User scenario compared to the Residential scenario.

For the Residential scenario, five remediated waste sites report individual carcinogens greater than the WAC 173-340-740 acceptable cancer risk level of 1×10^{-6}, two of the remediated waste sites are greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5} (see Table 6-21). For the Casual Recreational User scenario, four remediated waste sites report individual carcinogens greater than the WAC 173-340-740 acceptable cancer risk level of 1×10^{-6}; however, one of the remediated waste sites is greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}.

As presented in Table G-98, the potential HI from direct contact for noncancer effects without background contribution is less than the EPA target HI of 1 for 40 remediated waste sites. An HI was not reported at one remediated waste site because nonradiological COPC concentrations were less than background and COPCs were not reported at one remediated waste site. Following are results of the Casual Recreational User scenario compared to the Residential scenario.

For the Residential scenario, two remediated waste sites report a HI greater than the EPA target HI of 1 and the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1. For the Casual Recreational User scenario, noncancer hazards were less than the EPA target HI of 1 and the 2007 MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) target HI of 1.

Overburden. As presented in Table G-99, the total ELCR from all radiological COPCs without background contribution is within the target risk range of 10^{-4} to 10^{-6} for overburden material associated with one remediated waste site and less than the lower risk threshold value of 1×10^{-6} for overburden material associated with four remediated waste sites. Risks were not reported in overburden material associated with two remediated waste sites because radiological COPC concentrations were less than background. Radiological COPCs were not reported in overburden material associated with two remediated waste sites. Following are results of the Casual Recreational User scenario compared to the Residential scenario.

Results for the Residential scenario are similar to the Casual Recreational User scenario, as overburden material associated with remediated waste sites did not exceed the upper risk threshold of 1×10^{-4}.

As presented in Table G-100, the potential cumulative ELCR from direct contact for all nonradiological carcinogenic COPCs without background contribution ranges is within the target risk range of 10^{-4} to 10^{-6} for overburden material associated with four remediated waste sites and is less than 1×10^{-6} for overburden material associated with five remediated waste sites. Following are results of the Casual Recreational User scenario compared to the Residential scenario.

For the Residential scenario, overburden material associated with two remediated waste sites report individual carcinogens greater than the WAC 173-340-740 acceptable cancer risk level of 1×10^{-6}; one is also greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}. For the Casual Recreational User scenario, overburden material associated with one remediated waste site reports individual carcinogens greater than the 2007 MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) acceptable cancer risk level of 1×10^{-6}; however, this remediated waste site is less than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}.

As presented in Table G-100, the potential HI from direct contact for noncancer effects without background contribution is less than the EPA target HI of 1 for overburden material associated with the nine remediated waste sites. Following are results of the Casual Recreational User scenario compared to the Residential scenario.

For the Residential scenario, one remediated waste site reports a HI greater than the EPA target HI of 1 and the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1. For the Casual Recreational User scenario, noncancer hazards were less than the EPA target HI of 1 and the 2007 MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) target HI of 1.

Staging Pile Area. As presented in Table G-101, the total ELCR from all radiological COPCs without background contributions is less than the lower risk threshold of 1×10^{-6} for staging pile area material associated with two remediated waste sites. Risks were not reported in staging pile material associated with one remediated waste site because radiological COPC concentrations were less than background. Radiological COPCs were not reported in staging pile area material associated with one remediated waste site. The results of the Casual Recreational User scenario compared to the Residential scenario follow.

Results for the Residential scenario are similar to the Casual Recreational User scenario for radionuclides, as staging piles associated with remediated waste sites did not exceed the upper risk threshold of 1×10^{-4}.

As presented in Table G-102, the total ELCR from direct contact for all nonradiological carcinogenic COPCs without background contribution is within the target risk range of 10^{-4} to 10^{-6} for staging pile area material associated with three remediated waste sites and is less than 1×10^{-6} for staging pile area material associated with one remediated waste site. The results of the Casual Recreational User compared to the Residential scenario follow.

For the Residential scenario, staging pile material associated with one remediated waste site reports individual carcinogens greater than the 2007 MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) acceptable cancer risk level of 1×10^{-6}; it is also greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5} (see Table 6-25). For the Casual Recreational User scenario, staging pile material associated with one remediated waste sitereports individual carcinogens greater than the WAC 173-340-740 acceptable cancer risk level of 1×10^{-6}; it is also greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}. The only contributor to carcinogenic risk is arsenic which above the Hanford Site background.

As presented in Table G-102, the potential HI from direct contact for noncancer effects without background contribution is less than the EPA target HI of 1 for staging pile area material associated with the four remediated waste sites. The results of the Casual Recreational User scenario compared to the Residential scenario follow.

For the Residential scenario, staging pile material associated with one remediated waste site reports an HI greater than the EPA target HI of 1 and the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1. For the Casual Recreational User scenario, noncancer hazards were less than the EPA target HI of 1 and the 2007 MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) target HI of 1.

6.2.6 Uncertainties in the Soil Risk Assessment

The purpose of this soil risk assessment is to determine whether a further 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 are associated with sampling and analysis data, sampling design, the EPCs, radiological decay, exposure, toxicity assumptions, and risk characterization.

6.2.6.1 Uncertainties Associated with Sampling and Analysis Data

Sampling and analysis data used in this soil risk assessment represent post-remediation conditions of waste sites with a "no action" or an "interim closed out" remediation status. All soil samples were collected in accordance with the requirements stated in the 100 Area SAP (DOE/RL-96-22). These data were collected

specifically to determine whether the remedial action processes implemented under the work plan met the RAOs and remedial action goals stated in the interim action RODs listed in Section 6.2.1.1.

Some uncertainties may be associated with the changing requirements associated with the analysis of COCs identified in each ROD. When remediation initially began in 1996 in the 100 Area, only those analytes identified as COCs were analyzed and reported by the laboratory. However, as remediation continued, analytical methods improved, guidance was superseded, and reporting requirements changed. Currently, analytes identified as COCs are analyzed using a methods-based approach, which requires each laboratory to report the concentration of the COC and all associated target analytes included in the analytical method.

Waste sites associated with the earliest interim action RODs are generally the radioactive high volume liquid effluent sites. In general, verification samples collected to determine whether RAOs had been met report fewer analytes than those that have been remediated more recently. The majority of waste sites typicallyinclude verification samples analyzed using a methods-based approach. These generally include burial grounds and waste sites identified during the discovery process. If a method-based approach were used, risks may be slightly higher but would remain protective of human health. This conclusion is supported by results of the method-based approach used for RI samples collected for this report.

6.2.6.2 Uncertainties Associated with Sampling Design and Exposure Point Concentrations

Calculating UCL for EPCs (OSWER 9285.6-10) recommends using a 95 percent UCL on the mean for estimating EPCs. Section 6.2.2.2 describes the methodology for calculating the EPCs for detected analytes.

When any of the following conditions were met, the maximum concentration rather than the 95 percent UCL was selected as the EPC:

- Samples are collected using a focused sampling design.
- A valid 95 percent UCL cannot be calculated because of a limited number of detections (fewer than five).
- A valid 95 percent UCL is greater than the maximum detected concentration.

When any of these conditions are met, the sampling design is inadequate for estimating risk. The outcome may underestimate or overestimate risk.

There were a limited number of instances when ProUCL calculated a 95 percent UCL that was greater than the maximum detected concentration. Figure 6-6 and Figure 6-7 show the UCL selection steps for the "non-focused sampling design" decision units for the 100-D and 100-H source OUs, respectively. The steps that are shown in Figure 6-6 and Figure 6-7 are consistent with and follow ProUCL software and guidance. Table 6-27 provides a summary of the number of individual records considered in the UCL selection steps for the 100-D and 100-H source OUs. As shown in Table 6-27, there were 52 instances at 100-D and 25 instances at 100-H where a UCL was greater than the maximum detected concentration and the maximum detected concentration was selected as the EPC. Of the 52 instances at 100-D, a 97.5 percent Chebyshev (Mean, Sd) UCL was calculated for eight analytes and of the 25 instances at 100-H a 97.5 percent Chebyshev (Mean, Sd) UCL was calculated for three analytes. Only deep zone decision units were reported with instances where a 97.5 percent Chebyshev (Mean, Sd) UCL was greater than the maximum detected concentration. The outcome of this evaluation does not impact the human health direct contact risk assessment because the direct exposure pathway is incomplete at depths greater than 4.6 m (15 ft) bgs.

Table 6-28 shows the outcome of comparisons to SSL developed for groundwater protection and surface water protection when the 97.5 percent Chebyshev (Mean, Sd) UCL is used. As shown in Table 6-28,

there would be no impact to conclusions if the 97.5 percent Chebyshev (Mean, Sd) UCL had been selected as the EPC because both the maximum concentration and the 97.5 percent Chebyshev (Mean, Sd) UCL are less than the SSL or the SSL is not representative.

A description of the sample designs associated with these five decision areas shown in Table 6-28 is provided.

- A total of six composite samples were collected from the deep zone decision unit from 100-D-48:1 (100-D Group 2 pipelines). Samples from this waste site decision unit were collected in accordance with DOE/RL-96-22, Rev. 1, *100 Area Remedial Action Sampling and Analysis Plan*.

- A total of six composite samples were collected from the deep zone decision unit from 100-D-49:4 (105-DR-Reactor Cooling Water Effluent Underground Pipelines). Samples from this waste site decision unit were collected in accordance with DOE/RL-98-37, Rev. 5, *Removal Action Work Plan for 105-DR and 105-F Building Interim Safe Storage Projects and Ancillary Buildings*.
- A total of 12 samples were collected from the deep zone decision unit from 116-D-5 Outfall Spillway. A statistical sampling design was used to collect the samples within this excavation area. Samples from this waste site decision unit were collected in accordance with DOE/RL-96-22, Rev. 5, *100 Area Remedial Action Sampling and Analysis Plan*.

- A total of six composite samples were collected from the deep zone decision unit from 116-DR-1&2 process effluent trenches. Samples from this waste site decision unit were collected in accordance with DOE/RL-96-22, Rev. 1, *100 Area Remedial Action Sampling and Analysis Plan*.

- A total of six composite samples were collected from the deep zone decision unit from 116-H-1 peocess effluent trench. Samples from this waste site decision unit were collected in accordance with DOE/RL-96-22, Rev. 1, *100 Area Remedial Action Sampling and Analysis Plan*.

As shown in Figure 6-6 and Figure 6-7, there were 44 analytes from 100-D and 22 analytes from 100-H where a 97.5 percent Chebyshev (Mean, Sd) UCL was not calculated. The 66 analytes reported a detection frequency less than 100 percent and each analyte was reported with a low number of distinct results. In all 66 cases, ProUCL calculated a range of UCLs based on the minimum data set size requirements (e.g. Kaplan-Meier) and then provided a recommendation on a UCL to use. In all 66 cases, the recommended UCL was greater than the maximum observed concentration; therefore, the maximum concentration was selected for use as the EPC. This approach is consistent with the recommendations provided in the ProUCL Version 5.0.00 Technical Guide. The ProUCL technical guide does not recommend using a calculated 95 percent UCL value as the EPC when the UCL value is above the maximum observed concentration. The technical guide cites earlier EPA guidance "*Specifically, the EPA (1992) document suggests the use of the maximum detected value as a default value to estimate the EPC term when a 95% UCL (e.g., the H-UCL) exceeds the maximum value.*"

In addition, EPCs selected for shallow zone and deep zone decision units represent verification data collected from the floor and the sidewall of the excavated waste site. As a result, risks are likely overstated because the EPC does not take credit for the existing clean backfill that covers the remediated waste site.

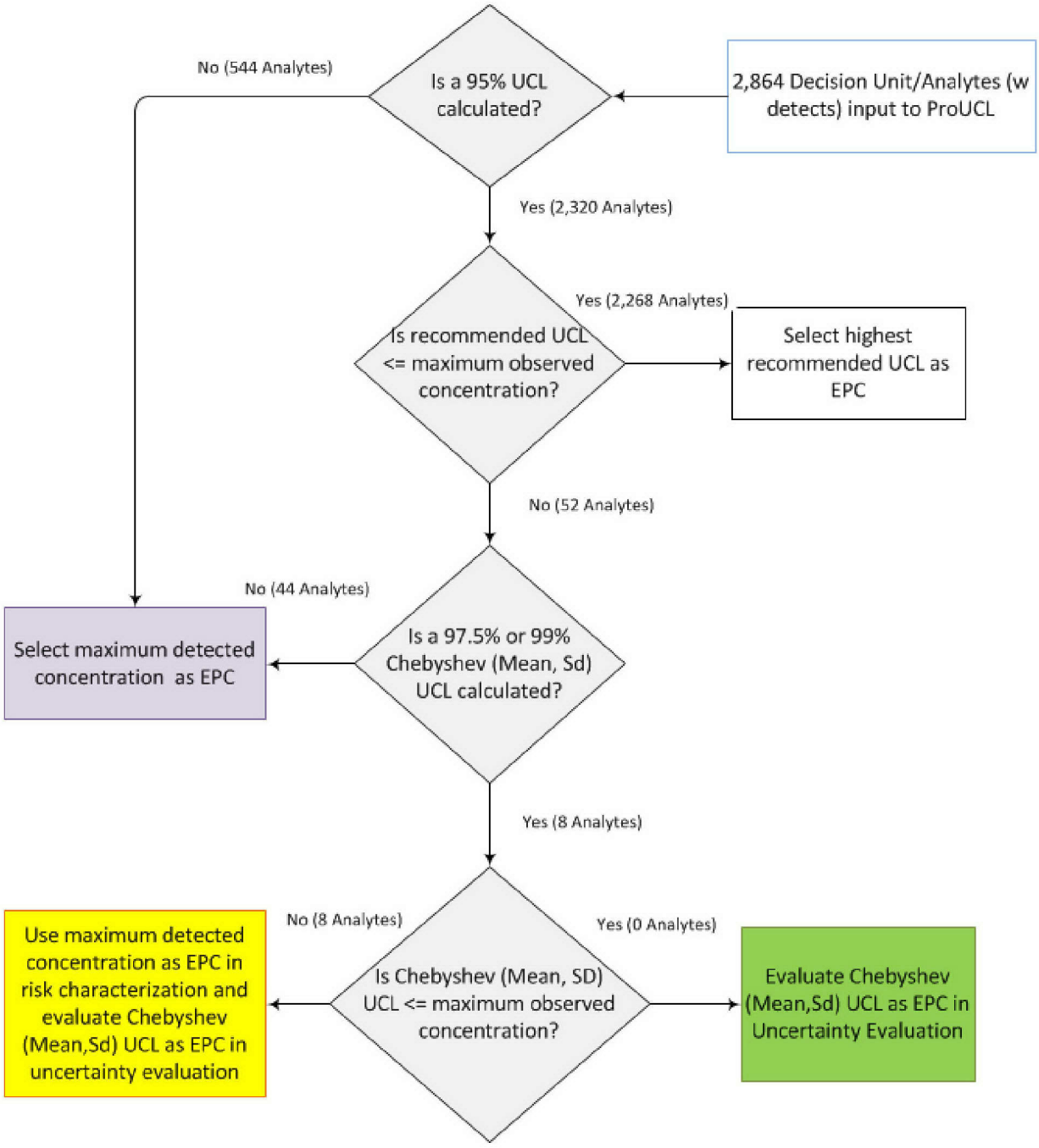

Figure 6-6. Upper Confidence Limit Selection Steps for 100-D Source OU

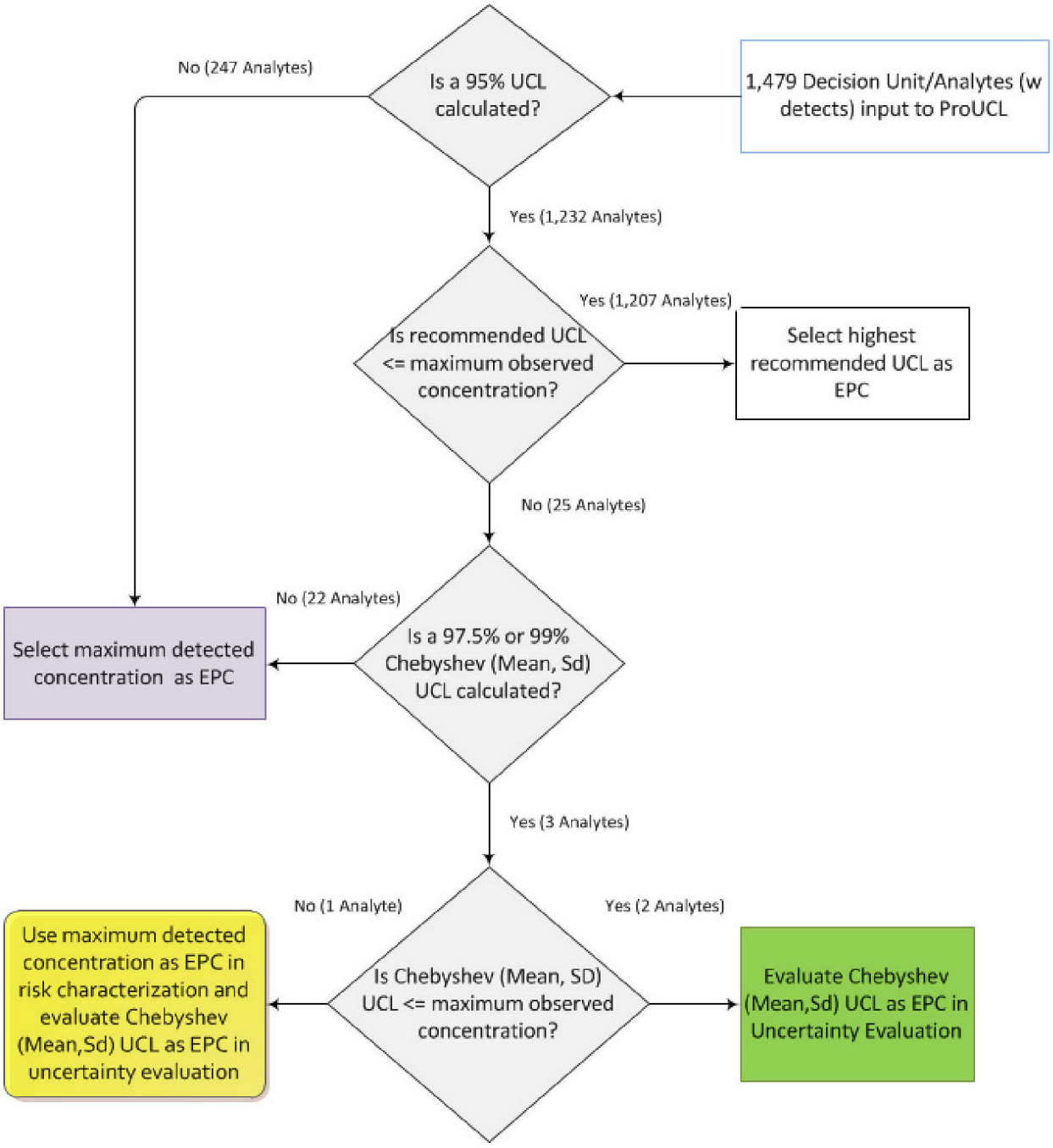

Figure 6-7. EPC Selection Steps for 100-H Source OU

Table 6-27. Records in EPC Selection Steps for 100-D and 100-H Source OUs

Number of Records	100-D	100-H
Total records input to ProUCL from "non-focus" decision units.	2,864	1,479
Number of instances where highest recommended UCL was used as EPC.	2,268	1,207
Number of instances that a UCLwas not calculated and maximum detection was used as EPC.	544	247
Number of instances that a UCL was greater than the maximum detection and maximum detection was used as EPC.	52	25

EPC = exposure point concentration

OU = operable unit

UCL = upper condidence limit

Table 6-28. Comparison of 97.5% Chebyshev (Mean, Sd) UCL to Groundwater and Surface Water Protection Soil Screening Levels.

Waste Site/Decision Unit	Analyte	# Samples	Maximum Detection (pCi/g or µg/kg)	97.5% Chebyshev (Mean, Sd) UCL (pCi/g or µg/kg)	Groundwater Protection Soil Screening Level (pCi/g or µg/kg)	Surface Water Protection Soil Screening Level (pCi/g or µg/kg)
100-D-48:1 Deep	Co-60	6	8.1	13	--(a)	--(a)
	Eu-152	6	64	82	--(a)	--(a)
100-D-49:4 Deep	Eu-152	6	8.3	12	--(a)	--(a)
116-D-5 Deep	Nitrate	7	35,000	46,500	2,270,000	--(a)
	Nitrogen in NO3	5	11,300	16,100	504,000	--(a)
116-DR-1,2 Deep	Co-60	6	3.5	4.4	--(a)	--(a)
	Eu-152	6	126	156	--(a)	--(a)
	Sr-90	6	29	35	1,012	1,012
116-H-1 Deep	Lead	6	23,100	34,600	--(a)	--(a)

a. Calculated soil screening level for analyte is considered non-representative because there is no breakthrough 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.

6.2.6.3 Adjustments in EPCs Associated with Decay of Radioisotopes

Section 6.2.5.2 provides a summary of the risk estimates by exposure scenario evaluated. The results of the soil risk assessment for the Residential scenario identified a group of waste sites with concentrations of Hanford Site-related COPCs that result in individual risks greater than the upper risk threshold value of 1×10^{-4}. Table G-103 and Table G-104 (Appendix G) list the 100-D and 100-H waste sites and the applicable decision unit, each radioisotope reported for the waste site decision unit, the year the samples were collected, the EPCs, the half-life for each radioisotope, and the year that each radioisotope decays to an activity level equal to the residential RBSL. The tables also present the number of years required for radioisotope decay to reach a total risk estimate (based on all radionuclides reported) less than the upper

risk threshold value of 1×10^{-4}. Deep vadose zone samples were evaluated to identify remediated waste sites where exposure to residual contamination could present a potential risk from an inadvertent exposure through deep excavation activities. While this exposure would be industrial in nature, the RBSLs (developed for the Residential exposure scenario) were used for convenience as screening values to identify such sites in order to allow institutional controls to be established to control access to deep contamination.

The elapsed time at which the activity level would decay below the residential RBSL is based on the radioactive decay law using the following equation:

$$\tau = \frac{\log \frac{A_E}{A_O}}{\log 0.5} \times \tau_{\frac{1}{2}}$$

where:

A_E	=	remaining amount of substance (the PRG) (pCi/g)
A_O	=	original amount of substance (the EPC) (pCi/g)
$\tau_{1/2}$	=	half-life of the substance (years)
τ	=	elapsed amount of time (years)

The number of years required for total risk to be less than 1×10^{-4} (represented by "t") was back-calculated using the following inequality for a waste site with "n" radionuclides reported:

$$\left(\frac{EPC_1 \times 10^{\left[\frac{t}{t_{\frac{1}{2}}} \times log\left(\frac{1}{2}\right)\right]}}{PRG_1}\right) + \cdots + \left(\frac{EPC_n \times 10^{\left[\frac{t}{t_{\frac{1}{2}}} \times log\left(\frac{1}{2}\right)\right]}}{PRG_n}\right) < 1 \times 10^{-4}$$

The following lists the year that concentrations of radioisotopes currently measured in shallow decision units decay to activity levels less than residential RBSLs and the year that the total ELCR is less than 1×10^{-4}:

- Strontium-90 concentrations at 100-D-48:3 decayed to levels less than residential RBSLs in year 2007. Activities of all radionuclides decayed to a total ELCR of less than 1.0×10^{-4} in year 2009.
- Activities of all radionuclides decayed to a total ELCR of less than 1.0×10^{-4} by year 2009 at 100-D-47.
- Europium-152 and nickel-63 concentrations at 100-D-42, 100-D-43, and 100-D-45 decayed to a total ELCR of less than 1.0×10^{-4} in 2012.
- Strontium-90 concentrations at 118-H-1:1 decayed to levels less than the residential RBSL in year 2011. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2016.
- Strontium-90 concentrations at 116-H-5 decay to levels less than the residential RBSL in year 2013. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2016.
- Activities of all radionuclides decayed to a total ELCR of less than 1.0×10^{-4} by year 2022 at 118-D-6:4.

- Cesium-137 concentrations at 116-DR-9 decay to levels less than residential RBSLs in year 2035. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2038.
- Cesium-137 concentrations at 116-D-8 decay to levels less than residential RBSLs in year 2035. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2035.
- Technetium-99 is detected at the 118-DR-2:2 shallow decision unit at concentrations that result in risks above 1 × 10-4. Decay does not occur within a reasonable period for technetium-99 because the half-life is 213,000 years and is not included in the above calculations.

The following lists the year that concentrations of radioisotopes currently measured in deep decision units decay to activity levels less than residential RBSLs:

- Activities of all radionuclides decayed to a total ELCR of less than 1.0×10^{-4} by year 2019 at 100-H-21.
- Cesium-137 concentrations at 100-D-48:2 decayed to levels less than residential RBSLs in year 2003. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2034.
- Strontium-90 concentrations at 100-D-48:3 decayed to levels less than residential RBSLs in year 2008. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2028.
- Europium-152 concentrations at 100-D-49:4 decay to levels less than residential RBSLs in year 2016. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2027.
- Cesium-137 and strontium-90 concentrations at 118-H-6:2, 118-H-6:3,118-H-6:6, 100-H-9, 100-H-10, 100-H-11, 100-H-12, 100-H-13,100-H-14, and 100-H-31 decay to levels less than residential RBSLs in year 2069. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2108.
- Cesium-137 and europium-152 concentrations at 116-DR-6 decay to levels less than residential RBSLs in year 2026. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2048.
- Cesium-137 and europium-152 concentrations at 116-DR-9 decay to levels less than residential RBSLs in year 2037. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2064.
- Cesium-137, cobalt-60, and europium-152 concentrations at 116-H-3 decay to levels less than residential RBSLs in year 2036. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2056.
- Cesium-137 concentrations at 118-DR-2:2 decay to levels less than residential RBSLs in year 2041. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2140.
- Nickel-63 concentrations at 100-D-19 (focused) decay to levels less than residential RBSL in year 2041. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2042.
- Cesium-137 and europium-152 concentrations at 100-D-18 decay to levels less than residential RBSLs in year 2060. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2066.
- Cesium-137, cobalt-60, europium-152, europium-154, and strontium-90 concentrations at 116-H-7 decay to levels less than residential RBSLs in year 2098.

- Cesium-137, cobalt-60, europium-152, and europium-154 concentrations at 100-D-48:1 decay to levels less than residential RBSLs in year 2083. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2093.
- Cesium-137, cobalt-60, europium-152, europium-154, and nickel-63 concentrations at 116-D-7 decay to levels less than residential RBSLs in year 2083. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2125.
- Cesium-137, europium-152, europium-154, and strontium-90 concentrations at 116-H-1 decay to levels less than residential RBSLs in year 2102. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2110.
- Cesium-137, cobalt-60, and europium-152 concentrations at 100-D-49:2 decay to levels less than residential RBSLs in year 2113. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2117.
- Cesium-137, cobalt-60, europium-152, europium-154, and strontium-90 concentrations at 116-DR-1&2 decay to levels less than residential RBSLs in year 2122. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2148.
- Cesium-137 and europium-152 concentrations at 118-D-6:4 decay to levels less than residential RBSLs in year 2138. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2143.
- Cesium-137, cobalt-60, europium-152, europium-154, and strontium-90 concentrations at 116-D-1A decay to levels less than residential RBSLs in year 2196. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2203.

6.2.6.4 Uncertainties Associated with Exposure Assumptions

The exposure assumptions used to develop the RBSLs for each exposure scenario represent an RME. For estimating the RME, 95 percentile 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 "Guidance on Risk Characterization for Risk Managers and Risk Assessors" (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 upper bound of the true risk or hazard.

6.2.6.5 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 guide (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 recently has 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-dose 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.

Slope Factors for Cr(VI). The oral RfD of 0.003 mg/kg-day published by IRIS is used to develop the 2007 MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) direct contact soil cleanup level for Cr(VI). NJDEP has recently published an oral carcinogenic potency factor of 0.5 $(mg/kg\text{-}day)^{-1}$ (*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 were used to calculate the 2007 MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) direct contact soil cleanup level, the concentration would decrease from 240 mg/kg to 2.0 mg/kg. The use of the oral RfD published by IRIS may result in underestimating risk.

6.2.6.6 Uncertainties Associated with Risk Characterization

In the risk characterization, the assumption was made that the total risk of developing cancer from exposure to Hanford 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, resulting in an overestimation or underestimation of risk.

6.2.6.6.1 Uncertainties in Risk Estimates Associated with Remedial Investigation and Limited Field Investigation Soil Data

In addition to the waste site closeout remediation data (CVP/RSVP), two additional sources of data were considered for use in the RI/FS and the soil risk assessment. 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-D/H OU. These data were collected for purposes other than fulfilling needs of the risk assessment; as such, they were not used to evaluate quantitative risks. However, these data were evaluated qualitatively by comparing concentrations of analytes to RBSLs to determine whether the results could be useful for risk management decisions. The results of this comparison are provided in Appendix G, Attachment G-1.

Soil data identified as useful for informing risk management decisions include those collected to fill Data Gaps 2, 3, and 7. Chapter 2, Table 2-1 lists the data gaps and the work conducted per the 100-D/H Work Plan (DOE/RL-2008-46-ADD1). Twelve boreholes (7 from 100-D and 5 from 100-H), 5 test pits (3 from 100-D and 2 from 100-H), and 14 monitoring wells (7 from 100-D and 7 from 100-H) were drilled for the RI. In general, the comparison of soil concentrations from RI data to RBSLs are consistent with those risk results reported for closeout documentation data (CVP/RSVP), because most boreholes and test pits were collected through waste sites that were previously remediated.

In the early 1990s, an LFI was performed in the 100-DR-1 and 100-DR-2 OUs, the 100-HR-1 and 100-HR-2 OUs, and the 100-HR-3 OU. Results of the qualitative risk evaluation show elevated risk results at some waste sites. However, use of the LFI data over state risks because these waste sites have been subsequently remediated under the interim action ROD.

6.3 Groundwater Risk Assessment

EPA guidance provided in "Summary of Key Existing EPA CERCLA Policies for Groundwater Restoration" (Woolford and Reeder, 2009, page 4), clarifies EPA's policies for determining whether a groundwater remedial action is warranted under CERCLA. In discussing the role of the baseline risk assessment, "Summary of Key Existing EPA CERCLA Policies for Groundwater Restoration" (Woolford and Reeder, 2009) quotes the preamble to the NCP (40 CFR 300):

"The results of the baseline risk assessment are used to determine whether remediation is necessary, to help provide justification for performing remedial action, and to assist in determining what exposure pathways need to be remediated."

"Summary of Key Existing EPA CERCLA Policies for Groundwater Restoration" (Woolford and Reeder, 2009) then continues to clarify when a CERCLA remedial action is appropriate (page 5):

"A CERCLA remedial action generally is appropriate[12] in various circumstances, including: a standard that helps define protectiveness (e.g., a federal or state MCL or nonzero MCLG for current or potential drinking water aquifers) is exceeded; 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 risk range for 'cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for both current and future land use;[13] the noncarcinogenic hazard index is greater than one (using reasonable maximum exposure assumptions for either the current or reasonably anticipated future land use); or the site contaminants cause adverse environmental impacts.[14] It is important to note that all conditions do not need to be present for action and the conditions may be independent of each other."

EPA guidance provided in "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions" (Clay, 1991) describes how to use the baseline risk assessment to make risk management decisions such as determining whether remedial action under CERCLA Section 104 or Section 106 is necessary. The "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions" (Clay, 1991) describes the following conditions when a CERCLA action is generally warranted:

- The baseline risk assessment indicates that a cumulative site risk to an individual using RME assumptions for either current or future land use exceeds the 10^{-4} ELCR end of the risk range.

[12] See EPA 540-R-97-013, *Rules of Thumb for Superfund Remedy Selection*.

[13] See Clay, 1991, "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions."

[14] See EPA 540-R-97-013, *Rules of Thumb for Superfund Remedy Selection*.

- For groundwater actions, MCLs and nonzero maximum contaminant limit goals (MCLG) will generally be used to gauge whether remedial action is warranted.
- Chemical-specific standards that define acceptable risk levels also may be used to determine whether an exposure is associated with an unacceptable risk to human health and the environment and whether remedial action is warranted.

Human health protection is evaluated by comparing groundwater concentrations within the groundwater OU to existing federal or state MCLs or nonzero MCLGs. Aquatic receptor protection is determined by the comparison of groundwater concentrations at the point of discharge to surface water to water quality criteria established under Section 304 or Section 303 of the *Clean Water Act of 1977* as well as Washington State water quality standards. The point of compliance for surface water cleanup levels is defined in the 2007 MTCA ("Surface Water Cleanup Standards" [WAC 173-340-730(7)(a)]) as the point or points at which hazardous substances are released to surface waters of the state. 2007 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 concentrations are compared to 2007 MTCA ("Ground Water Cleanup Standards" [WAC 173-340-720]) to determine whether EPCs result in a HI greater than one. The EPCs also are used to calculate ELCRs that are compared to the upper end of the NCP (40 CFR 300) risk range for cumulative carcinogenic site risk to an individual based on RME for both current and future land use.

EPA guidance provided in "Clarification of the Role of Applicable, or Relevant and Appropriate Requirements in Establishing Preliminary Remediation Goals under CERCLA" (Fields, 1997) clarifies the relationship between two statutory mandates of CERCLA: (1) protect human health and the environment, and (2) attain or waive, if justified, based on site-specific circumstances, ARARs. It remains EPA's policy that ARARs will generally be considered protective, absent multiple contaminants or pathways of exposure. However, the guidance clarifies that, in rare situations, even absent multiple pathways or contaminants, PRGs should be set at levels more protective than required by a given ARAR, where application of the ARAR would not protect human health and the environment.

The RCBRA (DOE/RL-2007-21) evaluated groundwater data collected from 1998 to 2008. During the development of the Integrated Work Plan (DOE/RL-2008-46) approximately one year of additional groundwater data were collected and evaluated. The Integrated Work Plan (DOE/RL-2008-46) identified the need to collect representative spatial and temporal samples from a subset of wells. These data were collected over an 8-month period between October 7, 2009 and June 11, 2010. In this RI/FS, three different analyses of groundwater data are conducted for the purpose of identifying COPCs. Section4.4.1.2 uses individual groundwater results collected over seven years (January 1, 2007 to December 31, 2012) to describe the nature and extent of contamination in groundwater. Section 4.4.1.2 provides summary statistics for groundwater data collected over the last 7 years and describes the comparison of individual groundwater measurements to action levels for the purpose of COPC identification. Exposure point concentrations were calculated for the groundwater data set collected for the RI (as described above) and were used to compare to action levels (Section 6.3.2.3) and used to calculate excess lifetime cancer risks and noncancer hazards for the residential tap water scenario (Section 6.3.7). These analyses were also used for the purpose of identifying groundwater COPCs.

A groundwater risk assessment was performed for the 100-HR-3 Groundwater OU. The 100-HR-3 Groundwater OU includes all groundwater in the 100-D, 100-H and Horn area impacted by waste sites. There are four primary groundwater plumes within the 100-HR-3 Ground OU. Contaminant plume areas are identified geographically as the 100-D southern plume, 100-D northern plume, 100-H plume, and Horn area plume, and are mainly based on the distribution of Cr(VI) concentrations. Other contaminants

are primarily collocated with the Cr(VI) plume. The 100-HR-3 Groundwater OU risk assessment followed the strategy outlined as follows:

- Evaluate groundwater data to identify contaminants present in groundwater in the OU. This includes analytical measurement data collected over the past seven years (data collected to resolve spatial, chemical, and temporal uncertainties described in the Integrated Work Plan (DOE/RL-2008-46) are included).
- Identify action levels for detected contaminants, using ARARs or risk-based concentrations to establish a basis for identifying COPCs.
- Compare individual measurements from the larger population of data to action levels to identify COPCs within each area of interest identified within the 100-HR-3 Groundwater OU.
- Calculate exposure point concentrations using the RI data set; EPCs are used for comparison to action levels and to provide a comprehensive evaluation of contribution to cumulative risk and total hazard using the residential tap water scenario.

Results of this groundwater risk assessment indicate that individual concentrations of contaminants in the 100-HR-3 Groundwater OU exceed action levels, and warrant investigation in an FS to address groundwater contamination within the OU. The COPCs represent contaminants that will be evaluated in the FS to define the COCs and to develop and select remedial alternatives. The residential tap water scenario also identifies multiple contaminants within the 100-D Source, Horn, and 100-H Source exposure areas that exceed the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)(a) cumulative cancer and noncancer hazard thresholds. The 2007 MTCA HHRA Procedures (WAC 173-340-708(5)(a)and WAC 173-340-708(6)(b)) 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}).

Additionally, several local and regional Tribes have ancestral ties to the Hanford Reach of the Columbia River and surrounding lands. DOE has requested that each Tribe provide an exposure scenario that reflects their traditional activities. At this time, the CTUIR (*Exposure Scenario for CTUIR Traditional Subsistence Lifeways* [Harris and Harper, 2004]) and the Yakama Nation (*Yakama Nation Exposure Scenario for Hanford Site Risk Assessment* [Ridolfi, Inc., 2007]) have provided scenarios. A quantitative groundwater risk assessment is included for both Tribal use scenarios to evaluate each of the potentially complete groundwater exposure pathways. The results for the Native American risk assessment are provided in *Native American Risk Assessment for the 100-HR-3 Groundwater Operable Unit* (ECF-100HR3-10-0477) (Appendix G). Section 6.3.8.4.1 provides a summary of this evaluation. A quantitative evaluation of human health risk to a resident from exposure to tap water is included for comparison to the Native American Risk Assessment. This comparison is provided because the Native American scenarios and the EPA tap water scenario include the same exposure pathways and exposure routes but have different exposure assumptions. The EPA tap water scenario includes RME assumptions whereas the Native American scenarios include high-end exposure assumptions. The Native American scenarios are discussed in more detail in the uncertainty section (Section 6.3.8.4.1). The results of the comparison show how the similarities and differences that result in use of RME and high-end assumptions. The results of the tap water risk assessment are provided in *Tap Water Risk Assessment for the 100-HR-3 Groundwater Operable Unit* (ECF-100HR3-10-0478) (Appendix G).

6.3.1 Findings of the River Corridor Baseline Risk Assessment

The RCBRA (DOE/RL-2007-21) provides a screening level groundwater risk assessment for the 100-HR-3 Groundwater OU to evaluate potential risks associated with groundwater exposure. The results of the groundwater screening level risk assessment indicate potential risk above EPA thresholds within the 100-HR-3 Groundwater OU. Noncancer chemical hazard results were also above the EPA's threshold value of 1.

Uncertainties associated with the groundwater dataset were identified in the RCBRA (DOE/RL-2007-21). These uncertainties relate to the ability of the groundwater dataset collected from 1998 to 2008 to represent current baseline conditions and potential exposure within each groundwater OU. Analytical data used for the screening level assessment were collected to fulfill a variety of state and federal regulations, including RCRA, CERCLA, the *Atomic Energy Act of 1954;* and Section 173 of the *Washington Administrative Code*. Although the monitoring data can be used for risk assessment purposes, there are uncertainties associated with its use. Specifically, target analytes, sampling frequencies, and MDLs (or reporting limits) are different between programs because the information is used to meet different requirements.

As a result of the uncertainties identified in the RCBRA, the Integrated Work Plan (DOE/RL-2008-46) added activities that would help reduce uncertainties, verify conclusions of the HHRA presented in the RCBRA, and ensure that no contaminants were inadvertently overlooked based on the use of the existing dataset. Section 3.6.5.1 of the Integrated Work Plan (DOE/RL-2008-46) identifies the following activities to reduce uncertainties:

Identify existing and/or install new monitoring wells that are spatially representative of the groundwater. This set of wells will represent locations where a receptor potentially could contact groundwater.

Conduct multiple rounds of sampling to obtain temporal representation of the unconfined aquifer from influence of river stage. Additional rounds of sampling at spatially representative monitoring wells will represent current groundwater conditions and capture the influence of river fluctuations on COPC concentrations.

Analyze all spatially representative monitoring wells for a focused list of groundwater COPCs identified for each round of sampling. Analyzing each of the monitoring wells for COPCs will provide a dataset that is representative of potential releases to the groundwater.

Evaluate sample results from characterization activities to support final remedial action decisions for groundwater.

The RCBRA evaluated exposure to groundwater for three residential scenarios (Subsistence Farmer, CTUIR Resident, and Yakama Resident scenarios) and the residential component of the resident Monument worker exposure scenario. Direct exposure to contaminants in groundwater was evaluated for household uses of groundwater in each of these scenarios, such as drinking and cooking (ingestion) and bathing (dermal absorption). If VOCs were measured in groundwater, indirect exposure by inhalation of VOCs in air may occur while bathing or when using groundwater in the home for other purposes. The inhalation pathway for VOCs associated with household use of groundwater is evaluated for VOCs that are identified as COPCs in groundwater. Additionally, ingestion, inhalation, and dermal exposures to COPCs in groundwater used in a sweat lodge were evaluated in the CTUIR Resident and Yakama Resident scenarios.

The results of the screening level groundwater risk assessment provided in the RCBRA (DOE/RL-2007-21) identified Cr(VI) in the 100-HR-3 Groundwater OU as the primary contributor to risk through ingestion and dermal contact with groundwater.

6.3.2 Identification of Contaminants of Potential Concern

The first step of this groundwater risk assessment is data evaluation to identify the COPCs for protection of human health and the environment. A preliminary COPC evaluation was conducted to support the 100-D/H Work Plan (DOE/RL-2008-46-ADD1) and the 100-D/H SAP (DOE/RL-2009-40). The work plan effort evaluated groundwater analytical data from the 100-HR-3 Groundwater OU collected over a 16-year period (1992 to 2008). Table 6-29 presents the 31 COPCs based on the evaluation of historical data in the work plan for the entire 100-HR-3 Groundwater OU.

Table 6-29. List of Historical Contaminants of Potential Concern in the 100-HR-3 Groundwater OU

Metals		
Antimony	Arsenic	Beryllium
Cadmium	Chromium	Cobalt
Copper	Cr(VI)	Lead
Manganese	Mercury	Nickel
Selenium	Silver	Thallium
Uranium	Vanadium	Zinc
Volatile Organic Compounds		
1,1-Dichloroethene	Benzene	Carbon tetrachloride
Chloroform	Trichloroethene	Vinyl chloride
Radiological		
Strontium-90	Technetium-99	Tritium
Anions		
Fluoride	Nitrate (as N)	Nitrite (as N)
Sulfate		

Source: *Sampling and Analysis Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study* (DOE/RL-2009-40), Table 1-2.

OU = operable unit

The COPCs identified during the work plan phase were validated by using groundwater samples analyzed using the methods documented in the 100-D/H SAP (DOE/RL-2009-40), Table 2-19. The groundwater dataset collected during the RI consists of sampling and analysis data collected from 52 monitoring wells within the 100-HR-3 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.

Identification of groundwater COPCs for the 100-HR-3 Groundwater OU is a three-step process. Analytical measurements from groundwater data collected over the past seven years (including those RI data collected as specificed in the RI Work Plan to resolve spatial, chemical and temporaly uncertainties described in the Integrated Work Plan (DOE/RL-2008-46) were evaluated using the following strategy:

- Compare individual measurements from the larger population of data to action levels to identify COPCs throughout the 100-HR-3 Groundwater OU (Figure 6-8).
- Compare EPCs from the RI data set to action levels to identify COPCs within each area of interest identified within the 100-HR-3 Groundwater OU (Figure 6-9).
- Calculate cumulative ELCR and noncancer hazards using EPCs from the RI data set based on the EPA residential tap water scenario (Figure 6-10) to identify the analytes that are the primary risk and hazard drivers within each area of interest identified within the 100-HR-3 Groundwater OU.

The process used to identify data for COPC selection and the selection of action levels for this groundwater risk assessment are described in Sections 6.3.2.1 and 6.3.2.2. The methodology used to calculate EPCs is described in Section 6.3.2.3. The exposure assessment and toxicity assessment are presented in Sections 6.3.3 and 6.3.4, respectively. Finally, the risk characterization step for each of the exposure areas is described in Section 6.3.5 and 6.3.6, and the EPA Tap Water scenario is described in Section 6.3.7. The primary objective of this groundwater risk assessment is to provide information necessary to identify what remedial actions will be necessary in the remedy selected for the 100-HR-3 Groundwater OU.

6.3.2.1 Data Used to Identify Contaminants of Potential Concern

Two different data sets were used for the purpose of identifying COPCs for the 100-HR-3 Groundwater OU. The following provides a description of each data set.

Section 4.4.1.2 presents the comparison of individual analyte measurements to action levels in groundwater collected over the last 7 years of measurement (that is, samples collected between January 2006 and December 2012). All monitoring wells within the 100-HR-3 Groundwater OU that are screened in the unconfined aquifer were included in this evaluation (see Figure 6-8). This evaluation includes the review of all historical analytes identified in Table 6-29 and those that report concentrations greater than an action level using the larger population of data. As described previously, historical COPCs were identified in the work plan using data collected over a 16-year period (1992 to 2008) (see Table 6-29 for a list of historical COPCs). The dataset used for the comparison of individual analytes is considered to be representative of current groundwater conditions based on the overall spatial coverage of monitoring wells across the OU and based on the inclusion of RI data that were collected to resolve uncertainties identified in the RCBRA (DOE/RL-2007-21) and the 100-D/H Work Plan (DOE/RL-2008-46-ADD1). This analysis is included to confirm that analytes that are identified as COPCs using RI data are consistent with the observations and characteristics of the data from a larger population of wells and analytical results collected over a longer period of time. Figure 6-8 shows the schematic steps of the individual contaminant evaluation used for COPC identification presented in Section 4.4.1.2. A summary of the COPCs identified in Section 4.4.1.2 of this RI report are provided in Tables 4-8 through 4-10 for the unconfined aquifer. In addition to the evaluation of groundwater screened in the unconfined aquifer, groundwater screened in the confined aquifer (first water bearing unit of the ringold upper mud) and groundwater from treatability test areas were also evaluated and COPCs are presented in Table 4-12 and Table 4-14 through Table 4-17, respectively.

Groundwater samples that comprise the RI data set were used to resolve uncertainties identified in the RCBRA (DOE/RL-2007-21) and the 100-D/H Work Plan (DOE/RL-2008-46-ADD1). These uncertainties were previously described in Section 6.3.1. The groundwater samples associated with the RI data set were collected over an 8-month period between October 7, 2009 and June 11, 2010. Three sampling events were used to capture the effects that temporal fluctuations of river stage have on groundwater conditions. Samples collected from mid-May to mid-June 2010 represent the aquifer when the river stage is at its highest elevation. Samples collected from early October 2009 to early November

2009 represent the aquifer when the river is at its lowest elevation. Samples collected from mid-March to mid-April 2010 represent the aquifer when the river is transitioning from high to low river stage.

All monitoring wells used in this monitoring network were screened in the unconfined aquifer. All of the wells in the network were existing monitoring or compliance wells and are listed in Table 6-30, which lists each well in the 100-HR-3 Groundwater OU; Figure 6-11 shows their locations.

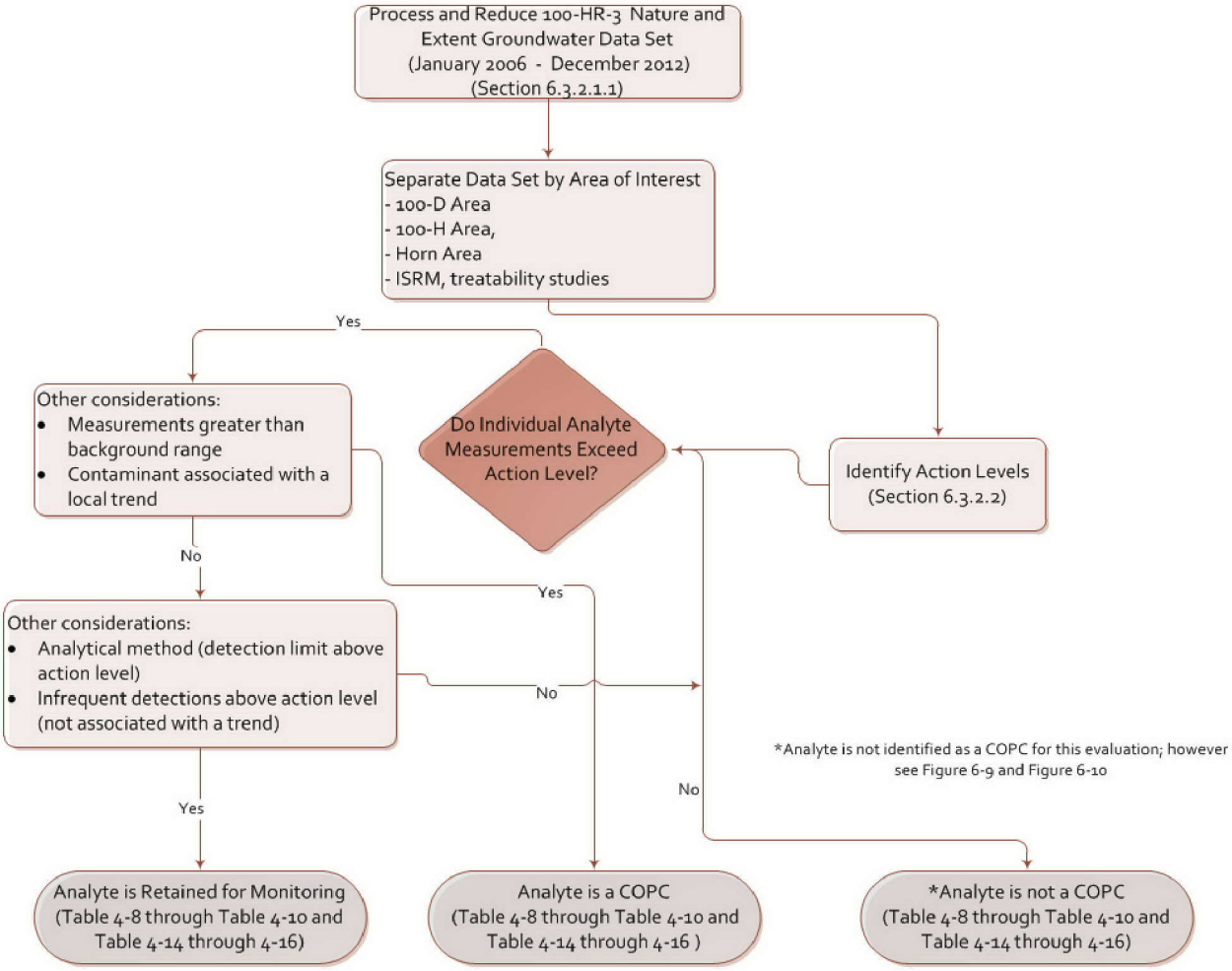

Figure 6-8. Individual Contaminant Evaluation Process

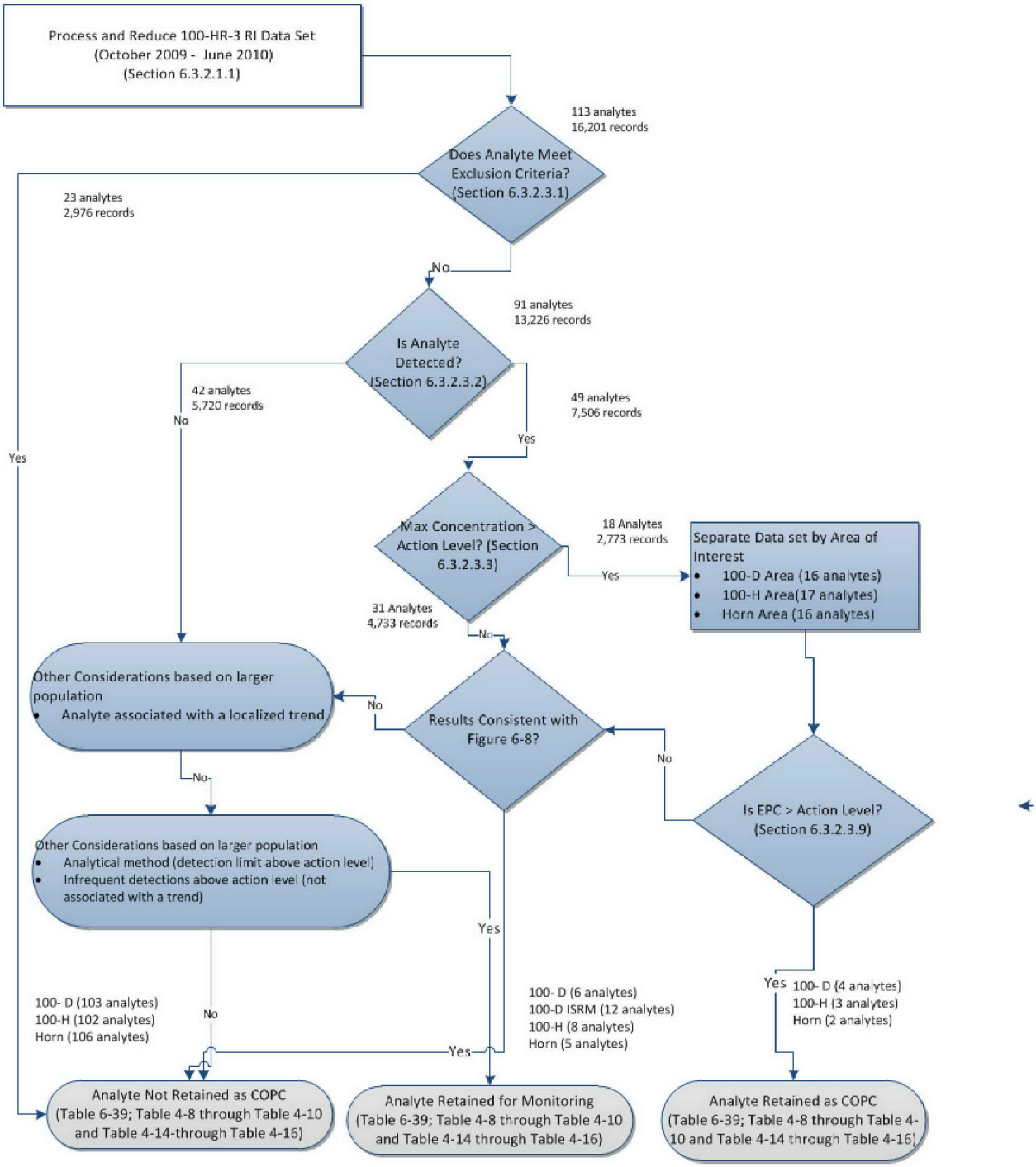

Figure 6-9. Comparison of EPC to Action Level Process

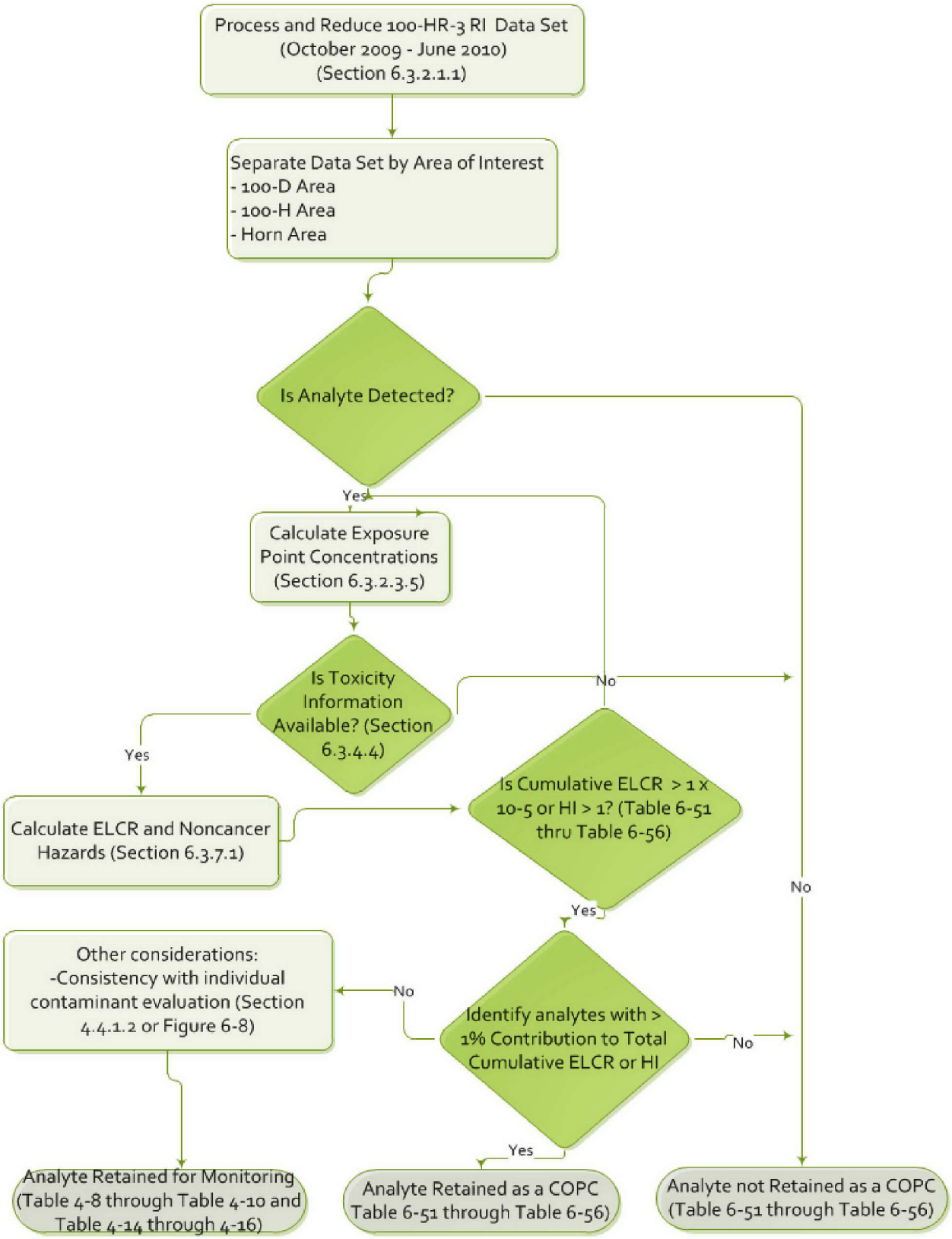

Figure 6-10. EPA Tap Water Risk Assessment Process

Table 6-30. Monitoring WellsIncluded in the RI Data Set from the 100-HR-3 Groundwater OU

Well Name			
100-D Source Exposure Area			
199-D2-11	199-D2-6	199-D4-23	199-D4-84
199-D5-13	199-D5-14	199-D5-15	199-D5-16
199-D5-17	199-D5-18	199-D5-19	199-D5-37
199-D5-38	199-D5-43	199-D5-99	199-D8-5
199-D8-55	199-D8-70	199-D8-71	199-D8-88
100-H Source Exposure Area			
199-H3-2A	199-H4-10	199-H4-11	199-H4-13
199-H4-16	199-H4-3	199-H4-45	199-H4-46
199-H4-48	199-H4-5	199-H4-6	199-H4-9
199-H6-1			
Horn Exposure Area			
199-H3-4	199-H3-5	199-H5-1A	699-101-45
699-87-55	699-90-45	699-93-48A	699-94-41
699-94-43	699-95-45	699-95-48	699-95-51
699-96-52B	699-97-41	699-97-45	699-97-48B
699-98-43	699-98-49A	699-98-51	

OU = operable unit
RI = remedial investigation

6.3.2.1.1 *Analytical Data Processing*

The analytical datasets used for COPC identification are extracted from the HEIS database. After extraction, the analytical data are processed to obtain a single set of results per sampling location and time of collection.

For the larger population of data, a total of 110,313 records were obtained from HEIS, and a total of 113 analytes were included in the dataset prior to analytical data processing. After analytical data processing (as described in the next section), the final dataset used for the COPC identification process contained a total of 95,126 record.

For the RI data set, a total of 27,354 records were obtained from HEIS, and a total of 113 analytes were included in the dataset prior to analytical data processing. After analytical data processing (as described in the next section), the final dataset used for the COPC identification process contained a total of 16,202 records, with 113 analytes included in the dataset.

The datasets obtained from HEIS included the following types of information:

- Analytical results from both unfiltered and filtered samples
- Data qualification and data validation flags, including rejected results
- Results for a given analyte reported by more than one analytical method
- Parent, field duplicate, and field split sample results

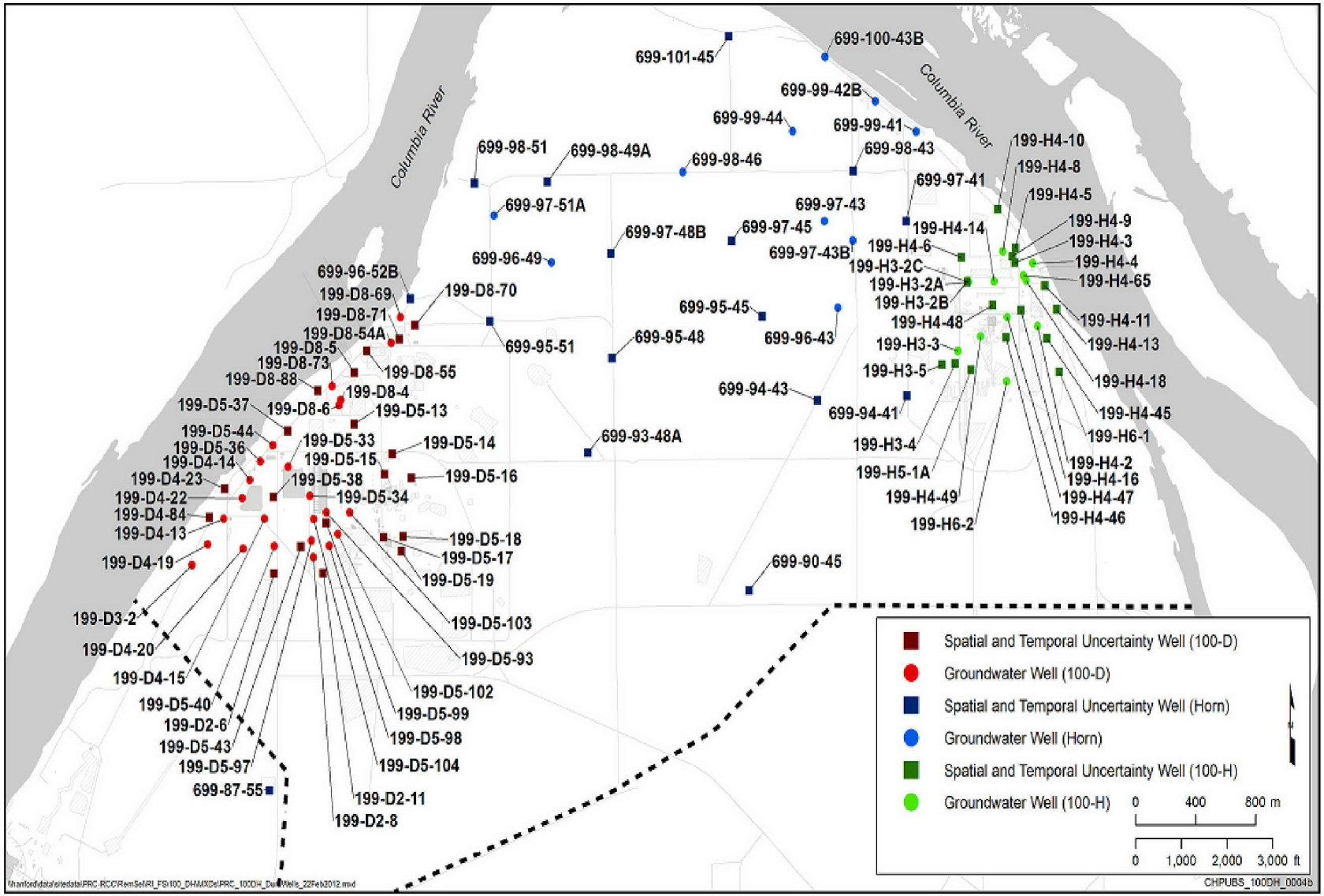

Figure 6-11. Monitoring Well Locations within the 100-HR-3 Groundwater OU

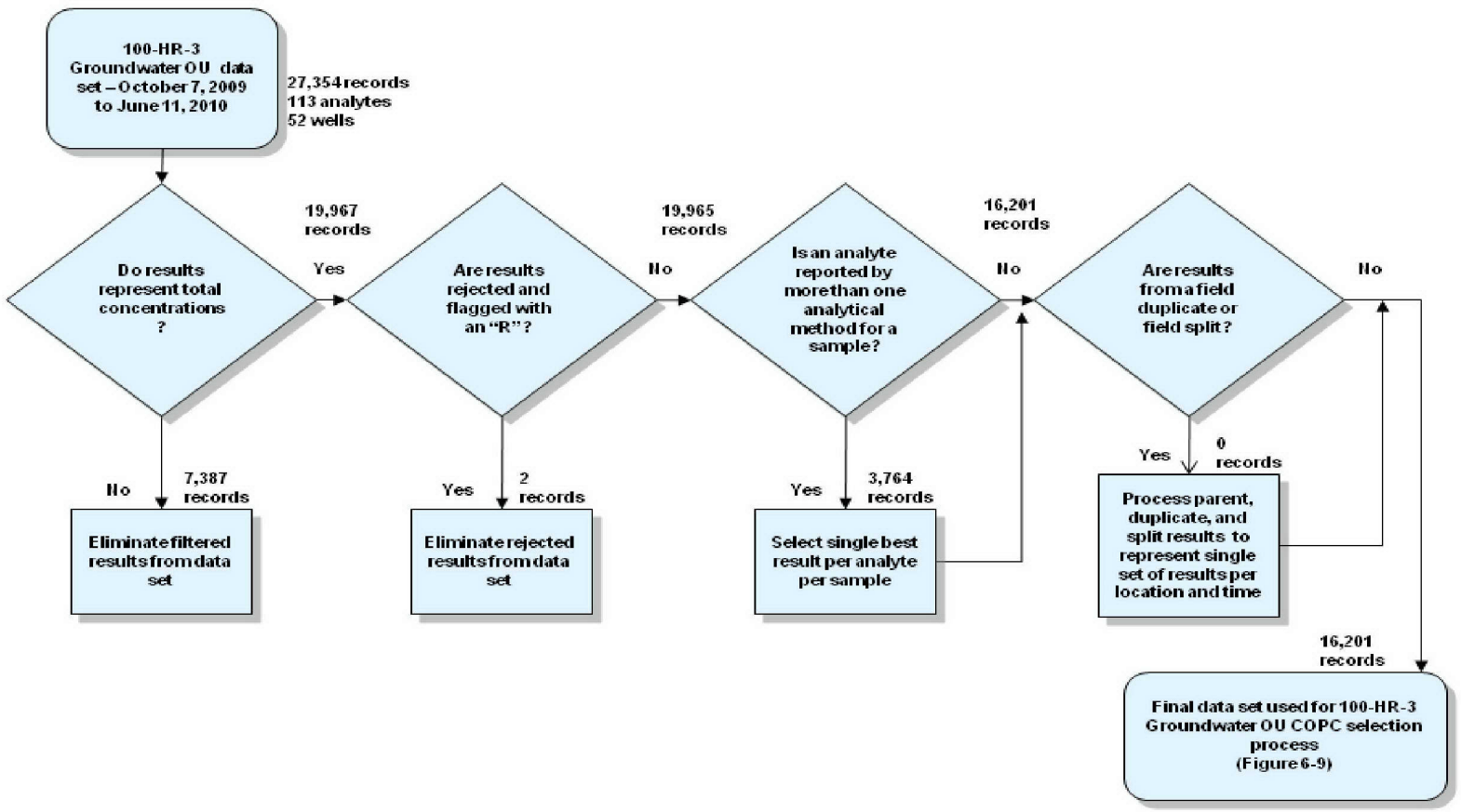

Figure 6-12. Data Processing and Reduction Steps for the RI Groundwater Data Set

The analytical data were processed using the steps described in the following paragraphs and thus identify one set of results per sampling location and date of sample collection. The data processing steps and the numbers of records associated with each step are presented on Figure 6-12 for the RI data set.

Descriptions of the data processing steps follow.

6.3.2.1.2 *Sample Results*

For the RI data set, only analytical results from unfiltered samples are used in identifying COPCs; results from filtered samples that may have been collected in support of other monitoring or compliance programs are excluded. Unfiltered sample results represent total concentrations of the analytes, while filtered sample results represent only dissolved concentrations. Use of filtered sampling results might lead to underestimation of chemical and radiological concentrations (for example, in water from an unfiltered tap). Note that the filtered metals results are included in the larger population of data to provide a comprehensive data set for evaluation of aquatic receptors.

The risk assessment guide (EPA/540/1-89/002) addresses this issue in providing guidance on estimating exposure concentrations in groundwater:

> While filtration of groundwater samples provides useful information for understanding chemical transport within an aquifer, the use of filtered samples for estimating exposure is very controversial, because these data may underestimate chemical concentrations in water from an unfiltered tap. Therefore, data from unfiltered samples should be used to estimate exposure concentrations.

6.3.2.1.3 *Laboratory and Data Validation Flags*

Analytical data are received from the laboratory with data qualification flags. Validation qualifiers are assigned during the data validation process. The following rules determine how flagged and/or qualified sample results are used in identifying COPCs.

- Sample results flagged with a "U" data qualifier or combinations of qualifiers that include a "U," such as a "UJ," are considered nondetected results.
- Sample results without a "U" data qualifier are considered detected concentrations, including results with no qualifier or with a "J" data qualifier.
- Sample results that are rejected and flagged with an "R" validation qualifier are not used in identifying COPCs.

where:

U	=	Analyzed for but not detected above limiting criteria
J	=	Estimated value
R	=	Do not use. Further review indicates the result is not valid

6.3.2.1.4 *Analytes Reported by Numerous Analytical Methods*

Often analytes are reported by more than one analytical method. Therefore, multiple results for an analyte at the same location and sample date are possible. Because multiple sets of analytical results cannot be used to quantify risk (that is, this would result in multiple counting of a chemical), the set of data that best represents the actual concentration will be retained. The results are processed to select the method that provides the most reliable results. Considerations for determining data to be retained include method-associated sample size, detection frequency, method sensitivity and detection limits. The most conservative (that is, health-protective) use of these types of data will be the goal. Larger sample size, higher detection frequencies, and lower detection limits are given higher priority for method selection.

For example, lead may be analyzed using EPA Method 200.8 (*Methods for the Determination of Metals in Environmental Samples, Supplement I* [EPA-600/R-94/111]) with an EQL of 2 µg/L or EPA Method 6010 in SW 846 [SW-846] with an EQL of 50 µg/L. For a sample with lead concentrations reported using both methods, the results reported by EPA Method 200.8 (*Methods for the Determination of Metals in Environmental Samples, Supplement I* [EPA-600/R-94/111]) is selected over EPA Method 6010 (SW 846 [SW-846]) because of the more sensitive detection limit.

6.3.2.1.5 *Field Duplicate and Field Split Results*

Field QC samples (field duplicates and field splits) are collected in the field and analyzed by the laboratory as unique samples. The parent sample and QC samples are collected from the same location (that is, monitoring well) on the same date, resulting in more than one sample per location and date. The following criteria are used to reduce multiple sample results for an individual location and date to a single result:

- If two or more detections exist, the maximum concentration is used.
- If at least one detection and one or more nondetected results exist, the detected concentration is used.
- If only (two or more) nondetected results exist, the lowest detection limit is used.

6.3.2.2 *Identify Action Levels*

For the purpose of risk assessment and identification of COPCs, action levels are screening levels derived from chemical-specific promulgated standards and/or risk based concentrations using default exposure assumptions. All sources of action levels for each of the 113 analytes reported in the HEIS database for the 100-HR-3 OU are identified in Table 6-31.

Although the term "action level" is used for screening purposes, the term "action level" is not used to determine remediation levels nor does it imply that a groundwater action should be taken. Cleanup levels for groundwater contaminants are developed in the ROD.

The sources of action levels from federal regulations are as follows:

- "National Primary Drinking Water Regulations" (40 CFR 141), MCLs, secondary MCLs, and nonzero MCLGs established under the *Safe Drinking Water Act of 1974* (SDWA)
- *National Recommended Water Quality Criteria* (EPA, 2009b), Ambient Water Quality Criteria (AWQC) established under Section 304 of the *Clean Water Act of 1977*
- "Water Quality Standards" (40 CFR 131) for states not complying with Section 303 of the *Clean Water Act of 1977*

The sources of the action levels from Washington State regulations are:

- "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A)
- "Groundwater Cleanup Standards" (WAC 173-340-720)
- "Group A Public Water Supplies," "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)" (WAC 246-290-310)

While surface water and AWQC standards are considered for the identification of action levels, it must be noted that these standards only apply for groundwater where it enters the Columbia River. For the upland parts of groundwater, only DWSs are applicable.

Derivation of State of Washington groundwater cleanup levels is provided in a separate calculation brief (*Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the*

100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports [ECF-100NPL-10-0462]). Derivation of State of Washington surface water cleanup levels is provided in a separate calculation brief (*Calculation of Standard Method B Surface Water Cleanup Levels for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports* [ECF-100NPL-10-0463]).

6.3.2.3 COPC Identification Process (Comparison of EPCs to Action Levels)

Section 6.3.2.1 defined the analytical dataset and described the analytical data processing steps used in this section for identifying groundwater COPCs. Section 6.3.2.2 identified the action levels used in this section for identifying groundwater COPCs. The COPC identification process described in this section is the second evaluation step used to identify COPCs; this step uses the RI sampling and analysis data collected from the 52 monitoring wells in the 100-HR-3 Groundwater OU. Initially all sampling and analysis data are grouped together from each exposure area (that is, the 100-D Source exposure area, the 100-H Source exposure area, and the Horn exposure area) to identify those analytes with detected concentrations above the lowest available action level before an EPC is calculated. Figure 6-9 is a flow chart showing the steps of the COPC identification process that compares EPCs to action levels. The COPC identification steps, number of records, and number of analytes associated with each step are depicted on Figure 6-9 and listed as follows:

- Apply exclusion criteria
- Identify nondetected analytes
- Identify analytes with maximum detected concentrations less than action levels
- Identify analytes with maximum detected concentrations greater than action levels
- Calculate EPCs for analytes with maximum detected concentrations greater than action levels
- Identify analytes with EPCs less than action level
- Identify analytes with EPCs greater than action level

6.3.2.3.1 Apply Exclusion Criteria

The first step in the groundwater COPC identification process is to apply certain exclusion criteria. Analytes that met one or more of the exclusion criteria were eliminated as COPCs. The eliminated analytes are listed in Table 6-32. Analytes that did not meet any of the exclusion criteria were carried forward into the next step. Following are the exclusion criteria:

- Naturally occurring radionuclides associated with background radiation
- Radionuclides that have half-lives of less than 3 years and are not significant daughter products
- Essential nutrients (minerals)
- Analytes without known toxicity information

One naturally occurring radionuclide associated with background radiation (potassium-40) was measured in groundwater from the 100-HR-3 Groundwater OU and was eliminated as a COPC.

Radioisotopes with half-lives less than or equal to 3 years are eliminated from further consideration, because only a small fraction of their original activity remains after 30 years of decay since the reactors ceased operation. Four radioisotopes met this exclusion criterion (antimony-125, beryllium-7, cesium-134, and ruthenium-106) and were eliminated from further consideration as COPCs. These radioisotopes were reported with nondetectable concentrations. Additionally, these isotopes are not significant daughter products associated with a decay chain.

Essential nutrients are those analytes considered essential for human nutrition. The essential nutrients calcium, magnesium, potassium and sodium were detected in the groundwater in the 100-HR-3 OU, but are excluded from further consideration as COPCs.

Analytes without an action level were identified in Table 6-31. Because of the lack of promulgated standards (see Table 6-32), these analytes were not evaluated herein because this section focuses on comparing detected concentrations against action levels. However, the overall contribution of these analytes (and all other detections) were evaluated in the EPA Tap Water scenario (Section 6.3.7), using all available toxicity information. For example, chloromethane does not have a promulgated standard, but toxicity information is published and was used to evaluate the risk contribution for this contaminant. For some analytes without an action level, toxicological information that could be considered in assessing any risks they may present is not available. Twelve analytes were eliminated from further consideration as COPCs because they do not have an action level nor do they have available toxicological information.

6.3.2.3.2 *Identify Nondetected Analytes*

The next step in the groundwater COPC identification process was to identify nondetected analytes. Chemicals and radionuclides that have been analyzed for, but not detected in any sample (collected from appropriate locations with adequate detection limits), were eliminated as COPCs. All analytes detected at least once were carried forward to the next step.

A total of 42 analytes were not detected in the 100-HR-3 OU groundwater samples collected for the RI. These analytes are listed in Table 6-33, each with sampling dates, minimum and maximum MDLs, the action level, the basis of the action level, and the level of exceedance.

Benzene, 1,1-dichloroethene, and vinyl chloride were not detected in the RI samples and were identified as historical COPCs in the work plan. These three analytes were not detected in samples collected specifically for the RI nor were they detected in the larger population of monitoring wells described previously in Section 4.4.1.2 or in Section 6.3.2.3.1. All MDLs associated with these analytes were less than the action level or the EQL (as applicable) listed in the 100-D/H SAP (DOE/RL-2009-40). Therefore, these three analytes are not retained as COPCs and will not be carried forward into the FS.

6.3.2.3.3 *Identify Analytes with Maximum Detected Concentrations Less than Action Levels*[15]

This step identifies analytes with maximum concentrations less than action levels. In this screening, the maximum concentration of each analyte detected in groundwater was compared to its action level, to identify analytes not likely to contribute significantly to overall risk. If the maximum detected concentration of an analyte was less than its action level, the analyte was eliminated as a COPC, unless the nature and extent evaluation indicates otherwise.

Thirty-one analytes were detected at least once and had maximum detected concentrations less than their respective action levels. A list of these analytes is presented in Table 6-34, each with sampling dates, minimum and maximum MDLs, minimum and maximum detected concentrations, the action levels, and the basis for each action level.

Antimony, beryllium, cadmium, cobalt, copper, fluoride, lead, nickel, nitrite, silver, technetium-99, tritium, trichloroethene, uranium, and vanadium were identified as historical COPCs in the 100-D/H Work Plan (DOE/RL-2008-46-ADD1). A discussion of these 15 analytes is provided in the following paragraphs.

[15] See Section 6.3.2.2 for the definition of an action level.

Table 6-31. Summary of Federal and State Water Quality Criteria used as Action Levels for the 100-HR-3 Groundwater OU

				Groundwater					Surface Water					Action Level Value	
				40 CFR 141		WAC 246-290-310	WAC 173-340-720		Clean Water Act National Recommended Water Quality Criteria		WAC 173-201 A	40 CFR 131			
CAS Number	Analyte Name	Alternate Analyte Name	Units	Federal MCL	Federal MCLG	State MCL	Groundwater Method A Cleanup Levels	Groundwater Method B Unrestricted Land Use	Acute Freshwater CMC	Freshwater CCC	Freshwater CCC	Freshwater CMC	Freshwater CCC	Action Level	Action Level Basis
630-20-6	1,1,1,2-Tetrachloroethane	--	µg/L	--	--	--	--	1.7	--	--	--	--	--	1.7	WAC 173-340-720(4)(b)(iii)(A) and (B)
71-55-6	1,1,1-Trichloroethane	--	µg/L	200	200	--	--	16,000	--	--	--	--	--	200	40 CFR 141 – Primary Federal MCL
79-34-5	1,1,2,2-Tetrachloroethane	--	µg/L	--	--	--	--	0.22	--	--	--	--	--	0.22	WAC 173-340-720(4)(b)(iii)(A) and (B)
79-00-5	1,1,2-Trichloroethane	--	µg/L	5.0	3.0	--	--	0.77	--	--	--	--	--	0.77	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-34-3	1,1-Dichloroethane	--	µg/L	--	--	--	--	7.7	--	--	--	--	--	7.7	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-35-4	1,1-Dichloroethene	1,1-Dichloroethylene	µg/L	7.0	7.0	--	--	400	--	--	--	--	--	400	WAC 173-340-720(4)(b)(iii)(A) and (B)
96-18-4	1,2,3-Trichloropropane	--	µg/L	--	--	--	--	0.0015	--	--	--	--	--	0.0015	WAC 173-340-720(4)(b)(iii)(A) and (B)
96-12-8	1,2-Dibromo-3-chloropropane	--	µg/L	0.20	--	--	--	0.055	--	--	--	--	--	0.055	WAC 173-340-720(4)(b)(iii)(A) and (B)
106-93-4	1,2-Dibromoethane	--	µg/L	0.050	--	--	--	0.022	--	--	--	--	--	0.022	WAC 173-340-720(4)(b)(iii)(A) and (B)
107-06-2	1,2-Dichloroethane	--	µg/L	5.0	--	--	--	0.48	--	--	--	--	--	0.48	WAC 173-340-720(4)(b)(iii)(A) and (B)
540-59-0	1,2-Dichloroethene (Total)	1,2-Dichloroethylene Mixed Isomers	µg/L	--	--	--	--	72	--	--	--	--	--	72	WAC 173-340-720(4)(b)(iii)(A) and (B)
78-87-5	1,2-Dichloropropane	--	µg/L	5.0	--	--	--	1.2	--	--	--	--	--	1.2	WAC 173-340-720(4)(b)(iii)(A) and (B)
106-46-7	1,4-Dichlorobenzene	--	µg/L	75	75	--	--	8.1	--	--	--	--	--	8.1	WAC 173-340-720(4)(b)(iii)(A) and (B)
123-91-1	1,4-Dioxane	--	µg/L	--	--	--	--	0.44	--	--	--	--	--	0.44	WAC 173-340-720(4)(b)(iii)(A) and (B)
71-36-3	1-Butanol	N-Butanol	µg/L	--	--	--	--	800	--	--	--	--	--	800	WAC 173-340-720(4)(b)(iii)(A) and (B)
78-93-3	2-Butanone	Methyl ethyl ketone	µg/L	--	--	--	--	4,800	--	--	--	--	--	4,800	WAC 173-340-720(4)(b)(iii)(A) and (B)
591-78-6	2-Hexanone	--	µg/L	--	--	--	--	40	--	--	--	--	--	40	WAC 173-340-720(4)(b)(iii)(A) and (B)
108-10-1	4-Methyl-2-pentanone	4-Methyl-2-penatone	µg/L	--	--	--	--	640	--	--	--	--	--	640	WAC 173-340-720(4)(b)(iii)(A) and (B)
67-64-1	Acetone	--	µg/L	--	--	--	--	7,200	--	--	--	--	--	7,200	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table 6-31. Summary of Federal and State Water Quality Criteria used as Action Levels for the 100-HR-3 Groundwater OU

				Groundwater					Surface Water					Action Level Value	
				40 CFR 141		WAC 246-290-310	WAC 173-340-720		Clean Water Act National Recommended Water Quality Criteria		WAC 173-201 A	40 CFR 131			
CAS Number	Analyte Name	Alternate Analyte Name	Units	Federal MCL	Federal MCLG	State MCL	Groundwater Method A Cleanup Levels	Groundwater Method B Unrestricted Land Use	Acute Freshwater CMC	Freshwater CCC	Freshwater CCC	Freshwater CMC	Freshwater CCC	Action Level	Action Level Basis
107-02-8	Acrolein	--	µg/L	--	--	--	--	4.0	--	3.0	--	--	--	3.0	Clean Water Act -- Freshwater CCC
107-05-1	Allyl chloride	--	µg/L	--	--	--	--	2.1	--	--	--	--	--	2.1	WAC 173-340-720(4)(b)(iii)(A) and (B)
7429-90-5	Aluminum	--	µg/L	--	--	--	--	16,000	750	87	--	--	--	87	Clean Water Act –Freshwater CCC
7440-36-0	Antimony	Antimony (metallic)	µg/L	6.0	6.0	6.0	--	6.4	--	--	--	--	--	6.0	40 CFR 141 - Primary Federal MCL
7440-38-2	Arsenic	Arsenic, inorganic	µg/L	10	--	10	--	0.058	340	150	190	360	190	0.058	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-39-3	Barium	--	µg/L	2,000	2,000	2,000	--	3,200	--	--	--	--	--	2,000	40 CFR 141 - Primary Federal MCL
71-43-2	Benzene	--	µg/L	5.0	--	--	--	0.80	--	--	--	--	--	0.80	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-41-7	Beryllium	Beryllium and compounds	µg/L	4.0	4.0	4.0	--	32	--	--	--	--	--	4.0	40 CFR 141 - Primary Federal MCL
7440-42-8	Boron	Boron and borates only	µg/L	--	--	--	--	3,200	--	--	--	--	--	3,200	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-27-4	Bromodichloromethane	--	µg/L	--	--	--	--	0.71	--	--	--	--	--	0.71	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-25-2	Bromoform	--	µg/L	--	80	--	--	5.5	--	--	--	--	--	5.5	WAC 173-340-720(4)(b)(iii)(A) and (B)
74-83-9	Bromomethane	--	µg/L	--	--	--	--	11	--	--	--	--	--	11	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-43-9	Cadmium	Cadmium (water)	µg/L	5.0	5.0	5.0	--	8.0	2.0	0.25	0.91	3.9	1.0	0.25	Clean Water Act -- Freshwater CCC
75-15-0	Carbon disulfide	--	µg/L	--	--	--	--	800	--	--	--	--	--	800	WAC 173-340-720(4)(b)(iii)(A) and (B)
56-23-5	Carbon tetrachloride	--	µg/L	5.0	--	--	--	0.63	--	--	--	--	--	0.63	WAC 173-340-720(4)(b)(iii)(A) and (B)
10045-97-3	Cesium-137	--	pCi/L	200	--	--	--	--	--	--	--	--	--	200	40 CFR 141 - Primary Federal MCL
16887-00-6	Chloride	--	µg/L	250,000	--	250,000	--	--	860,000	230,000	230,000	--	--	230,000	Clean Water Act -- Freshwater CCC
108-90-7	Chlorobenzene	--	µg/L	100	100	--	--	160	--	--	--	--	--	100	40 CFR 141 - Primary Federal MCL
75-00-3	Chloroethane	Ethylchloride	--	--	--	--	--	--	--	--	--	--	--	--	--
67-66-3	Chloroform	--	µg/L	80	--	--	--	1.4	--	--	--	--	--	1.4	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table 6-31. Summary of Federal and State Water Quality Criteria used as Action Levels for the 100-HR-3 Groundwater OU

				Groundwater					Surface Water					Action Level Value	
				40 CFR 141		WAC 246-290-310	WAC 173-340-720		Clean Water Act National Recommended Water Quality Criteria		WAC 173-201 A	40 CFR 131			
CAS Number	Analyte Name	Alternate Analyte Name	Units	Federal MCL	Federal MCLG	State MCL	Groundwater Method A Cleanup Levels	Groundwater Method B Unrestricted Land Use	Acute Freshwater CMC	Freshwater CCC	Freshwater CCC	Freshwater CMC	Freshwater CCC	Action Level	Action Level Basis
74-87-3	Chloromethane	--	--	--	--	--	--	--	--	--	--	--	--	--	--
126-99-8	Chloroprene	2-Chloro-1,3-butadiene	µg/L	--	--	--	--	160	--	--	--	--	--	160	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-47-3	Chromium	--	µg/L	100	100	100	--	24,000	570	65	156	550	180	65	Clean Water Act -- Freshwater CCC
156-59-2	cis-1,2-Dichloroethylene	--	µg/L	70	70	--	--	16	--	--	--	--	--	16	WAC 173-340-720(4)(b)(iii)(A) and (B)
10061-01-5	cis-1,3-Dichloropropene	--	µg/L	--	--	--	--	0.44	--	--	--	--	--	0.44	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-48-4	Cobalt	--	µg/L	--	--	--	--	4.8	--	--	--	--	--	4.8	WAC 173-340-720(4)(b)(iii)(A) and (B)
10198-40-0	Cobalt-60	--	pCi/L	100	--	--	--	--	--	--	--	--	--	100	40 CFR 141 - Primary Federal MCL
7440-50-8	Copper	--	µg/L	1,300	1,300	--	--	640	13	9.0	--	17	11	9.0	Clean Water Act -- Freshwater CCC
124-48-1	Dibromochloromethane	--	µg/L	60	60	--	--	0.52	--	--	--	--	--	0.52	WAC 173-340-720(4)(b)(iii)(A) and (B)
74-95-3	Dibromomethane	Methylene bromide	µg/L	--	--	--	--	80	--	--	--	--	--	80	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-71-8	Dichlorodifluoromethane	--	µg/L	--	--	--	--	1,600	--	--	--	--	--	1,600	WAC 173-340-720(4)(b)(iii)(A) and (B)
97-63-2	Ethyl methacrylate	--	µg/L	--	--	--	--	720	--	--	--	--	--	720	WAC 173-340-720(4)(b)(iii)(A) and (B)
100-41-4	Ethylbenzene	--	µg/L	700	700	--	--	4.0	--	--	--	--	--	4.0	WAC 173-340-720(4)(b)(iii)(A) and (B)
14683-23-9	Europium-152	--	pCi/L	200	--	--	--	--	--	--	--	--	--	200	40 CFR 141 - Primary Federal MCL
15585-10-1	Europium-154	--	pCi/L	60	--	--	--	--	--	--	--	--	--	60	40 CFR 141 - Primary Federal MCL
14391-16-3	Europium-155	--	pCi/L	600	--	--	--	--	--	--	--	--	--	600	40 CFR 141 - Primary Federal MCL
16984-48-8	Fluoride	--	µg/L	4,000	4,000	4,000	--	960	--	--	--	--	--	960	WAC 173-340-720(4)(b)(iii)(A) and (B)
12587-46-1	Gross alpha	--	pCi/L	15	--	--	--	--	--	--	--	--	--	15	40 CFR 141 - Primary Federal MCL
12587-47-2	Gross beta	--	mrem/year	4.0	--	--	--	--	--	--	--	--	--	4.0	40 CFR 141 - Primary Federal MCL
18540-29-9	Hexavalent chromium	Cr(VI)	µg/L	--	--	--	--	48	16	11	10	15	10	10	WAC 173-201A

Table 6-31. Summary of Federal and State Water Quality Criteria used as Action Levels for the 100-HR-3 Groundwater OU

				Groundwater					Surface Water					Action Level Value	
				40 CFR 141		WAC 246-290-310	WAC 173-340-720		Clean Water Act National Recommended Water Quality Criteria		WAC 173-201 A	40 CFR 131			
CAS Number	Analyte Name	Alternate Analyte Name	Units	Federal MCL	Federal MCLG	State MCL	Groundwater Method A Cleanup Levels	Groundwater Method B Unrestricted Land Use	Acute Freshwater CMC	Freshwater CCC	Freshwater CCC	Freshwater CMC	Freshwater CCC	Action Level	Action Level Basis
7439-89-6	Iron	--	µg/L	--	--	300	--	11,200	--	1,000	--	--	--	1,000	Clean Water Act -- Freshwater CCC
78-83-1	Isobutyl alcohol	--	µg/L	--	--	--	--	2,400	--	--	--	--	--	2,400	WAC 173-340-720(4)(b)(iii)(A) and (B)
7439-92-1	Lead	Lead and compounds	µg/L	15	--	--	15	--	65	2.5	2.1	65	2.5	2.1	WAC 173-201A
7439-93-2	Lithium	--	µg/L	--	--	--	--	32	--	--	--	--	--	32	WAC 173-340-720(4)(b)(iii)(A) and (B)
7439-96-5	Manganese	Manganese (water)	µg/L	--	--	50	--	384	--	--	--	--	--	384	WAC 173-340-720(4)(b)(iii)(A) and (B)
7487-94-7	Mercury	Mercuric chloride	µg/L	2.0	2.0	2.0	--	4.8	1.4	0.77	0.012	2.1	0.012	0.012	40 CFR 131 -- Freshwater CCC
126-98-7	Methacrylonitrile	--	µg/L	--	--	--	--	0.80	--	--	--	--	--	0.80	WAC 173-340-720(4)(b)(iii)(A) and (B)
80-62-6	Methyl methacrylate	--	µg/L	--	--	--	--	11,200	--	--	--	--	--	11,200	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-09-2	Methylene chloride	--	µg/L	5.0	--	--	--	21.9	--	--	--	--	--	5.0	40 CFR 141 - Primary Federal MCL
7439-98-7	Molybdenum	--	µg/L	--	--	--	--	80	--	--	--	--	--	80	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-02-0	Nickel	Nickel soluble salts	µg/L	--	100	100	--	320	470	52	137	1,400	160	52	Clean Water Act -- Freshwater CCC
14797-55-8	Nitrate	--	µg/L	45,000	45,000	45,000	--	113,600	--	--	--	--	--	45,000	40 CFR 141 - Primary Federal MCL
14797-65-0	Nitrite	--	µg/L	3,300	3,300	3,300	--	5,280	--	--	--	--	--	3,300	40 CFR 141 - Primary Federal MCL
14265-44-2	Phosphate	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7782-49-2	Selenium	--	µg/L	50	50	50	--	80	--	5.0	5.0	20	5.0	5.0	Clean Water Act -- Freshwater CCC
7440-22-4	Silver	--	µg/L	100	--	100	--	80	3.2	--	2.6	3.4	--	2.6	WAC 173-201A
7440-24-6	Strontium	Strontium, Stable	µg/L	--	--	--	--	9,600	--	--	--	--	--	9,600	WAC 173-340-720(4)(b)(iii)(A) and (B)
10098-97-2	Strontium-90	--	pCi/L	8.0	--	--	--	--	--	--	--	--	--	8.0	40 CFR 141 - Primary Federal MCL
100-42-5	Styrene	--	µg/L	100	100	--	--	1,600	--	--	--	--	--	100	40 CFR 141 - Primary Federal MCL
14808-79-8	Sulfate	--	µg/L	250,000	--	250,000	--	--	--	--	--	--	--	250,000	40 CFR 141 – Secondary Federal MCL

Table 6-31. Summary of Federal and State Water Quality Criteria used as Action Levels for the 100-HR-3 Groundwater OU

				Groundwater					Surface Water					Action Level Value	
				40 CFR 141		WAC 246-290-310	WAC 173-340-720		Clean Water Act National Recommended Water Quality Criteria		WAC 173-201 A	40 CFR 131			
CAS Number	Analyte Name	Alternate Analyte Name	Units	Federal MCL	Federal MCLG	State MCL	Groundwater Method A Cleanup Levels	Groundwater Method B Unrestricted Land Use	Acute Freshwater CMC	Freshwater CCC	Freshwater CCC	Freshwater CMC	Freshwater CCC	Action Level	Action Level Basis
14133-76-7	Technetium-99	--	pCi/L	900	--	--	--	--	--	--	--	--	--	900	40 CFR 141 - Primary Federal MCL
127-18-4	Tetrachloroethene	Perchloroethylene (PCE)	µg/L	5.0	--	--	--	21	--	--	--	--	--	5	40 CFR 141 - Primary Federal MCL
7440-28-0	Thallium	Thallium (soluble salts)	µg/L	2.0	0.50	2.0	--	--	--	--	--	--	--	0.50	40 CFR 141 - Primary Federal MCLG
7440-31-5	Tin	--	µg/L	--	--	--	--	9,600	--	--	--	--	--	9,600	WAC 173-340-720(4)(b)(iii)(A) and (B)
108-88-3	Toluene	--	µg/L	1,000	1,000	--	--	640	--	--	--	--	--	640	WAC 173-340-720(4)(b)(iii)(A) and (B)
156-60-5	trans-1,2-dichloroethylene	--	µg/L	100	100	--	--	160	--	--	--	--	--	100	40 CFR 141 - Primary Federal MCL
10061-02-6	trans-1,3-dichloropropene	--	µg/L	--	--	--	--	0.44	--	--	--	--	--	0.44	WAC 173-340-720(4)(b)(iii)(A) and (B)
110-57-6	trans-1,4-dichloro-2-butene	--	--	--	--	--	--	--	--	--	--	--	--	--	--
79-01-6	Trichloroethene	Trichloroethylene	µg/L	5.0	--	--	--	0.95	--	--	--	--	--	0.95	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-69-4	Trichloromonofluoro-methane	Trichlorofluoro-methane	µg/L	--	--	--	--	2,400	--	--	--	--	--	2,400	WAC 173-340-720(4)(b)(iii)(A) and (B)
10028-17-8	Tritium	--	pCi/L	20,000	--	--	--	--	--	--	--	--	--	20,000	40 CFR 141 - Primary Federal MCL
7440-61-1	Uranium	Uranium (soluble salts)	µg/L	30	--	--	--	48	--	--	--	--	--	30	40 CFR 141 - Primary Federal MCL
7440-62-2	Vanadium	Vanadium and compounds	µg/L	--	--	--	--	80	--	--	--	--	--	80	WAC 173-340-720(4)(b)(iii)(A) and (B)
108-05-4	Vinyl acetate	--	µg/L	--	--	--	--	8,000	--	--	--	--	--	8,000	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-01-4	Vinyl chloride	--	µg/L	2.0	--	--	--	0.061	--	--	--	--	--	0.061	WAC 173-340-720(4)(b)(iii)(A) and (B)
1330-20-7	Xylenes (total)	Xylenes (mixture)	µg/L	10,000	10,000	--	--	1,600	--	--	--	--	--	1,600	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-66-6	Zinc	Zinc (metallic)	µg/L	5,000	--	5,000	--	4,800	120	120	91	110	100	91	WAC 173-201A

Table 6-31. Summary of Federal and State Water Quality Criteria used as Action Levels for the 100-HR-3 Groundwater OU

				Groundwater					Surface Water					Action Level Value	
				40 CFR 141		WAC 246-290-310	WAC 173-340-720		Clean Water Act National Recommended Water Quality Criteria		WAC 173-201 A	40 CFR 131			
CAS Number	Analyte Name	Alternate Analyte Name	Units	Federal MCL	Federal MCLG	State MCL	Groundwater Method A Cleanup Levels	Groundwater Method B Unrestricted Land Use	Acute Freshwater CMC	Freshwater CCC	Freshwater CCC	Freshwater CMC	Freshwater CCC	Action Level	Action Level Basis

Note: That 40 CFR 131, "Water Quality Standards," *National Recommended Water Quality Criteria* (EPA, 2009b), and WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington" only apply in locations where groundwater has the potential to discharge to the Columbia River. Sources:

40 CFR 131, "Water Quality Standards."

40 CFR 141, "National Primary Drinking Water Regulations."

Ecology Publication 94-06, *Model Toxics Control Act Cleanup Regulation Chapter 173-340 WAC*.

EPA, 2009b, *National Recommended Water Quality Criteria*.

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

WAC 173-340-720(4)(b)(ii)(A) and (B), "Groundwater Cleanup Standards," "Noncarcinogens and Carcinogens."

WAC 246-290-310, "Group A Public Water Supplies," "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)."

CCC = criteria continuous concentration

CMC = criteria maximum concentration

MCL = maximum contaminant level

MCLG = maximum contaminant level goal

Table 6-32. Summary of Groundwater Analytes that Meet Exclusion Criteria in the 100-HR-3 Groundwater OU

Analyte Name	Analyte Class	Begin Sampling Date	End Sampling Date	Total Samples	Total Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Basis for Exclusion
Bromide	ANION	10/7/2009	6/11/2010	117	86	73.50%	µg/L	90	450	98	320	No Action Level/No Toxicity Values
Phosphate	ANION	10/7/2009	6/11/2010	117	3	2.56%	µg/L	429	2,150	460	1,260	No Action Level/No Toxicity Values
Bismuth	METAL	10/7/2009	6/11/2010	122	7	5.74%	µg/L	0	23	23	38	No Action Level/No Toxicity Values
Calcium	METAL	10/7/2009	6/11/2010	156	156	100.00%	µg/L	--	--	34,200	157,000	Essential Nutrient
Magnesium	METAL	10/7/2009	6/11/2010	156	156	100.00%	µg/L	--	--	774	39,600	Essential Nutrient
Potassium	METAL	10/7/2009	6/11/2010	156	156	100.00%	µg/L	--	--	1,870	7,190	Essential Nutrient
Silicon	METAL	10/7/2009	6/11/2010	122	122	100.00%	µg/L	--	--	7,510	22,800	No Action Level/No Toxicity Values
Sodium	METAL	10/7/2009	6/11/2010	156	156	100.00%	µg/L	--	--	4,200	38,100	Essential Nutrient
Antimony-125	RAD	10/7/2009	6/11/2010	156	0	0.00%	pCi/L	-4.30E+00	6.5	--	--	Half-Life less than 3 years
Beryllium-7	RAD	10/7/2009	6/11/2010	156	0	0.00%	pCi/L	-3.28E+01	32	--	--	Half-Life less than 3 years
Cesium-134	RAD	10/7/2009	6/11/2010	156	0	0.00%	pCi/L	-2.81E+00	2.7	--	--	Half-Life less than 3 years
Gross beta	RAD	10/7/2009	6/11/2010	156	116	74.36%	pCi/L	0.055	6.3	3.4	58	No Action Level/No Toxicity Values
Potassium-40	RAD	10/7/2009	6/11/2010	156	1	0.64%	pCi/L	-8.60E+01	37	58	58	Background Radiation
Ruthenium-106	RAD	10/7/2009	6/11/2010	156	0	0.00%	pCi/L	-2.79E+01	26	--	--	Half-Life less than 3 years
1-Chloro-1,1-difluoroethane	VOC	10/9/2009	10/9/2009	1	1	100.00%	µg/L	--	--	56	56	No Action Level/No Toxicity Values
Acetonitrile	VOC	3/18/2010	6/11/2010	104	0	0.00%	µg/L	2.0	2.0	--	--	No Action Level/Toxicity Values Available
Chloroethane	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.085	1.0	--	--	No Action Level/No Toxicity Values
Chloromethane	VOC	10/7/2009	6/11/2010	156	1	0.64%	µg/L	0.077	1.0	0.10	0.10	No Action Level/Toxicity Values Available
Ethyl cyanide	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	1.2	2.0	--	--	No Action Level/No Toxicity Values
Iodomethane	VOC	3/18/2010	6/11/2010	104	0	0.00%	µg/L	0.092	0.092	--	--	No Action Level/No Toxicity Values
Tetrahydrofuran	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	1.1	2.0	--	--	No Action Level/No Toxicity Values
trans-1,4-Dichloro-2-butene	VOC	3/18/2010	6/11/2010	104	0	0.00%	µg/L	0.29	0.29	--	--	No Action Level/No Toxicity Values
Trichloroacetyl chloride	VOC	10/9/2009	10/9/2009	1	1	100.00%	µg/L	--	--	1.5	1.5	No Action Level/No Toxicity Values

Table 6-33. Summary of Analytes that Were Not Detected in the 100-HR-3 Groundwater OU

Analyte Name	Analyte Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit	Action Level	Action Level Basis	Level of Exceedance
Cesium-137	RAD	10/7/2009	6/11/2010	156	0	0.00%	pCi/L	-2.15	2.96	200	40 CFR 141 - Primary Federal MCL	-0.011
Cobalt-60	RAD	10/7/2009	6/11/2010	156	0	0.00%	pCi/L	-2.98	2.09	100	40 CFR 141 - Primary Federal MCL	-0.030
Europium-152	RAD	10/7/2009	6/11/2010	156	0	0.00%	pCi/L	-6.76	6.52	200	40 CFR 141 - Primary Federal MCL	-0.034
Europium-154	RAD	10/7/2009	6/11/2010	156	0	0.00%	pCi/L	-6.14	7.94	60	40 CFR 141 - Primary Federal MCL	-0.10
Europium-155	RAD	10/7/2009	6/11/2010	156	0	0.00%	pCi/L	-5.03	4.24	600	40 CFR 141 - Primary Federal MCL	-0.008
1,4-Dichlorobenzene	SVOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.12	1	8.1	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.015
1,1,1,2-Tetrachloroethane	VOC	3/18/2010	6/11/2010	104	0	0.00%	µg/L	0.09	0.09	1.7	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.054
1,1,1-Trichloroethane	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.067	1	200	40 CFR 141 - Federal MCL	0.00034
1,1,2,2-Tetrachloroethane	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.098	1	0.22	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.45
1,1,2-Trichloroethane	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.063	1	0.77	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.082
1,1-Dichloroethane	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.068	1	7.7	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.0088
1,1-Dichloroethene	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.051	1	400	40 CFR 131 -- Human Health Water + Organism	0.00013
1,2,3-Trichloropropane	VOC	3/18/2010	6/11/2010	104	0	0.00%	µg/L	0.15	0.15	0.0015	WAC 173-340-720(4)(b)(iii)(A) and (B)	103
1,2-Dibromo-3-chloropropane	VOC	3/18/2010	6/11/2010	104	0	0.00%	µg/L	0.41	0.41	0.055	WAC 173-340-720(4)(b)(iii)(A) and (B)	7.5
1,2-Dibromoethane	VOC	3/18/2010	6/11/2010	104	0	0.00%	µg/L	0.13	0.13	0.022	WAC 173-340-720(4)(b)(iii)(A) and (B)	5.9
1,2-Dichloroethene (Total)	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.13	1	72	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.0018
1,2-Dichloropropane	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.097	1	1.2	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.081
1,4-Dioxane	VOC	3/18/2010	6/11/2010	104	0	0.00%	µg/L	7.6	7.6	0.44	WAC 173-340-720(4)(b)(iii)(A) and (B)	17.2
1-Butanol	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	12	100	800	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.015
2-Hexanone	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.22	1.0	40	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.0055
4-Methyl-2-pentanone	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.12	1.0	640	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.00019
Acrolein	VOC	3/18/2010	6/11/2010	104	0	0.00%	µg/L	2.8	2.8	3.0	Clean Water Act -- Freshwater CCC	0.93
Allyl chloride	VOC	3/18/2010	6/11/2010	104	0	0.00%	µg/L	0.091	0.11	2.1	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.044
Benzene	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.045	1.0	0.80	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.057
Chlorobenzene	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.15	1.0	100	40 CFR 141 - Primary Federal MCL	0.0015
Chloroprene	VOC	3/18/2010	6/11/2010	104	0	0.00%	µg/L	0.086	0.097	160	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.00054
cis-1,2-Dichloroethylene	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.083	1.0	16	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.0052
cis-1,3-Dichloropropene	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.073	1.0	0.44	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.17
Dibromochloromethane	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.057	1.0	0.52	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.11
Dibromomethane	VOC	3/18/2010	6/11/2010	104	0	0.00%	µg/L	0.21	0.21	80	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.0026
Dichlorodifluoromethane	VOC	3/18/2010	6/11/2010	104	0	0.00%	µg/L	0.070	0.084	1,600	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.00004

Table 6-33. Summary of Analytes that Were Not Detected in the 100-HR-3 Groundwater OU

Analyte Name	Analyte Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit	Action Level	Action Level Basis	Level of Exceedance
Ethyl methacrylate	VOC	3/18/2010	6/11/2010	104	0	0.00%	µg/L	0.11	0.11	720	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.00015
Ethylbenzene	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.086	1.0	4.0	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.022
Isobutyl alcohol	VOC	3/18/2010	6/11/2010	104	0	0.00%	µg/L	8.7	8.7	2,400	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.0036
Methacrylonitrile	VOC	3/18/2010	6/11/2010	104	0	0.00%	µg/L	0.050	0.50	0.80	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.063
Methyl methacrylate	VOC	3/18/2010	6/11/2010	104	0	0.00%	µg/L	0.26	0.26	11,200	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.00002
Styrene	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.036	1.0	100	40 CFR 141 - Primary Federal MCL	0.00036
trans-1,2-Dichloroethylene	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.083	1.0	100	40 CFR 141 - Primary Federal MCL	0.00083
trans-1,3-Dichloropropene	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.083	1.0	0.44	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.19
Trichloromonofluoromethane	VOC	3/18/2010	6/11/2010	104	0	0.00%	µg/L	0.041	0.11	2,400	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.00002
Vinyl acetate	VOC	3/18/2010	6/11/2010	104	0	0.00%	µg/L	0.17	0.18	8,000	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.00002
Vinyl chloride	VOC	10/7/2009	6/11/2010	156	0	0.00%	µg/L	0.032	1.0	0.061	WAC 173-340-720(4)(b)(iii)(A) and (B)	0.52

Note: Shading indicates that an analyte was identified in the list of COPCs in DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*.

MCL = maximum contaminant level

OU = operable unit

Table 6-34. Summary of Groundwater Analytes That Do Not Exceed an Action Level in the 100-HR-3 Groundwater OU

Analyte Name	Analyte Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Action Level	Action Level Basis
Chloride	ANION	10/7/2009	6/11/2010	156	156	100.00%	µg/L	--	--	3,960	44,900	230,000	Clean Water Act -- Freshwater CCC
Fluoride	ANION	10/7/2009	6/11/2010	156	63	40.38%	µg/L	60	300	60	343	960	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrite	ANION	10/7/2009	6/11/2010	156	10	6.41%	µg/L	9.9	591	1,140	2,270	3,300	40 CFR 141 - Primary Federal MCL
Antimony	METAL	10/7/2009	6/11/2010	156	13	8.33%	µg/L	0.30	1.1	0.61	1.0	6.0	40 CFR 141 - Primary Federal MCL
Barium	METAL	10/7/2009	6/11/2010	156	156	100.00%	µg/L	--	--	25	133	2,000	40 CFR 141 - Primary Federal MCL
Beryllium	METAL	10/7/2009	6/11/2010	156	5	3.21%	µg/L	0.050	0.11	0.10	0.31	4.0	40 CFR 141 - Federal MCL
Boron	METAL	10/7/2009	6/11/2010	122	44	36.07%	µg/L	19	19	9.7	102	3,200	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cadmium	METAL	10/7/2009	6/11/2010	156	2	1.28%	µg/L	0.055	0.20	0.11	0.22	0.25	Clean Water Act -- Freshwater CCC
Cobalt	METAL	10/7/2009	6/11/2010	156	44	28.21%	µg/L	0.050	0.22	0.062	3.0	4.8	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	METAL	10/7/2009	6/11/2010	156	104	66.67%	µg/L	0.10	0.20	0.10	2.8	9.0	Clean Water Act -- Freshwater CCC
Lead	METAL	10/7/2009	6/11/2010	156	23	14.74%	µg/L	0.10	0.20	0.20	0.71	2.1	WAC 173-201A
Molybdenum	METAL	10/7/2009	6/11/2010	122	115	94.26%	µg/L	4.0	4.0	0.56	12	80	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	METAL	10/7/2009	6/11/2010	156	33	21.15%	µg/L	4.0	4.0	2.4	39	52	Clean Water Act -- Freshwater CCC
Silver	METAL	10/7/2009	6/11/2010	156	6	3.85%	µg/L	0.040	0.20	0.13	1.00	2.6	WAC 173-201A
Strontium	METAL	10/7/2009	6/11/2010	156	156	100.00%	µg/L	--	--	138	938	9,600	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tin	METAL	10/7/2009	6/11/2010	122	11	9.02%	µg/L	0.050	39	0.055	43	9,600	WAC 173-340-720(4)(b)(iii)(A) and (B)
Uranium	METAL	10/7/2009	6/11/2010	156	156	100.00%	µg/L	--	--	0.29	13	30	40 CFR 141 - Federal MCL
Vanadium	METAL	10/7/2009	6/11/2010	156	66	42.31%	µg/L	4.1	12	5.4	33	80	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	RAD	10/7/2009	6/11/2010	156	34	21.79%	pCi/L	-2.90	11	2.0	7.9	15	40 CFR 141 - Primary Federal MCL
Technetium-99	RAD	10/7/2009	6/11/2010	155	8	5.16%	pCi/L	-17	3.6	7.9	35	900	40 CFR 141 - Primary Federal MCL
Tritium	RAD	10/7/2009	6/11/2010	156	142	91.03%	pCi/L	-13	170	180	12,000	20,000	40 CFR 141 - Primary Federal MCL
2-Butanone	VOC	10/7/2009	6/11/2010	156	1	0.64%	µg/L	0.52	1.0	10	10	4,800	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	VOC	10/7/2009	6/11/2010	156	2	1.28%	µg/L	0.34	1.0	0.82	6.9	7,200	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromodichloromethane	VOC	10/7/2009	6/11/2010	156	2	1.28%	µg/L	0.082	1.0	0.67	0.68	0.71	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromoform	VOC	10/7/2009	6/11/2010	156	1	0.64%	µg/L	0.094	1.0	0.58	0.58	5.5	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromomethane	VOC	10/7/2009	6/11/2010	156	1	0.64%	µg/L	0.084	1.0	0.97	0.97	11	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon disulfide	VOC	10/7/2009	6/11/2010	156	1	0.64%	µg/L	0.050	1.0	0.076	0.076	800	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tetrachloroethene	VOC	10/7/2009	6/11/2010	156	8	5.13%	µg/L	0.088	1.0	0.093	0.43	5	40 CFR 141 - Federal MCL
Toluene	VOC	10/7/2009	6/11/2010	156	3	1.92%	µg/L	0.062	1.0	0.062	0.18	640	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	VOC	10/7/2009	6/11/2010	156	3	1.92%	µg/L	0.21	1.0	0.26	0.33	0.95	WAC 173-340-720(4)(b)(iii)(A) and (B)
Xylenes (total)	VOC	10/7/2009	6/11/2010	156	2	1.28%	µg/L	0.11	1.0	0.44	0.46	1,600	WAC 173-340-720(4)(b)(iii)(A) and (B)

Note:Shading indicates that an analyte was identified in the list of COPCs in DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*.

CCC = criteria continuous concentration

OU = operable unit

MCL = maximum contaminant level

Beryllium, technetium-99, tritium, and vanadium were detected in groundwater at concentrations below their respective action level in samples collected for the RI and in the larger population of wells described previously in Sections 4.4.1.2 and 6.3.2.3.1. Beryllium, tritium, and vanadium are not retained as COPCs and will not be carried forward into the risk characterization section or into the FS. It should also be noted that concentrations of beryllium and fluoride (outside the 100-D ISRM area) in filtered groundwater samples are less than their 90th percentile Hanford Site background value.

Antimony, cadmium, cobalt, copper, fluoride, lead, nickel, nitrite, silver, trichloroethene, and uranium were detected in groundwater samples collected for the RI at concentrations below their respective action level. However, these analytes were detected at concentrations above their respective action level in the larger population of wells described previously in Sections 4.4.1.2 and 6.3.2.3.1. The following text discusses the results for these 10 analytes.

Detections of antimony, cadmium, cobalt, copper and silver above the action level were from the larger population of wells sampled in the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. All antimony, cadmium, cobalt, copper, and silver results (detected concentrations and MDLs) reported by Method 6010 (SW 846 [SW-846]) were greater than the action level. Groundwater samples analyzed by Method 6010 generally report MDLs greater than the action level, resulting in nondetected concentrations greater than the action level. Similarly, detected concentrations are reported as estimates (flagged with a "B" qualifier) at concentrations greater than the action level and are below the contract-required calibration range of the instrument. Some results are also flagged with a "C" qualifier indicating that the analyte was detected in both the sample and the associated QC blank, and the sample concentration is less than or equal to five times the blank concentration. Additionally, antimony, cadmium, cobalt, copper, and silver concentrations above the action level are not associated with a specific location or with a trend. Although antimony, cadmium, cobalt, copper, and silver were detected at concentrations less than the action level in samples analyzed for the RI by Method 200.8 (*Methods for the Determination of Metals in Environmental Samples, Supplement 1* [EPA-600/R-94/111]), their historical presence with infrequent detections above the action level result in an uncertain status. Therefore, antimony, cadmium, cobalt, copper, and silver are retained as COPCs for further monitoring.

Detections of fluoride and nitrite above the action level were from the larger population of wells sampled in the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Fluoride and nitrite were each detected in two wells from the 100-D ISRM area at concentrations above their respective action levels. Elevated fluoride and nitrite concentrations are associated with the reducing conditions created by the presence of zero valence iron at the 100-D ISRM area. Based on these results, fluoride and nitrite are both retained as COPCs for further monitoring at 100-D ISRM area.

Detections of lead above the action level were from the larger population of wells sampled in the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. At the 100-D groundwater area, all lead results (detected concentrations and MDLs) were less than the DWS. All MDLs were less than the state water quality criteria of 2.1 μg/L. Lead in filtered samples were reported above the state water quality standard at two wells (199-D5-142 and 199-D8-101). A single detection of lead was reported at 199-D5-142 (2.24 μg/L) and at 199-D8-101 (3.66 μg/L) and both lead results were flagged with a "B" laboratory qualifier. Samples from these wells were not analyzed by the trace methods identified in the 100-D/H SAP (Method 6020 or 200.8) but were analyzed by Method 6010, which is not accurate for measuring trace levels of lead. At the 100-H area, all MDLs (10 μg/L) for samples analyzed by Method 6010 were above the state water quality standard. At the Horn area, all lead results (MDLs and detected concentrations) were less than the state water quality standard and the DWS, this is a result of being analyzed by the the trace methods identified in the 100-D/H SAP (Method 6020 or 200.8). However, lead was detected in a single well at the 100-D ISRM at concentrations above the state water quality standard

and the DWS. Elevated lead concentrations at this well are associated with the reducing conditions created by the presence of zero valence iron at the 100-D ISRM area. Lead is retained as a COPC for further monitoring in the 100-D, 100-D ISRM, and 100-H groundwater areas.

Detections of nickel above the AWQC were from the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Although all groundwater results were compared to the AWQC, these concentrations would need to be measured as close as practicable to the groundwater/surface water interface or biologically active zone. Wells located inland would need to meet the DWS of 100 µg/L. All nickel results (detected concentrations and MDLs) are less than the DWS. With the exception of four samples from the 100-D Area analyzed in 2011, all MDLs for filtered samples were less than the AWQC. All detected nickel concentrations in filtered samples are less than the AWQC. Therefore, nickel in not retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

Detections of trichloroethene above the action level were from the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. The action level for trichloroethene is 0.95 µg/L based on the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) cleanup level. However, the analytical method cannot achieve the action level for trichloroethene; therefore, nondetected concentrations are reported at the EQL of 1 µg/L listed in the 100-D/H SAP (DOE/RL-2009-40). Trichloroethene was detected infrequently in the Horn area plume (6 percent frequency) at concentrations less than the EQL. Therefore, trichloroethene is not retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

Detections of uranium above the DWS were from the larger population of wells sampled over the past 7years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Uranium concentrations were infrequently reported above the DWS at well 199-H4-3 (86 µg/L) between May 2006 and February 2014. Well 199-H4-3 monitors groundwater conditions near the 183-H Solar Evaporation Basin. As a result of this evaluation, uranium is retained as a COPC for further monitoring at the 100-H area.

6.3.2.3.4 *Identify Analytes with Maximum Detected Concentrations Greater than Action Levels*[16]

This step identifies analytes with maximum concentrations greater than their respective action levels. Such analytes have the potential to contribute to overall risk. If the maximum detected concentration of an analyte is greater than its action level, the analyte is carried forward into the next step of the analysis for calculation of EPCs.

Eighteen analytes were detected in the RI data at least once, with maximum detected concentrations greater than their respective action levels. A list of these analytes is presented in Table 6-35, each with sampling dates, minimum and maximum MDLs, minimum and maximum detected concentrations, the action level, and the basis of the action level.

[16] See Section 6.3.2.2 for the definition of an action level.

Table 6-35. Summary of Analytes that Exceed an Action Level in the 100-HR-3 Groundwater OU

Analyte Name	Analyte Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Action Level	Action Level Basis
Nitrate	ANION	10/7/2009	6/11/2010	155	155	100.00%	µg/L	--	--	7,880	99,200	45,000	40 CFR 141 - Primary Federal MCL
Sulfate	ANION	10/7/2009	6/11/2010	156	156	100.00%	µg/L	--	--	24,900	438,000	250,000	40 CFR 141 – Secondary Federal MCL
Aluminum	METAL	10/7/2009	6/11/2010	156	65	41.67%	µg/L	5.0	10	5.4	188	87	Clean Water Act -- Freshwater CCC
Arsenic	METAL	10/7/2009	6/11/2010	156	147	94.23%	µg/L	0.40	0.80	0.61	7.5	0.058	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	METAL	10/7/2009	6/11/2010	156	156	100.00%	µg/L	--	--	5.6	4,460	65	Clean Water Act -- Freshwater CCC
Cr(VI)	METAL	10/7/2009	6/11/2010	156	144	92.31%	µg/L	2.0	2.0	2.6	6,390	10	WAC 173-201A
Iron	METAL	10/7/2009	6/11/2010	156	110	70.51%	µg/L	18	18	17	7,840	1,000	Clean Water Act -- Freshwater CCC
Lithium	METAL	10/7/2009	6/11/2010	122	102	83.61%	µg/L	4.0	4.0	2.6	133	32	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	METAL	10/7/2009	6/11/2010	156	24	15.38%	µg/L	3.3	4.0	0.60	122	384	WAC 173-340-720(4)(b)(iii)(A) and (B)
Mercury	METAL	10/7/2009	6/11/2010	156	1	0.64%	µg/L	0.050	0.10	0.11	0.11	0.012	40 CFR 131 -- Freshwater CCC
Selenium	METAL	10/7/2009	6/11/2010	156	150	96.15%	µg/L	0.60	0.60	0.38	7.1	5.0	Clean Water Act -- Freshwater CCC
Thallium	METAL	10/7/2009	6/11/2010	156	6	3.85%	µg/L	0.050	0.10	0.10	1.0	0.50	40 CFR 141 - Primary Federal MCLG
Zinc	METAL	10/7/2009	6/11/2010	156	36	23.08%	µg/L	5.2	6.0	0.90	260	91	WAC 173-201A
Strontium-90	RAD	10/7/2009	6/11/2010	156	19	12.18%	pCi/L	-14	2.6	2.2	27	8.0	40 CFR 141 - Primary Federal MCL
1,2-Dichloroethane	VOC	10/7/2009	6/11/2010	156	1	0.64%	µg/L	0.10	1.0	0.67	0.67	0.48	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon tetrachloride	VOC	10/7/2009	6/11/2010	156	14	8.97%	µg/L	0.063	1.0	0.088	2.7	0.63	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chloroform	VOC	10/7/2009	6/11/2010	156	113	72.44%	µg/L	0.10	1.0	0.12	8.3	1.4	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	VOC	10/7/2009	6/11/2010	156	18	11.54%	µg/L	0.11	1.0	0.12	11	5.0	40 CFR 141 - Primary Federal MCL

Note: Shading indicates that the analyte is identified in the list of COPCs in DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*.

CCC = criteria continuous concentration

MCL = maximum contaminant level

OU = operable unit

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6.3.2.3.5 *Calculate EPCs for Each Analyte with Maximum Detected Concentrations Greater than Action Levels*[17]

COPCs are identified by comparing statistical EPC estimates to action levels for each analyte and exposure area. EPCs are calculated as the 90th percentile value for each analyte with a maximum detected concentration greater than the action level from the groundwater dataset collected specifically for the RI. The MDL is used as the concentration for nondetect results in the percentile calculations. The 90th percentile exposure is identified in Guidelines for Exposure Assessment (EPA/600/Z-92/001) for describing and characterizing health risks and produces risk estimates corresponding to an RME. A description of the methodology used to calculate the 90th percentile values is provided in *Calculation of Exposure Point Concentrations for the 100-HR-3 Groundwater Operable Unit* (ECF-100HR3-10-0473) (Appendix G).

In general, Calculating UCL for EPCs (OSWER 9285.6-10) recommends using a 95 percent UCL on the average for estimating EPCs. However, experience at the Hanford Site indicates that averages and UCLs cannot be reliably calculated for groundwater datasets. The 100-HR-3 Groundwater OU exhibits an aquifer setting where multiple groundwater contaminants are present in overlapping plumes, and the highest concentrations of the various COPCs have different locations within the plumes.

Use of the 90th percentile value from a distribution of groundwater concentration data as an estimate of the EPC is a different approach for estimating EPCs than that provided in Calculating UCL for EPCs (OSWER 9285.6-10). However, as described in the following text, the 90th percentile exposure concentration is identified in other EPA risk assessment guidance as appropriate for describing and characterizing health risks; its use yields risk estimates that correspond to an RME.

According to *An Examination of EPA Risk Assessment Principles and Practices* (EPA/100/B-04/001), the RME is an appropriate exposure scenario for risk calculations, within the realistic range of exposure, since the goal of the Superfund program is to protect against high-end, not worst-case, exposures. The "high end" is defined as that part of the exposure distribution that is above the 90th percentile, but below the 99.9th percentile. The approach is consistent with the peer-reviewed *Guidelines for Exposure Assessment* (EPA/600/Z-92/001). Groundwater concentrations directly reflect potential exposures and risks, so a 90th percentile concentration reflects an RME scenario.

Groundwater datasets at the Hanford Site are highly skewed, with a large proportion of below detection limit (BDL) values. *Data Quality Assessment: Statistical Methods for Practitioners* (EPA/240/B-06/003) provides guidance for estimating statistical parameters (whether means or upper percentiles) depending on the variability in the dataset. The variability of the dataset is assessed in terms of the CV and the proportion of observations that are BDL. For datasets with CVs greater than 0.5 and 50 percent or more observations that are BDL, EPA recommends using upper percentiles as opposed to means to develop summary statistics

Therefore, the rationale for using a 90th percentile value as an estimate of the EPC is consistent with the definition of an RME scenario, and is an appropriate statistic for groundwater datasets in this groundwater OU. Additional statistical evaluation of the 100-HR-3 Groundwater OU datasets that support the selection of the 90th percentile value as the EPC is provided in *Calculation of Exposure Point Concentrations for the 100-HR-3 Groundwater Operable Unit* (ECF-100HR3-10-0473) (Appendix G). This evaluation includes an estimation of the 95 percent UCL value for each detected analyte, along with the analysis of variability, to assess the reliability of the 95 percent UCL estimates. Results of the evaluation indicate that, for the majority of analytes, a reliable and meaningful 95 percent UCL estimate cannot be calculated, because of (1) an insufficient number of samples, (2) an insufficient number of detections, or (3) a high variance of

[17] See Section 6.3.2.2 for the definition of an action level.

the data. Therefore, the 90th percentile is adopted as the estimated EPC for all analytes. A comparison of the 90th percentile and 95 percent UCL values is provided in the uncertainty analysis (Section 6.3.8.2).

A flowchart depicting the COPC identification process and the number of analytes associated with each process step is provided on Figure 6-9. The steps in the sequence are described in the following sections.

6.3.2.3.6 *Identify Monitoring Wells in Each Exposure Area*

Three exposure areas are identified for the 100-HR-3 Groundwater OU including: (1) the 100-D Source exposure area, (2) the 100-H Source exposure area, and (3) the Horn exposure area. Table 6-30 lists the monitoring wells associated with each exposure area.

6.3.2.3.7 *Identify Nondetected Analytes in Each Exposure Area*

Analytes that have not been detected in any of the groundwater samples from an exposure area are eliminated as COPCs for that exposure area. The analytes 1,2-dichloroethane and mercury were eliminated as COPCs in the 100-D Source exposure area. The analyte 1,2-dichloroethane was eliminated as a COPC in the 100-H Source exposure area. The analytes mercury and thallium were eliminated as COPCs in the Horn exposure area. All analytes detected at least once in an exposure area are carried forward to the next step of the process for that exposure area.

6.3.2.3.8 *Identify Analytes with 90th Percentile Values Less than Action Levels in Each Exposure Area.*

The 90th percentile values are compared to the lowest available action level for protection of human health and aquatic receptors. Comparisons of EPCs to action levels for the 100-D Source, 100-H Source, and Horn exposure areas are provided in Tables 6-36, 6-37, and 6-38, respectively.

100-D Source Exposure Area. Ten of the 16 analytes have been detected at least once in groundwater and have 90th percentile values less than their respective action levels (Table 6-36).

Six of the ten analytes (manganese, selenium, strontium-90, sulfate, thallium, and zinc) were identified as historical COPCs in the work plan. A discussion of all analytes with EPCs less than the action level is provided in the following paragraphs.

Aluminum was detected in groundwater samples collected for the RI and the EPC is less than the AWQC of 87 µg/L. There were no detections of aluminum reported above the AWQC in groundwater samples collected for the RI. Aluminum was not analyzed in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Although all monitoring wells within the groundwater OU were compared to the AWQC of 87 µg/L, these concentrations would need to be measured as close as practicable to the groundwater/surface water interface or biologically active zone. Wells located inland would need to meet the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level of 16,000 µg/L. Only one filtered aluminum result was greater than the AWQC (199-D5-38; 110 µg/L) and all aluminum results (detected concentrations and MDLs) in unfiltered samples were less than the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level of 16,000 µg/L. Based on these results, aluminum is not retained as a COPC and will not be carried forward into the risk characterization section.

Table 6-36. Comparison of EPCs to Action Levels for the 100-D Source Exposure Area

Analyte Name	Analyte Class	Total Number of Samples	Number of Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	90th Percentile of RI Data	Action Level	Action Level Basis	90th Percentile > Action Level?
Nitrate	ANION	60	60	100.00%	µg/L	--	--	10,800	99,200	69,500	45,000	40 CFR 141 – Primary Federal MCL	Yes
Sulfate	ANION	60	60	100.00%	µg/L	--	--	24,900	438,000	161,500	250,000	40 CFR 141 – Secondary Federal MCL	No
Aluminum	METAL	60	19	31.67%	µg/L	5	10	5.9	42	24	87	Clean Water Act -- Freshwater CCC	No
Arsenic	METAL	60	56	93.33%	µg/L	0.8	0.8	0.61	2.9	2.6	0.058	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes
Chromium	METAL	60	60	100.00%	µg/L	--	--	7.7	4,460	925	65	Clean Water Act -- Freshwater CCC	Yes
Cr(VI)	METAL	60	60	100.00%	µg/L	--	--	7.9	6,390	992	10	WAC 173-201A	Yes
Iron	METAL	60	39	65.00%	µg/L	18	18	22	265	106	1,000	Clean Water Act -- Freshwater CCC	No
Lithium	METAL	47	42	89.36%	µg/L	4	4	4.3	133	21	32	WAC 173-340-720(4)(b)(iii)(A) and (B)	No
Manganese	METAL	60	3	5.00%	µg/L	3.3	4	5.5	47.0	4.0	384	WAC 173-340-720(4)(b)(iii)(A) and (B)	No
Selenium	METAL	60	56	93.33%	µg/L	0.6	0.6	0.38	6.5	4.4	5.0	Clean Water Act -- Freshwater CCC	No
Thallium	METAL	60	4	6.67%	µg/L	0.05	0.1	0.12	1.0	0.10	0.50	40 CFR 141 – Primary Federal MCLG	No
Zinc	METAL	60	18	30.00%	µg/L	5.2	6	6.4	260	34	91	WAC 173-201A	No
Strontium-90	RAD	60	3	5.00%	pCi/L	-14	2.4	2.3	3.7	0.67	8.0	40 CFR 141 - Primary Federal MCL	No
Carbon tetrachloride	VOC	60	2	3.33%	µg/L	0.063	1	2.6	2.7	1.0	0.63	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes
Chloroform	VOC	60	50	83.33%	µg/L	1	1	0.12	8.3	5.1	1.4	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes
Methylene chloride	VOC	60	6	10.00%	µg/L	0.11	1	0.16	0.27	1.0	5.0	40 CFR 141 – Primary Federal MCL	No

Table 6-37. Comparison of EPCs to Action Levels for the 100-H Source Exposure Area

Analyte Name	Analyte Class	Total Number of Samples	Number of Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	90th Percentile of RI Data	Action Level	Action Level Basis	90th Percentile > Action Level?
Nitrate	ANION	38	38	100.00%	µg/L	--	--	16,700	46,900	39,800	45,000	40 CFR 141 – Primary Federal MCL	No
Sulfate	ANION	39	39	100.00%	µg/L	--	--	38,000	88,700	79,700	250,000	40 CFR 141 - Secondary Federal MCL	No
Aluminum	METAL	39	13	33.33%	µg/L	10	10	6.1	188	41	87	Clean Water Act -- Freshwater CCC	No
Arsenic	METAL	39	39	100.00%	µg/L	--	--	1.4	3.7	3.3	0.058	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes
Chromium	METAL	39	39	100.00%	µg/L	--	--	7.3	39	31	65	Clean Water Act -- Freshwater CCC	No
Cr(VI)	METAL	39	34	87.18%	µg/L	2.0	2.0	2.6	29	26	10	WAC 173-201A	Yes
Iron	METAL	39	29	74.36%	µg/L	18	18	17	7,840	444	1,000	Clean Water Act -- Freshwater CCC	No
Lithium	METAL	32	27	84.38%	µg/L	4.0	4.0	4.4	23	14	32	WAC 173-340-720(4)(b)(iii)(A) and (B)	No
Manganese	METAL	39	8	20.51%	µg/L	4.0	4.0	12	120	35	384	WAC 173-340-720(4)(b)(iii)(A) and (B)	No
Mercury	METAL	39	1	2.56%	µg/L	0.050	0.10	0.11	0.11	0.10	0.012	40 CFR 131 -- Freshwater CCC	Yes
Selenium	METAL	39	38	97.44%	µg/L	0.60	0.60	0.83	3.2	2.7	5.0	Clean Water Act -- Freshwater CCC	No
Thallium	METAL	39	2	5.13%	µg/L	0.050	0.10	0.10	0.28	0.10	0.50	40 CFR 141 – Primary Federal MCLG	No
Zinc	METAL	39	9	23.08%	µg/L	6.0	6.0	2.8	30	16	91	WAC 173-201A	No
Strontium-90	RAD	39	12	30.77%	pCi/L	-7.8	2.6	3.2	27	14	8.0	40 CFR 141 - Primary Federal MCL	Yes
Carbon tetrachloride	VOC	39	2	5.13%	µg/L	0.063	1.0	0.088	2.0	1.0	0.63	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes
Chloroform	VOC	39	31	79.49%	µg/L	1.0	1.0	0.55	1.7	1.4	1.4	WAC 173-340-720(4)(b)(iii)(A) and (B)	No
Methylene chloride	VOC	39	5	12.82%	µg/L	0.11	1.0	0.13	11	1.0	5.0	40 CFR 141 – Primary Federal MCL	No

Table 6-38. Comparison of EPCs to Action Levels for the Horn Exposure Area

Analyte Name	Analyte Class	Total Number of Samples	Number of Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	90th Percentile of RI Data	Action Level	Action Level Basis	90th Percentile > Action Level?
Nitrate	ANION	57	57	100.00%	µg/L	--	--	7,880	33,900	29,550	45,000	40 CFR 141 - Primary Federal MCL	No
Sulfate	ANION	57	57	100.00%	µg/L	--	--	30,000	97,300	78,350	250,000	40 CFR 141 – Secondary Federal MCL	No
Aluminum	METAL	57	33	57.89%	µg/L	5	10	5.4	150	54	87	Clean Water Act -- Freshwater CCC	No
Arsenic	METAL	57	52	91.23%	µg/L	0.4	0.8	0.6	7.5	5.5	0.058	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes
Chromium	METAL	57	57	100.00%	µg/L	--	--	6	88	76	65	Clean Water Act -- Freshwater CCC	Yes
Cr(VI)	METAL	57	50	87.72%	µg/L	2	2	4	90	71	10	WAC 173-201A	Yes
Iron	METAL	57	42	73.68%	µg/L	18	18	18	2490	422	1,000	Clean Water Act -- Freshwater CCC	No
Lithium	METAL	43	33	76.74%	µg/L	4	4	3	16	12	32	WAC 173-340-720(4)(b)(iii)(A) and (B)	No
Manganese	METAL	57	13	22.81%	µg/L	4	4	1	122	11	384	WAC 173-340-720(4)(b)(iii)(A) and (B)	No
Selenium	METAL	57	56	98.25%	µg/L	0.6	0.6	0.9	7.1	3.2	5.0	Clean Water Act -- Freshwater CCC	No
Zinc	METAL	57	9	15.79%	µg/L	1	6	6	46	12	91	WAC 173-201A	No
Strontium-90	RAD	57	4	7.02%	pCi/L	-9.70	1.00	2.20	4.20	0.90	8.0	40 CFR 141 - Primary Federal MCL	No
1,2-Dichloroethane	VOC	57	1	1.75%	µg/L	0.1	1.0	0.7	0.7	1.0	0.48	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes
Carbon tetrachloride	VOC	57	10	17.54%	µg/L	0.1	1.0	0.2	1.7	1.3	0.63	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes
Chloroform	VOC	57	32	56.14%	µg/L	0.1	1.0	0.2	1.0	1.0	1.4	WAC 173-340-720(4)(b)(iii)(A) and (B)	No
Methylene chloride	VOC	57	7	12.28%	µg/L	0.1	1.0	0.1	0.6	1.0	5.0	40 CFR 141 - Primary Federal MCL	No

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Iron was detected in groundwater samples collected for the RI and the EPC is less than the AWQC of 1,000 µg/L. There were no detections of iron reported above theAWQC in groundwater samples collected for the RI and the larger population of wells from the 100-D groundwater area sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. However, iron concentrations above the AWQC were measured in three wells at the 100-D ISRM area; elevated concentrations are associated with the reducing conditions created by the presence of zero valence iron at the 100-D ISRM area. Although all monitoring wells within the groundwater OU were compared to the AWQC of 1,000 µg/L, these concentrations would need to be measured as close as practicable to the groundwater/surface water interface or biologically active zone. Wells located inland would need to meet the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level of 11,200 µg/L. Except for three wells within the 100-D ISRM, all iron concentrations are less than the AWQC of 1,000 µg/L. In addition, iron concentrations in unfiltered and filtered water samples are less than the background level of 760 µg/L. Based on these results, iron is retained as a COPC for further monitoring at the 100-D ISRM area.

Lithium was detected in groundwater samples collected for the RI and the EPC is less than the action level. Detections of lithium above the action level were reported in groundwater samples collected for the RI. Lithium was not analyzed in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. A single detection of lithium (133 µg/L) was measured at well 199-D8-71 at a concentration greater than the action level of 32 µg/L. However, lithium concentrations at this well were less than the action level in the previous and subsequent sampling rounds. The single detection of lithium at 199-D8-71 does not appear to be associated with a trend. Based on these results, lithium is not retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

Manganese was detected in groundwater samples collected for the RI and the EPC is less than the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level of 384 µg/L. There were no detections of manganese reported above the action level in groundwater samples collected for the RI and the larger population of wells from the 100-D groundwater area sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. However, manganese concentrations above the action level were measured in three wells at the 100-D ISRM area; elevated concentrations are associated with the reducing conditions created by the presence of zero valence iron at the 100-D ISRM area. Based on these results, manganese is retained as a COPC for further monitoring at the 100-D ISRM area.

Methylene chloride was detected in groundwater samples collected for the RI and the EPC is less than the DWS. Methylene chloride was not analyzed in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. All detections of methylene chloride were less than the DWS of 5.0 µg/L. Based on these results, methylene chloride is not retained as a COPC and will not be carried forward into the risk characterization section.

Selenium was detected in groundwater samples collected for the RI and the EPC is less than the AWQC. Selenium concentrations above the AWQC of 5 µg/L were measured in four RI wells and in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Although all monitoring wells within the groundwater OU were compared to the AWQC of 5 µg/L, these concentrations would need to be measured as close as practicable to the groundwater/surface water interface or biologically active zone. Wells located inland would need to meet theDWS of 50 µg/L. Additionally, all selenium concentrations in filtered and unfiltered groundwater samples are less than or equal to the 90th percentile Hanford Site background level of 11 µg/L. Therefore, selenium is not retained a COPC and will not be carried forward into the risk characterization section or the FS.

Strontium-90 was detected in groundwater samples collected for the RI and the EPC is less than the action level. With the exception of a single result reported at Well 199-D5-132, all strontium-90 concentrations in RI samples and the larger population of wells were less than the DWS of 8 pCi/L. Strontium-90 was reported at a concentration of 45 pCi/L at Well 199-D5-32, this is the only result reported at this well during the specified time period because it was installed during the RI to fill data gap 2 and data gap 5. Additionally, Well 199-D5-12, located south of the 116-D-1A liquid waste stream, historically reported strontium-90 concentrations above the DWS (with concentrations up to 52.6 pCi/L) until it was decommissioned in 2002. Based on these results, strontium-90 is retained as a COPC and will be carried forward into the FS for further evaluation.

Sulfate was detected in groundwater samples collected for the RI and the EPC is less than the secondary DWS. Sulfate concentrations above the secondary DWS were measured in two RI wells and in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Sulfate concentrations are associated with a trend at Wells 199-D4-23, 199-D4-84, 199-D4-13, and 199-D4-19 where concentrations are above the secondary MCL (note these wells are associated with the ISRM at 100-D). In addition to the four wells listed above, sulfate concentrations in five additional wells from the ISRM at 100-D are above the secondary DWS. The presence of sulfate in these nine wells is associated with sodium dithionite, which is used for the ISRM barrier at the OU and is not the result of a Hanford Site release. Therefore, sulfate is retained as a COPC for further monitoring at the 100-D ISRM area.

Thallium was detected in groundwater samples collected for the RI and the EPC is less than theDWS goal. Thallium was detected in four groundwater samples collected for the RI at concentrations above the action level. However, the analytical method cannot attain the action level for thallium; therefore, nondetected concentrations are reported at the EQL of 2 μg/L identified in the 100-D/H SAP (DOE/RL-2009-40). All MDLs are 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 these results, thallium is not retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

Zinc was detected in groundwater samples collected for the RI and the EPC is less than the state water quality standard (WAC 173-201A). Zinc concentrations above the state standard were measured in five RI wells and in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Although all monitoring wells within the groundwater OU were compared to the state water quality standard (WAC 173-201A) of 91 μg/L, these concentrations would need to be measured as close as practicable to the groundwater/surface water interface or biologically active zone. Wells located inland would need to meet the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level of 4,800 μg/L. All zinc results (detected concentrations and MDLs) are less than the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) groundwater cleanup level of 4,800 μg/L. Detections of zinc in filtered samples above the state standard were reported in the larger population of wells during 2006. It is likely that the presence of zinc in these samples is associated with a source of zinc that was introduced in the laboratory. Zinc is also associated with a trend at 199-D3-2, 199-D4-20, and 199-D4-84 (associated with the 100-D ISRM) where concentrations in filtered samples are above the state standard. Zinc concentrations above the state water quality standard were measured in three additional wells at the 100-D ISRM area. Elevated zinc concentrations are associated with the reducing conditions created by the presence of zero valence iron at the 100-D ISRM area. Therefore, zinc is retained as a COPC for further monitoring at the 100-D ISRM area.

100-H Source Exposure Area. Twelve of 17 analytes have been detected at least once in groundwater and have 90th percentile values less than their respective action level (Table 6-37).

Eight analytes (chloroform, chromium, manganese, nitrate, selenium, sulfate, thallium, and zinc) were identified as historical COPCs in the work plan. A discussion of all analytes with EPCs less than the action level is provided in the following paragraphs.

Aluminum was detected in groundwater samples collected for the RI and the EPC is less than the AWQC of 87 µg/L. Detections of aluminum above the AWQC were reported in groundwater samples collected for the RI. Aluminum was not analyzed in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Although all monitoring wells within the groundwater OU were compared to the AWQC of 87 µg/L, these concentrations would need to be measured as close as practicable to the groundwater/surface water interface or biologically active zone. Wells located inland would need to meet the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level of 16,000 µg/L. All groundwater results (detected concentrations and MDLs) are less than the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level of 16,000 µg/L. All filtered aluminum results (detected concentrations and MDLs) are less than the AWQC. Based on these results, aluminum is not retained as 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. The action level for chloroform is 1.4 µg/L based on the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level. However, the analytical method cannot attain the action level for chloroform; therefore, nondetected concentrations are reported at the EQL of 5 µg/L listed in the 100-D/H SAP (DOE/RL-2009-40). All chloroform results (detected concentrations and MDLs) for RI samples and the larger population of wells sampled over the past 7 years are less than the EQL. Therefore, chloroform is not retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

Chromium was detected in groundwater samples collected for the RI and the EPC is less than the AWQC of 65 µg/L. Detections of chromium above the AWQC were measured in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Although all monitoring wells within the groundwater OU were compared to the AWQC of 65 µg/L, these concentrations would need to be measured as close as practicable to the groundwater/surface water interface or biologically active zone. Wells located inland would need to meet the DWS of 100 µg/L. All chromium results (detected concentrations and MDLs) are less than the DWS. Except for chromium detected at 199-H3-5, chromium concentrations above the AWQC are not associated with a specific location or with a trend. Chromium concentrations above theAWQC are associated with a trend at 199-H3-5; however, Cr(VI) is collocated at this well with concentrations greater than the State water quality standard. The results of this evaluation indicate that chromium is locally present in groundwater at 199-H3-5; and, infrequent detections above theAWQC result in an uncertain status. Therefore, chromium is retained as a COPC and warrants further evaluation in the FS.

Zinc was detected in groundwater samples collected for the RI and the EPCs are less than the state water quality standard (WAC 173-201A). Detections of zinc above the standard were measured in RI samples and the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Although all monitoring wells within the groundwater OU were compared to the standard of 91 µg/L, these concentrations would need to be measured as close as practicable to the groundwater/surface water interface or biologically active zone. Wells located inland would need to meet the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level of 4,800 µg/L. All zinc results (detected concentrations and MDLs) were less than the 2007 MTCA groundwater cleanup level. All filtered zinc results (detected concentrations and MDLs) were less than the state water quality

standard. Therefore, zinc is not retained as a COPC and and will not be carried forward into the risk characterization section or into the FS.

Iron was detected in groundwater samples collected for the RI and the EPC is less than the AWQC of 1,000 µg/L. Detections of iron above the AWQC were reported in groundwater samples collected for the RI and the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Although all monitoring wells within the groundwater OU were compared to the AWQC of 1,000 µg/L, these concentrations would need to be measured as close as practicable to the groundwater/surface water interface or biologically active zone. Wells located inland would need to meet the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level of 11,200 µg/L. All iron results (detected concentrations and MDLs) are less than the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level of 11,200 µg/L. All filtered iron results (detected concentrations and MDLs) are less than the AWQC. Additionally, iron concentrations in filtered water samples are less than the background level of 570 µg/L. Based on these results, iron is not retained a COPC and will not be carried forward into the risk characterization section or into the FS.

Selenium and sulfate were detected in groundwater samples collected for the RI and their EPCs are less than the AWQCor secondary DWS, respectively. Detections of these analytes in RI samples and the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1 were measured at concentrations less than the AWQC or secondary DWS. In addition, selenium concentrations in filtered and unfiltered samples are less than the 90th percentile Hanford Site background level. Based on these results, selenium and sulfate are not retained as COPCs and will not be carried forward into the risk characterization section or into the FS.

Lithium was detected in groundwater samples collected for the RI and the EPC is less than the action level. Lithium was not analyzed in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. All detections of lithium are less than the action level of 32 µg/L. Based on these results, lithium is not retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

Manganese was detected in groundwater samples collected for the RI and the EPC is less than the action level. The action level for manganese is 384 µg/L based on the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level. Detections of manganese above the action level were reported in groundwater samples collected for the RI and the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Manganese concentrations reported in RI samples and the larger population of wells are less than 384 µg/L. Based on these results, manganese is not retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

Methylene chloride was detected in groundwater samples collected for the RI and the EPC is less than the DWS of 5 µg/L. Methylene chloride was not analyzed in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. All methylene chloride results (detected concentrations and MDLs) were less than the DWS of 5.0 µg/L. Based on these results, methylene chloride is not retained as 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 DWS goal of 0.5 µg/L. However, the analytical method cannot attain the action level for thallium; therefore, nondetected concentrations are report at the EQL of 2 µg/L identified in the 100-D/H SAP (DOE/RL-2009-40). Thallium concentrations detected in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1 were also less than the EQL. 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 these results, thallium is not retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

Nitrate was detected in groundwater samples collected for the RI and the EPC is less than the DWS. Detections of nitrate above the DWS were reported in the RI samples and the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Nitrate concentrations at or above the DWS were measured at 199-H4-3, 199-H4-46, and 199-H6-1. Concentrations range between 27,400 and 253,000 µg/L in these wells. Nitrate is retained as a COPC because it is associated with a trend and will be carried forward into the risk characterization section.

Horn Exposure Area. Eleven of 16 analytes have been detected at least once in groundwater and have 90th percentile values less than their respective action level (Table 6-38).

Seven analytes (chloroform, manganese, nitrate, selenium, strontium-90, sulfate, and zinc) were identified as historical COPCs in the work plan. A discussion of all analytes with EPCs less than action levels is provided in the following paragraphs.

Aluminum was detected in groundwater samples collected for the RI and the EPC is less than the AWQC of 87 µg/L. Detections of aluminum above the AWQC were reported in groundwater samples collected for the RI. Aluminum was not analyzed in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Although all monitoring wells within the groundwater OU were compared to the AWQC of 87 µg/L, these concentrations would need to be measured as close as practicable to the groundwater/surface water interface or biologically active zone. Wells located inland would need to meet the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level of 16,000 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 retained as 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. The action level for chloroform is 1.4 µg/L based on the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level. However, the analytical method cannot attain the action level for chloroform; therefore, nondetected concentrations are report at the EQL of 5 µg/L reported in the 100-D/H SAP (DOE/RL-2009-40). All chloroform results (detected concentrations and MDLs) are less than the EQL for the RI samples and in the larger population of wells. Therefore, chloroform is not retained a COPC and will not be carried forward into the risk characterization or into the FS.

Nitrate, sulfate, and strontium-90 were detected in groundwater samples collected for the RI and their EPCs are less than the DWS or secondary DWS. Detections of these analytes were not reported above their action levels in RI samples or the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Based on these results, nitrate, strontium-90, and sulfate are not retained as COPCs and will not be carried forward into the risk characterization section or into the FS.

Iron was detected in groundwater samples collected for the RI and the EPC is less than the AWQC of 1,000 µg/L. Detections of iron above the AWQC were reported in groundwater samples collected for the RI and the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Although all monitoring wells within the groundwater OU were compared to the AWQC of 1,000 µg/L, these concentrations would need to be measured as close as practicable to the groundwater/surface water interface or biologically active zone. Wells located inland would need to meet the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level of 11,200 µg/L.

All iron results (detected concentrations and MDLs) are less than the 2007 MTCA groundwater cleanup value of 11,200 µg/L. Iron concentrations above the AWQC in filtered samples were measured at 699-90-45 (1,780 to 2,050 µg/L), this well is located approximately 3,700 m (12,100 ft) and would not discharge directly into the river. Based on these results, iron is not retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

Lithium was detected in groundwater samples collected for the RI and the EPC is less than the action level. Lithium was not analyzed in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. All detections of lithium are less than the action level of 32 µg/L. Based on these results, lithium is not retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

Manganese was detected in groundwater samples collected for the RI and the EPC is less than the action level of 384 µg/L. The action level for manganese is based on the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level. Detections of manganese were not reported above the action level in groundwater samples collected for the RI and the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Based on these results, manganese is not retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

Methylene chloride was detected in groundwater samples collected for the RI and the EPC is less than the DWS. Methylene chloride was not analyzed in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. All methylene chloride results (detected concentrations and MDLs) were less than theDWS of 5.0 µg/L. Based on these results, methylene chloride is not retained as a COPC and will not be carried forward into the risk characterization section.

Zinc was detected in groundwater samples collected for the RI and its EPCs is less than the state water quality standard (WAC 173-201A). Zinc wasdetected above the AWQC in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Although all monitoring wells within the groundwater OU were compared to the state standard of 91 µg/L, these concentrations would need to be measured as close as practicable to the groundwater/surface water interface or biologically active zone. Wells located inland would need to meet the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level of 4,800 µg/L. All zinc results (detected concentrations and MDLs) were less than the 2007 MTCA groundwater cleanup level. Zinc concentrations in filtered samples above the state water quality standard were reported at four wells (699-87-55, 699-97-43, 699-99-41, and 699-99-42B). Zinc concentrations above the state water quality standard were reported in one of seven sample rounds at 699-87-55 (364 µg/L); however, four previous and two subsequent rounds were less than the standard. Zinc concentrations in filtered samples above the state water quality standard were reported in one of three sample rounds at 699-97-43 (93 µg/L); however, one previous and one subsequent sample rounds were less than the standard. Zinc concentrations above the state water quality standard were reported in one of six sample rounds at 699-99-42B (306 µg/L); however, five previous sample rounds were reported as nondetected concentrations less than the action level. Zinc concentrations above the action level in these four wells are not associated with a trend. Therefore, zinc is not retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

Selenium was detected in groundwater samples collected for the RI and the EPC is less than the AWQC. Detections of selenium above the AWQC were measured in RI samples and in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. However, selenium concentrations in filtered and unfiltered samples are less than the 90th percentile Hanford Site

background level. Based on these results, selenium is not retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

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

The 90th percentile values are compared to the lowest available action level for protection of human health and aquatic receptors. Comparisons of EPCs to action levels for the 100-D Source, 100-H Source, and Horn exposure areas are provided in Tables 6-32, 6-33, and 6-34, respectively.

100-D Source Exposure Area. Six of the 16 analytes have been detected at least once in groundwater and have 90th percentile values greater than their respective action levels (Table 6-36). A discussion of all analytes reported with an EPC greater than the action level is provided in the following paragraphs.

Arsenic, carbon tetrachloride, chloroform, chromium, Cr(VI), and nitrate were identified as historical COPCs in the work plan and are also listed on Table 6-36 because EPCs are greater than their respective action levels.

Arsenic is detected in groundwater samples collected for the RI and the EPC is above the action level. Detections of arsenic above the action level have also been measured in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. 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 retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

Carbon tetrachloride was detected in groundwater samples collected for the RI and the EPC is greater than the action level. The action level for carbon tetrachloride is 0.63 µg/L based on the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level. However, the analytical method cannot attain the action level for carbon tetrachloride; therefore, nondetected concentrations are reported at the EQL of 1 µg/L identified in the 100-D/H SAP (DOE/RL-2009-40). Nonrecurring detections of carbon tetrachloride above the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level were measured at well 199-D2-6 and well 199-D5-18; subsequent measurements at both wells were nondetected concentrations less than or equal to the EQL as described below. Carbon tetrachloride was detected twice in 199-D2-6 with values of 1.7 µg/L on 8/2/2009 (transitional river stage) and 2.6 µg/L on 10/8/2010 (low river stage), both at concentrations greater than the action level. Well 199-D2-6 (see Figure 4-63 for well location) was sampled and analyzed for carbon tetrachloride during a subsequent transitional river stage (3-30-2010) for the spatial and temporal sampling (0.063 U) and again in May 2010 (0.12 U) both results were nondetected and reported below the action level. No other carbon tetrachloride results were reported for 199-D2-6 during a low river stage. Carbon tetrachloride was detected once in 199-D5-18 (2.7 µg/L) at a concentration greater than the action level. Carbon tetrachloride was analyzed in four subsequent sampling rounds at this well and reported as nondetected concentrations less than the action level or the EQL. All MDLs are less than or equal to the EQL listed in the 100-D/H SAP (DOE/RL-2009-40). The nonrecurring presence of carbon tetrachloride at well 199-D2-6 and 199-D5-18 is not associated with a trend. Therefore, carbon tetrachloride is not retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

Chloroform, chromium, Cr(VI), and nitrate were detected in groundwater samples collected for the RI. Their EPCs are greater than the action level. Concentrations of chloroform, chromium, Cr(VI), and nitrate are widely distributed and are consistently present at concentrations above the DWS (nitrate), AWQC (chromium), the state water quality standard (WAC 173-201A) (Cr(VI)), and the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level (chloroform). The distribution of these analytes within the groundwater OU are discussed in detail in Section 4.5.1. Based on the results of this

evaluation, chloroform, chromium, Cr(VI), and nitrate are retained as COPCs and are carried forward into the risk characterization section.

100-H Source Exposure Area. Five of the 17 analytes have been detected at least once in groundwater and have 90th percentile values greater than their respective action levels (Table 6-37). A discussion of all analytes reported with an EPC greater than the action level is provided in the following paragraphs.

Arsenic, carbon tetrachloride, Cr(VI), mercury, and strontium-90 were identified as historical COPCs in the work plan and are also listed on Table 6-37 because EPCs are greater than their respective action levels.

Arsenic is detected in groundwater samples collected for the RI and the EPC is above the action level. Detections of arsenic above the action level have also been measured in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. 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 retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

Carbon tetrachloride was detected in groundwater samples collected for the RI and the EPC is greater than the action level. The action level for carbon tetrachloride is 0.63 µg/L based on the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level. However, the analytical method cannot attain the action level for carbon tetrachloride; therefore, nondetected concentrations are reported at the EQL of 1 µg/L reported in the 100-D/H SAP (DOE/RL-2009-40). Detections of carbon tetrachloride above the EQL were measured in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Nonrecurring single detections of carbon tetrachloride above the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level were measured at well 199-H3-5, well 199-H4-10 and well 199-H4-11; previous and subsequent measurements at all wells were nondetected concentrations less than or equal to the EQL as described below. Carbon tetrachloride was detected once in 199-H4-10 (0.088 µg/L) at a concentration less than the EQL of 1 µg/L. Carbon tetrachloride was analyzed at 199-H4-10 in one previous and one subsequent sampling round and reported with nondetected concentrations less than or equal to the EQL. Carbon tetrachloride was detected once in 199-H4-11 (2 µg/L) at a concentration greater than the EQL of 1 µg/L. Carbon tetrachloride was analyzed in two subsequent sampling rounds at 199-H4-11 and reported at nondetected concentrations less than the EQL. Carbon tetrachloride was detected in well 199-H3-5 (1.2 µg/L) at a concentration greater than the EQL of 1 µg/L. Carbon tetrachloride was analyzed at 199-H3-5 in two previous and four subsequent sampling rounds and reported with nondetected concentrations less than or equal to the EQL. All MDLs are less than or equal to the EQL listed in the 100-D/H SAP (DOE/RL-2009-40). The nonrecurring presence of carbon tetrachloride in these three wells does not suggest it is associated with a trend. Therefore, carbon tetrachloride is not retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

Mercury was detected in groundwater samples collected for the RI and the EPC is above the action level. The action level for mercury is 0.012 µg/L based on the AWQC. However, the analytical method cannot attain the action level for mercury; therefore, nondetected concentrations are reported at the EQL of 0.05 µg/L identified in the 100-D/H SAP (DOE/RL-2009-40). Mercury was not measured at concentrations greater than the EQL of 0.05 µg/L in RI samples and in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Based on these results, mercury is not retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

Cr(VI) and strontium-90 were detected in groundwater samples collected for the RI and their EPCs are greater than the State water quality standard (WAC 173-201A) or the DWS, respectively. Concentrations

of Cr(VI) and strontium-90 are widely distributed and are consistently present at concentrations above the State water quality standard (Cr(VI)) or the DWS (strontium-90). The distribution of these analytes within the groundwater OU is discussed in detail in Section 4.5.1. Based on the results of this evaluation, Cr(VI) and strontium-90 are both retained as COPCs and are carried forward into the risk characterization section.

Horn Exposure Area. Five of the 16 analytes have been detected at least once in groundwater and have 90th percentile values greater than their respective action levels (Table 6-38). A discussion of all analytes reported with an EPC greater than the action level is provided in the paragraphs in the following text.

Arsenic, carbon tetrachloride, total chromium, and Cr(VI) were identified as historical COPCs in the work plan and are also listed on Table 6-38 because EPCs are greater than their respective action levels.

Arsenic is detected in groundwater samples collected for the RI and the EPC is above the action level. Detections of arsenic above the action level have also been measured in the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. 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 not retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

1,2-Dichloroethane was detected in groundwater samples collected for the RI and the EPC is greater than the action level. 1,2-Dichloroethane was not analyzed in the larger population of wells sampled over the past 6 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. The action level for 1,2-dichloroethane is 0.38 µg/L based on the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) groundwater cleanup level; however, it defaults to the EQL of 5 µg/L reported in DOE/RL-2009-40 when the analytical method cannot achieve the action level. Detections of 1,2-dichloroethane in RI samples are less than the EQL. Therefore, 1,2-dichloroethane is not retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

Carbon tetrachloride was detected in groundwater samples collected for the RI and the EPC is greater than the action level. The action level for carbon tetrachloride is 0.63 µg/L based on the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level. However, the analytical method cannot attain the action level for carbon tetrachloride; therefore, nondetected concentrations are reported at the EQL of 1 µg/L identified in the 100-D/H SAP (DOE/RL-2009-40). Detections of carbon tetrachloride greater than the EQL were measured in RI samples and the larger population of wells sampled over the past 7 years as described previously in Sections 4.4.1.2 and 6.3.2.3.1. Detections of carbon tetrachloride above the EQL were infrequent and were not associated with a specific location or with a trend, resulting in an uncertain status. Therefore, carbon tetrachloride is retained as a COPC for further monitoring.

Chromium and Cr(VI) were detected in groundwater samples collected for the RI and their EPCs are greater than the AWQC or the State water quality standard. Concentrations of chromium and Cr(VI) are widely distributed and are consistently present at concentrations above the AWQC and the state water quality standard (WAC 173-201A). The distribution of these analytes within the groundwater OU is discussed in detail in Section 4.5.1. Based on the results of this evaluation, chromium and Cr(VI) are retained as COPCs and are carried forward into the risk characterization section.

6.3.2.4 Summary of COPCs

Table 6-39 presents a summary of the COPCs identified for the 100-HR-3 Groundwater OU. This list of COPCs represents the analytes most likely to contribute to overall risk within each 100-HR-3 Groundwater OU exposure area.

Table 6-39. Summary of Groundwater COPCs Identified for the 100-HR-3 Groundwater OU

100-D Source Exposure Area		
Metals	**VOCs**	**Nonradioactive Anions**
Antimony[a]	Chloroform	Fluoride[c]
Cadmium[a]		Nitrate
Chromium		Nitrite[c]
Cobalt[a]		Sulfate[c]
Copper[a]		
Cr(VI)	**Radionuclides**	
Iron[c]	Strontium-90	
Lead[a,c]		
Manganese[c]		
Silver[a]		
Zinc[c]		
100-H Source Exposure Area		
Metals	**Radionuclides**	**Nonradioactive Anions**
Antimony[a]	Strontium-90	Nitrate[b]
Cadmium[a]		
Cobalt[a]		
Copper[a]		
Chromium[b]		
Cr(VI)		
Lead[a]		
Silver[a]		
Uranium[b]		
Horn Exposure Area		
Metals	**VOCs**	
Antimony[a]	Carbon tetrachloride[a]	
Cadmium[a]		
Chromium		
Cobalt[a]		
Copper[a]		
Cr(VI)		
Silver[a]		

a. Exposure Point Concentration (EPC) did not exceed action level, but infrequent detections above action level result in uncertain status and warrant further evaluation in the FS.

b. EPC did not exceed an action level but retained as a COPC due to localized contamination.

c. EPC did not exceed action level; elevated concentrations above action level associated with reducing conditions at the 100-D ISRM area.

Chromium, Cr(VI), chloroform, and strontium-90 were retained as COPCs because the 90th percentile concentration exceeded the action level. As described in Section 6.3.2.3, nitrate and strontium-90 in the 100-H Source exposure area are retained as COPCs becausethey are associated with a localized source of contamination. As described in Section 6.3.2.2.3, uranium is retained as a COPC because it is associated with a localized source of contamination.

The COPC identification process identified ten analytes for the 100-HR-3 Groundwater OU that were retained as COPCs for further monitoring. The occurrence of antimony, cadmium, carbon tetrachloride, cobalt, copper, lead, silver, and zinc in groundwater is uncertain because these analytes historically have been detected in groundwater at concentrations above their respective action level; however, their 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 EPCs for these analytes (except carbon tetrachloride in the Horn area) are less than their respective action level. Therefore, antimony, cadmium, carbon tetrachloride, cobalt, copper, lead, and silver are retained as COPCs where they warrant further monitoring. Fluoride, iron, manganese, nitrite, sulfate, and zinc were retained as COPCs for further monitoring at the 100-D ISRM area because they are associated with the reducing conditions from the presence of zero valence iron at the 100-D ISRM area.

In addition the COPC identification steps performed in this section and Section 4.4 of this report, a set of seven monitoring wells were identified for well-specific risk evaluation. The purpose of this well-specific evaluation is to confirm the COPCs identified in Sections 4.4 and 6.3.2 of this report are consistent with those that are identified in the select wells. The results of this well-specific evaluation are presented in Appendix G.

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

Contaminant sources (that is, facilities and waste sites) were previously discussed in Section 6.2.3.1 and are listed in Sections 4.2.1 and 5.2 of this report.

6.3.3.2 Release Mechanisms and Environmental Transport Media

The primary COPC release mechanisms and transport pathways evaluated at the 100-D/H Source OU 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-HR-3 Groundwater Operable Unit Exposure Areas

The 100-HR-3 Groundwater OU is generally distinguished by the presence of Cr(VI) plumes within the 100-D, 100-H, and the Horn area as discussed in detail in Chapter 4. The 100-D Source exposure area represents the northern and southern plume sources in the 100-D Area. The 100-H Source exposure area represents the plume sources within the 100-H Area. The Horn exposure area represents the portion of the plume that is located in the Horn area. The Horn exposure area is located downgradient from the 100-D sources where contaminant concentrations have migrated over time. The primary objectives for

evaluating each exposure area are to provide information necessary to determine the need for remedial action and to use this information to select the best remedy. These objectives are achieved by performing the following steps for each exposure area:

1. EPCs for each COPC are compared to action levels for understanding the potential for exposure to groundwater contaminants and the associated health risks.
2. Specific locations are identified within the exposure area for evaluating remedial alternatives in the FS.

The basis for each exposure area and the known or suspected sources are described in the following text. Exposure areas and the location of associated monitoring wells are shown on Figures 2-1 and 2-2. Table 6-30 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 action levels (see Section 6.3.2.2) evaluated in this groundwater risk assessment.

6.3.3.4.1 *Action Levels Used to Evaluate Protection of Human Health*

All of the action levels 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 action levels may result in an overestimation of the cleanup level; uncertainties associated with exclusion of this exposure route are addressed in Section 6.3.6.4.

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 2007 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 *Action Levels Used to Evaluate 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 action level 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 action levels takes into consideration the likelihood of an adverse health effect to occur to the potentially exposed population. The risk-based concentrations, such as the 2007 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 described in Section 6.2.2. The assignment of action levels 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* amendments in 1996, the MCL was set as close to the MCLG as was feasible. The 1996 Amendments to the SDWA permit 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.

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 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 Ra-226, but excluding uranium and

radon), and 5 pCi/L combined for Ra-226 and Ra-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 on 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 and in Water for Occupational Exposure* (NBS Handbook 69).

6.3.4.3 Washington State Regulations

Toxicological parameter values are obtained from the CLARC database (Ecology, 2010) compendium of technical information related to the calculation of cleanup levels under the 2007 MTCA (WAC 173-340). The sources for the oral cancer potency values and RfDs are provided in the CLARC database.
The sources for identifying RfD s and carcinogenic potency factors are defined in 2007 MTCA ("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 the 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 action level 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 it is decided 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, they are used to derive the acute criterion. If sufficient data on the ratio of acute to chronic toxicity concentrations are available, they 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 (for example, 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 estimate both carcinogenic and noncarcinogens risks quantitatively. The risk characterization step is completed through the comparison of the EPC to the action level using the equations presented in Section 6.3.5.1. As described earlier in this section, the comparison to action levels determines whether existing groundwater concentrations protect human health and the environment. It is also used to determine whether current groundwater concentrations have the potential to exceed an HI greater than 1 or the upper end of the NCP risk range for cumulative carcinogenic site risk to an individual based on RME for both current and future land use.

6.3.5.1 Protectiveness Evaluation

Human health protection is determined by the comparison of 90th percentile groundwater concentrations to existing federal or state MCLs. Similarly, aquatic receptor protection 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. This step is also included to address the requirements of

2007 MTCA (HHRA 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 risk range for cumulative carcinogenic site risk to an individual based on RME for both current and future land use, the following standards are used:

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

For the purposes of this evaluation, 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. 2007 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 might 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.

Human protection 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, the sum of fractions is used determine the annual dose from exposure to beta/photon emitters.

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 Hanford 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 (that is, its RfD). The ratio of the chronic daily intake divided by RfD is the HQ.

When the HQ for a chemical exceeds 1 (that is, 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 = 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 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 whether 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 = EPC activity concentration of specific beta/photon emitting nuclide A

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

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

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

The 4 mrem standard is not exceeded if the sum of fractions 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 Action Levels by Exposure Area

Action levels that are considered to protect human health and the environment were used to identify COPCs that warrant further evaluation in the FS. The lowest of the available action levels was selected for comparison if more than one action level exists for a certain analyte. The analytes listed in Tables 6-40, 6-41, and 6-42 are considered COPCs because the 90th percentile groundwater concentration is greater than the lowest available action level, or the analyte is measured at concentrations above the lowest action level in a localized area.

Table 6-40. Summary of Current Conditions 90th Percentile Groundwater Concentrations, Federal and State MCLs, and WAC 173-340-720 Groundwater Cleanup Levels for the 100-D Source Exposure Area (Human Health Action Levels)

COPCs	Units	90th Percentile Value	Federal MCL	State MCL	2007 MTCA, "Groundwater Cleanup Standards" (WAC 173-340-720) Cleanup Levels		
					Noncarcinogens	Carcinogens at 10^{-6} Risk Level	Carcinogens at 10^{-5} Risk Level
Chloroform	µg/L	5.1	80	--	80	1.4	14
Chromium	µg/L	925	100	100	24,000	--	--
Cr(VI)	µg/L	992	--	--	48	--	--
Nitrate	µg/L	69,500	45,000	45,000	113,600	--	--

Source: WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

Table 6-41. Summary of Current Conditions 90th Percentile Groundwater Concentrations, and Federal and State Water Quality Standards for the 100-D Source Exposure Area (Aquatic Action Levels)

COPCs	Units	90th Percentile Value	AWQC		WAC 173-201A	40 CFR 131 Water Quality Standards	
			Freshwater CMC (acute)	Freshwater CCC (chronic)	Freshwater CCC (chronic)	Freshwater CMC (acute)	Freshwater CCC (chronic)
Chloroform	µg/L	5.1	--	--	--	--	--
Chromium	µg/L	925	570	65	156	550	180
Cr(VI)	µg/L	992	16	11	10	15	10
Nitrate	µg/L	69,500	--	--	--	--	--

Sources:40 CFR 131, "Water Quality Standards."

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

Table 6-42. Summary of 90th Percentile Current Groundwater Concentrations and Associated Cancer Risk and Noncancer Hazard Index for the 100-D Source Exposure Area

COPC	Units	90th Percentile Value	2007 MTCA, "Groundwater Cleanup Standards (WAC 173-340-720) Cleanup Levels			
			Noncarcinogens	HQ	Carcinogens at 10^{-6} Risk Level	ELCR
Chloroform	µg/L	5.1	80	0.06	1.4	3.6×10^{-6}
Total ELCR					**--**	**3.6×10^{-6}**
Chromium	µg/L	925	24,000	0.04	--	--
Cr(VI)	µg/L	992	48	21	--	--
Nitrate	µg/L	69,500	113,600	0.61	--	--
Hazard Index				**21**		

Source: WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

6.3.6.1 100-D Source Exposure Area

Groundwater in the 100-D Source exposure area is evaluated as a potential drinking water source and nearshore groundwater has the potential to discharge to the Columbia River. Table 6-40 provides a summary of the COPCs, the 90th percentile groundwater concentration, federal and state MCLs, and the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) for carcinogenic and noncarcinogenic effects. Table 6-41 provides a summary of the COPCs, the 90th percentile groundwater concentration, and federal and state surface water quality standards. These standards (listed in Tables 6-40 and 6-41) represent the action levels that were exceeded by at least one COPC.

6.3.6.1.1 *Protectiveness Evaluation for Human Health*

This evaluation for human health is 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 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 chromium is greater than the federal and state MCL developed for the protection of human health. Chromium is identified as a COPC indicating the need to evaluate potential remedial technologies for chromium in the FS. Of the 20 monitoring wells in the 100-D Source exposure area, 11 monitoring wells were reported with concentrations of chromium above 100 µg/L. A detailed discussion of the chromium plume is also provided in Section 4.5.1.

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 and the risk evaluation.

The 90th percentile groundwater concentration for nitrate is greater than the federal and state MCL developed for the protection of human health. Nitrate is identified as a final COPC indicating the need to evaluate potential remedial technologies for nitrate in the FS. Of the 20 monitoring wells in the 100-D Source exposure area, nine monitoring wells were reported with concentrations of nitrate above 45,000 µg/L. A detailed discussion of the nitrate plume is provided in Section 4.5.2.

The 90th percentile groundwater concentration for chloroform is less than the federal and state MCL developed for the protection of human health. Chloroform is not an identified as a COPC indicating 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*

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 2007 MTCA ("Surface Water Cleanup Standards" [WAC 173-340-730(7)(a)]) as the point or points at which hazardous substances are released to surface waters of the state. 2007 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-HR-3 Groundwater OU are compared to determine whether groundwater concentrations discharging to the Columbia River are in compliance with federal and state standards.

The 90th percentile groundwater concentration for chromium is greater than the federal freshwater AWQC value of 65 µg/L. Chromium is identified as a COPC, indicating the need to evaluate potential remedial technologies for chromium in the FS. Of the 20 monitoring wells, 13 monitoring wells were reported with concentrations of chromium above the freshwater AWQC value of 65 µg/L. It is assumed that a portion of the dissolved concentrations of total chromium are present in the form of Cr(VI) and total chromium is not presented separately from Cr(VI) in the nature and extent evaluation and the FS.

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 20 monitoring wells, 19 monitoring wells were reported with concentrations of chromium above the "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A) freshwater AWQC value of 10 µg/L. Cr(VI) concentrations above the AWQC were also measured in 25 additional wells, based on the results from the larger population of wells and longer

sampling timeframe. The following lists the approximate distance from the Columbia River for those wells reporting concentrations greater than 10 µg/L.

199-D2-11 (1,134 m [3,720 ft])	199-D5-13 (602 m [1,975 ft])	199-D5-93 (624 m [2,047 ft])
199-D2-6 (832 m [2,730 ft])	199-D5-132 (1,269 m [4,163 ft])	199-D5-97 (647 m [2,123 ft])
199-D2-8 (1,008 m [3,307 ft])	199-D5-14 (983 m [3,070 ft])	199-D5-98 (769 m [2,523 ft])
199-D3-2 (241 m [790 ft])	199-D5-140 (950 m [3,117 ft])	199-D5-99 (659 m [2,162 ft])
199-D4-14 (212 m [696 ft])	199-D5-142 (1,219 m [3,999 ft])	199-D8-101 (470 m [1,542 ft])
199-D4-15 (488 m [1,601 ft])	199-D5-143 (889 m [2,917 ft])	199-D8-4 (224 m [735 ft])
199-D4-19 (250 m [820 ft])	199-D5-15 (1,035 m [3,396 ft])	199-D8-5 (143 m [469 ft])
199-D4-20 (500 m [1,640 ft])	199-D5-16 (1,235 m [4,052 ft])	199-D8-54A (174 m [571 ft])
199-D4-22 (247 m [810 ft])	199-D5-17 (1,368 m [4,488 ft])	199-D8-55 (106 m [348 ft])
199-D4-23 (81 m [266 ft])	199-D5-18 (1,510 m [4,954 ft])	199-D8-6 (251 m [823 ft])
199-D4-84 (120 m [394 ft])	199-D5-34 (670 m [2,198 ft])	199-D8-69 (93 m [305 ft])
199-D5-102 (1,045 m [3,428 ft])	199-D5-37 (161 m [528 ft])	199-D8-70 (188 m [617 ft])
199-D5-103 (1,028 m [3,373 ft])	199-D5-38 (294 m [964 ft])	199-D8-71 (185 m [607 ft])
199-D5-104 (811 m [2,661 ft])	199-D5-40 (537 m [1,762 ft])	199-D8-73 (136 m [446 ft])
199-D5-122 (921 m [3,022 ft])	199-D5-43 (649 m [2,129 ft])	199-D8-88 (106 m [348 ft])

Although all monitoring wells within the plume area were compared to the AWQC concentration, these concentrations would need to be measured as close as practicable to the groundwater/surface water interface or biologically active zone. Section 4.5.1 provides a detailed discussion of the Cr(VI) plume.

Federal and state water quality standards for the protection of freshwater organisms are not published for chloroform or nitrate; therefore, an evaluation for them is not included. Chloroform and nitrate are evaluated in the evaluation for human health in Section 6.3.6.1.1 and the risk evaluation is presented in Section 6.3.6.1.3.

6.3.6.1.3 *Risk Evaluation*

The potential cumulative ELCR for the 100-D Source exposure area from all nonradiological carcinogenic COPCs is 3.6×10^{-6}, which is less than the 2007 MTCA (HHRA Procedures [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 6-42 shows the only contributor to risk is chloroform (3.6×10^{-6}, 100 percent contribution). Chloroform is not identified as a COPC based on the results of this evaluation. As discussed previously, the nature and extent evaluation of groundwater presented in Section 4.5 also supports the conclusion of this analysis. Over the past 7 years, chloroform has been associated with a trend in 12 wells (199-D8-88, 199-D2-6, 199-D2-11, 199-D4-84, 199-D5-13, 199-D5-14, 199-D5-15, 199-D5-16, 199-D5-37, 199-D5-38, 199-D5-99, and 199-D8-5) where concentrations have ranged between 1.1 to 5.9 times greater than the action level of 1.4 µg/L. However, there have been no measured concentrations above the 10^{-5} level of 14 µg/L.

The HI for the 100-D Source exposure area is 21, which is greater than the EPA and 2007 MTCA (WAC 173-340) target HI of 1. The primary contributor to the noncancer HI is Cr(VI) (HQ=21,

97 percent contribution). The individual HQs for chloroform, chromium, and nitrate are each less than 1. The primary noncancer health effects associated with exposure to Cr(VI) is nasal septum atrophy. Cr(VI) is identified as a COPC based on the results of this evaluation. Chromium, nitrate, and zinc are not identified as COPCs based on the results of this evaluation.

6.3.6.2 100-H Source Exposure Area

Groundwater in the 100-H Source exposure area is evaluated as a potential drinking water source and nearshore groundwater has the potential to discharge to the Columbia River. Table 6-43 provides a summary of the COPCs, the 90th percentile groundwater concentration, federal and state MCLs, and the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) for carcinogenic and noncarcinogenic effects. Table 6-44 provides a summary of the COPCs, the 90th percentile groundwater concentration, and federal and state water quality standards. These standards (listed in Tables 6-43 and 6-44) represent the action levels that were exceeded by at least one COPC.

Table 6-43. Summary of Current Conditions 90th Percentile Groundwater Concentrations, Federal and State MCLs, and WAC 173-340-720 Groundwater Cleanup Levels for the 100-H Source Exposure Area (Human Health Action Levels)

COPCs	Units	90th Percentile Value	Federal MCL	State MCL	2007 MTCA, "Groundwater Cleanup Standards" (WAC 173-340-720) Cleanup Levels		
					Noncarcinogens	Carcinogens at 10^{-6} Risk Level	Carcinogens at 10^{-5} Risk Level
Strontium-90	pCi/L	14	8	--	--	--	--
Cr(VI)	µg/L	26	--	--	48	--	--
Nitrate	µg/L	39,800	45,000	45,000	113,600	--	--

Source: WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

Table 6-44. Summary of Current Conditions 90th Percentile Groundwater Concentrations, and Federal and State Water Quality Standards for the 100-H Source Area (Aquatic Action Levels)

COPCs	Units	90th Percentile Value	AWQC		WAC 173-201A	40 CFR 131 Water Quality Standards	
			Freshwater CMC (acute)	Freshwater CCC (chronic)	Freshwater CCC (chronic)	Freshwater CMC (acute)	Freshwater CCC (chronic)
Strontium-90	pCi/L	14	--	--	--	--	--
Cr(VI)	µg/L	26	16	11	10	15	10
Nitrate	µg/L	39,800	--	--	--	--	--

Sources: 40 CFR 131, "Water Quality Standards,"

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

6.3.6.2.1 *Protectiveness Evaluation for Human Health*

The 90th percentile groundwater concentration for strontium-90 is greater than the federal MCL developed for the protection of human health. As Table 6-45 shows, potential exposure to groundwater as a drinking water source would result in a dose greater than 4 mrem per year from strontium-90. Of the 13 wells, three monitoring wells (199-H4-11, 199-H4-13, and 199-H4-45) were reported with strontium-90 concentrations greater than the MCL of 8 pCi/L. Strontium-90 is identified as a COPC, indicating the need to evaluate potential remedial technologies for strontium-90 in the FS. A detailed discussion of the strontium-90 plume is provided in Section 4.5.

Table 6-45. Summary of 90th Percentile Current Groundwater Concentrations and Associated Sum of Fractions for the 100-H Source Exposure Area

Final COPC	Units	90th Percentile Value	Federal MCL	Individual Fraction
Strontium-90	pCi/L	14	8	1.8
Sum of Fractions				**1.8**
Cumulative Annual Dose (mrem)				**7.0**

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

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

The 90th percentile groundwater concentration for nitrate is less than the federal and state MCL developed for the protection of human health. Nitrate has only been detected in Wells 199-H4-3, 199-H4-46, and 199-H6-1 at concentrations above the MCL, indicating its presence is localized downgradient of the following sources: 105-H reactor or the 1607-H1 septic system (199-H4-46), the solar evaporation basin (199-H4-3) and the 116-H-1 trench (199-H6-1). Although the 90th percentile groundwater concentration is less than the federal MCL, nitrate is identified as a COPC and it warrants further evaluation in the FS. A detailed discussion of the nitrate plume is provided in Section 4.5.2.

6.3.6.2.2 *Protectiveness Evaluation for Aquatic Receptors*

Federal and state water quality standards for the protection of freshwater organisms are not published for strontium-90 or nitrate; therefore, an evaluation is not included. Strontium-90 is evaluated for human health in Section 6.3.6.2.1. Nitrate is for human health in Section 6.3.6.2.1 and the risk evaluation is 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. Of the 13 monitoring wells, 10 monitoring wells were reported with concentrations of Cr(VI) above 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. Cr(VI) concentrations above the AWQC were also measured in 15 additional wells, based on the results from the larger population of wells and longer sampling timeframe. The following lists the approximate distance from the Columbia River for those wells reporting concentrations greater than 10 µg/L.

199-H1-7 (256 m [840 ft])
199-H3-2A (482 m [1,581 ft])
199-H3-2C (472 m [1,549 ft])
199-H3-3 (746 m [2,447 ft])
199-H3-4 (792 m [2,598 ft])
199-H3-5 (868 m [2,848 ft])
199-H4-10 (54 m [177 ft])
199-H4-11 (55 m [180 ft])
199-H4-13 (55 m [180 ft])
199-H4-14 (332 m [1,089 ft])
199-H4-18 (150 m [492 ft])
199-H4-3 (162 m [531 ft])
199-H4-4 (62 m [203 ft])
199-H4-45 (205 m [673 ft])
199-H4-46 (422 m [1,384 ft])
199-H4-48 (413 m [1,355 ft])
199-H4-49 (566 m [1,857 ft])
199-H4-5 (107 m [351 ft])
199-H4-6 (415 m [1,361 ft])
199-H4-65 (152 m [499 ft])
199-H4-84 (200 m [656 ft])
199-H4-9 (152 m [499 ft])
199-H5-1A (717 m [2,352 ft])
199-H6-1 (295 m [968 ft])
199-H6-2 (575 m [1,886 ft])

Although all monitoring wells within the plume area were compared to the AWQC concentration, these concentrations would need to be measured as close as practicable to the groundwater/surface water interface or biologically active zone. A discussion of the Cr(VI) plume is presented in Section 4.5.

6.3.6.2.3 *Risk Evaluation*

No carcinogenic COPCs were identified in the 100-H Source exposure area.

Table 6-46 shows the HI for the 100-H Source exposure area is 0.89, which is less than the EPA and 2007 MTCA (WAC 173-340) target HI of 1. The individual HQs for Cr(VI) and nitrate are less than one. Cr(VI) and nitrate are not identified as COPCs based on the results of this evaluation.

Table 6-46. Summary of 90th Percentile Current Groundwater Concentrations and Associated Cancer Risk and Noncancer Hazard Index for the 100-H Source Exposure Area

COPC	Units	90th Percentile Value	2007 MTCA, "Groundwater Cleanup Standards" (WAC 173-340-720) Cleanup Levels			
			Noncarcinogens	HQ	Carcinogens at 10^{-6} Risk Level	ELCR
Cr(VI)	µg/L	26	48	0.54	--	--
Nitrate	µg/L	39,800	113,600	0.35	--	--
Hazard Index				**0.89**		

Source: WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

6.3.6.3 *Horn Exposure Area*

Groundwater in the Horn exposure area is evaluated as a potential drinking water source and nearshore groundwater has the potential to discharge to the Columbia River. Table 6-47 provides a summary of the COPCs, the 90th percentile groundwater concentration, federal and state MCLs, national recommended water quality criteria (human health water + organism), and 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) for carcinogenic and noncarcinogenic effects. Table 6-48 provides a summary of the COPCs, the 90th percentile groundwater concentration, and federal and state water quality standards. These standards (listed in Tables 6-47 and 6-48) represent the action levels that were exceeded by at least one COPC.

Table 6-47. Summary of Current Conditions 90th Percentile Groundwater Concentrations, and Federal and State MCLs, and WAC 173-340-720 Groundwater Cleanup Levels for the Horn Exposure Area

COPCs	Units	90th Percentile Value	Federal and State MCL	Human Health Water + Organism	2007 MTCA, "Groundwater Cleanup Standards" (WAC 173-340-720) Cleanup Levels		
					Noncarcinogens	Carcinogens at 10^{-6} Risk Level	Carcinogens at 10^{-5} Risk Level
Chromium	µg/L	76	100	--	24,000	--	--
Cr(VI)	µg/L	71	--	--	48	--	--

Source: WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

Table 6-48. Summary of Current Conditions 90th Percentile Groundwater Concentrations, and Federal and State Water Quality Standards for the Horn Exposure Area (Aquatic Action Levels)

COPCs	Units	90th Percentile Value	AWQC		WAC 173-201A	40 CFR 131 Water Quality Standards	
			Freshwater CMC (acute)	Freshwater CCC (chronic)	Freshwater CCC (chronic)	Freshwater CMC (acute)	Freshwater CCC (chronic)
Chromium	µg/L	76	570	65	156	550	180
Cr(VI)	µg/L	71	16	11	10	15	10

Sources: 40 CFR 131, "Water Quality Standards."

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

6.3.6.3.1 *Protectiveness Evaluation for Human Health*

The 90th percentile groundwater concentration for chromium is less than the federal and state MCL developed for the protection of human health. Chromium 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. A detailed discussion of the chromium plume is provided in Section 4.5.

A federal MCL is not available for Cr(VI); therefore, the evaluation was not performed. Cr(IV) is discussed in the evaluation for aquatic organisms presented in Section 6.3.6.3.1 and the risk evaluation presented in Section 6.3.6.3.3.

6.3.6.3.2 *Protectiveness Evaluation for Aquatic Receptors*

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. Of the 19 monitoring wells, 16 monitoring wells were reported with concentrations of Cr(VI) above the "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A) freshwater AWQC value of 10 µg/L. Cr(IV) is identified as a COPC, indicating the need to evaluate potential remedial technologies for Cr(VI) in the FS. Cr(VI) concentrations above the AWQC were also measured in eight additional wells, based on the results from the larger population of wells and longer sampling timeframe. The following lists the approximate distance from the Columbia River for those wells reporting concentrations greater than 10 µg/L.

699-100-43B (22 m [72 ft])

699-101-45 (232 m [761 ft])

699-95-51 (595 m [1,952 ft])

699-96-43 (1,171 m [3,842 ft])

699-97-48B (1,217 m [3,993 ft])

699-97-51A (437 m [1,430 ft])

699-87-55 (1,384 m [4,541 ft])	699-96-49 (891 m [2,923 ft])	699-98-43 (461 m [1,512 ft])
699-93-48A (1,553 m [5,095 ft])	699-96-52B (54 m [177 ft])	699-98-46 (1,046 m [3,432 ft])
699-94-41 (1,170 m [3,839 ft])	699-97-41 (522 m [1,713 ft])	699-98-51 (230 m [754 ft])
699-94-43 (1,645 m [5,397 ft])	699-97-43 (796 m [2,611 ft])	699-99-41 (51 m [167 ft])
699-95-45 (1,469 m [4,819 ft])	699-97-43B (792 m [2,598 ft])	699-99-42B (59 m [194 ft])
699-95-48 (1,430 m [4,692 ft])	699-97-45 (1,228 m [4,029 ft])	699-99-44 (488 m [1,601 ft])

Although all monitoring wells within the plume area were compared to the AWQC concentration, these concentrations would need to be measured as close as practicable to the groundwater/surface water interface or biologically active zone. Section 4.5.1 provides a detailed discussion of the distribution of Cr(VI) in the 100-HR-3 Groundwater OU.

6.3.6.3.3 *Risk Evaluation*

No carcinogenic COPCs were identified in the Horn exposure area.

Table 6-49 shows the HI for the Horn exposure area is 1.7, which is greater than the EPA and 2007 MTCA (WAC 173-340) target HI of 1. The primary contributor to the noncancer HI is Cr(VI) (HQ=1.5; 88 percent contribution). The individual HQ for chromium is less than 1. The primary noncancer health effects associated with exposure to Cr(VI) is nasal septum atrophy. Cr(VI) is identified as a COPC based on the results of this evaluation. Chromium is not identified as COPC based on the results of this evaluation.

Table 6-49. Summary of 90th Percentile Current Groundwater Concentrations and Associated Cancer Risk and Noncancer Hazard Index for the Horn Exposure Area

COPC	Units	90th Percentile Value	2007 MTCA, "Groundwater Cleanup Standards" (WAC 173-340-720) Cleanup Levels			
			Non Carcinogens	HQ	Carcinogens at 10^{-6} Risk Level	ELCR
Chromium	µg/L	76	24,000	<0.01	--	--
Cr(VI)	µg/L	71	48	1.5	--	--
Hazard Index				**1.7**		

Source: WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

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 Regional Screening Levels (EPA, 2013a), the EPA Tap Water scenario reflects a RME scenario. The EPA Tap Water scenario is consistent with a residential exposure scenario because it incorporates default residential exposure assumptions. The results of the *Tap Water Risk Assessment for the 100-HR-3 Groundwater Operable Unit* (ECF-100HR3-10-0478) (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 and include 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 (risk assessment guide [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-HR-3 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 6-50 provides a summary of the risk estimates by exposure route for each exposure area evaluated. As discussed earlier in Section 6.3.2 and shown in Figure 6-10, all analytes which have reported concentrations and have available toxicity values are included in the calculation of cancer risks and noncancer hazards for the for the RI data set (see Section 4.2 of ECF-100HR3-10-0478, Appendix G). Tables 6-51 and 6-52 show the details of contribution to risk and hazard, respectively, by contaminant for the 100-D Source exposure area, Tables 6-53 and 6-54 for the 100-H Source exposure area, and Tables 6-55 and 6-56 for the Horn exposure area. The results in Tables 6-51 through 6-56 provide overall summaries of the EPA Tap Water scenario analysis for all detected analytes identified in Section 6.3.2.4.

Table 6-50. Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source Using EPA Tap Water Equations

Exposure Route	100-D Source Exposure Area		100-H Source Exposure Area		Horn Exposure Area	
	ELCR	HI	ELCR	HI	ELCR	HI
Nonradionuclide Analytes						
Ingestion	7.1×10^{-5}	10	7.7×10^{-5}	1.5	1.4×10^{-4}	2.0
Dermal	5.7×10^{-6}	3.8	9.1×10^{-7}	0.12	6.3×10^{-6}	0.30
Inhalation	8.7×10^{-7}	<0.01	2.4×10^{-7}	<0.01	5.0×10^{-7}	<0.01
Total	**7.7×10^{-5}**	**14**	**7.8×10^{-5}**	**1.6**	**1.4×10^{-4}**	**2.3**
Radionuclide Analytes						
Ingestion	1.0×10^{-5}	--	1.9×10^{-5}	--	5.2×10^{-6}	--
Inhalation	1.3×10^{-6}	--	5.7×10^{-7}	--	6.4×10^{-7}	--
Total	**1.1×10^{-5}**	**--**	**2.0×10^{-5}**	**--**	**5.9×10^{-6}**	**--**
Total ELCR*	**8.8×10^{-5}**	**--**	**9.8×10^{-5}**	**--**	**1.5×10^{-4}**	**--**

* Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.
-- = Indicates HI not applicable

Table 6-51. 100-D Source 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	0.0010	Yes	--	--	--	--	--
Aluminum	0.024	--	--	--	--(b)	--	--
Arsenic	0.0026	--	5.72E-05	3.08E-07	--(b)	5.75E-05	65
Barium	0.10	--	--	--	--(b)	--	--
Beryllium	0.00010	--	--	--	--(b)	--	--
Boron	0.067	--	--	--	--(b)	--	--
Bromodichloromethane	0.0010	Yes	9.22E-07	7.27E-08	1.84E-07	1.18E-06	1.33
Cadmium	0.00020	--	--	--	--(b)	--	--
Carbon tetrachloride	0.0010	Yes	1.93E-06	4.99E-07	7.45E-08	2.51E-06	2.8
Chloroform	0.0051	Yes	2.35E-06	2.07E-07	5.82E-07	3.14E-06	3.6
Chromium	0.92	--	--	--	--(b)	--	--
Cobalt	0.0013	--	--	--	--(b)	--	--
Copper	0.00073	--	--	--	--(b)	--	--
Fluoride	0.12	--	--	--	--(b)	--	--
Cr(VI)	0.99	--	--	--	--(b)	--	--
Iron	0.11	--	--	--	--(b)	--	--
Lithium	0.021	--	--	--	--(b)	--	--
Manganese	0.0040	--	--	--	--(b)	--	--
Methylene chloride	0.0010	Yes	1.12E-07	4.04E-09	2.33E-09	1.18E-07	0.13
Molybdenum	0.0044	--	--	--	--(b)	--	--

Table 6-51. 100-D Source 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
Nickel	0.0095	--	--	--	--(b)	--	--
Nitrate	70	--	--	--	--(b)	--	--
Selenium	0.0044	--	--	--	--(b)	--	--
Silver	0.00020	--	--	--	--(b)	--	--
Strontium	0.63	--	--	--	--(b)	--	--
Tetrachloroethene	0.0010	Yes	8.03E-06	4.62E-06	2.93E-08	1.27E-05	14.3
Tin	0.039	--	--	--	--(b)	--	--
Uranium	0.0041	--	--	--	--(b)	--	--
Vanadium	0.026	--	--	--	--(b)	--	--
Zinc	0.034	--	--	--	--(b)	--	--
Strontium-90	0.67	--	7.03E-07	--	--(b)	7.03E-07	0.79
Technetium-99	16	--	8.32E-07	--	--(b)	8.32E-07	0.94
Tritium	8,800	Yes	8.43E-06	--	1.29E-06	9.73E-06	11
Total Cumulative ELCR			8.05E-05	5.71E-06	2.17E-06	8.84E-05	100

a. Volatile contaminants as defined by EPA, 2013a, "Regional Screening Levels for Chemical Contaminants at Superfund Sites," or as defined by EPA 540-R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update*, "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 contribution greater than 1 percent to total cumulative risk.

Table 6-52. 100-D Source Exposure Area - Summary of Tap Water Scenario Noncancer Hazard Results for Nonradiological Analytes in Groundwater

Analyte Name	90th Percentile Concentration in Groundwater C_w (mg/L)	Volatile[a]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Acetone	0.0010	Yes	<0.01	--	<0.01	<0.01	0.00022
Aluminum	0.024	--	<0.01	<0.01	--(b)	<0.01	0.0047
Arsenic	0.0026	--	0.23	<0.01	--(b)	0.24	1.7
Barium	0.10	--	0.014	<0.01	--(b)	0.015	0.10
Beryllium	0.00010	--	<0.01	<0.01	--(b)	<0.01	0.017
Boron	0.067	--	<0.01	<0.01	--(b)	<0.01	0.065
Bromodichloromethane	0.0010	Yes	<0.01	<0.01	--	<0.01	0.010
Cadmium	0.00020	--	0.011	<0.01	--(b)	0.012	0.085
Carbon tetrachloride	0.0010	Yes	0.039	0.011	<0.01	0.050	0.35
Chloroform	0.0051	Yes	0.014	<0.01	<0.01	0.016	0.11
Chromium	0.92	--	0.017	<0.01	--(b)	0.024	0.17
Cobalt	0.0013	--	0.12	<0.01	--(b)	0.12	0.85
Copper	0.00073	--	<0.01	<0.01	--(b)	<0.01	0.0035
Fluoride	0.12	--	0.053	<0.01	--(b)	0.053	0.37
Cr(VI)	0.99	--	9.1	3.8	--(b)	13	90
Iron	0.11	--	<0.01	<0.01	--(b)	<0.01	0.029
Lithium	0.021	--	0.28	<0.01	--(b)	0.29	2.0
Manganese	0.0040	--	<0.01	<0.01	--(b)	<0.01	0.036
Methylene chloride	0.0010	Yes	<0.01	<0.01	<0.01	<0.01	0.003
Molybdenum	0.0044	--	0.024	<0.01	--(b)	0.024	0.17

Table 6-52. 100-D Source Exposure Area - Summary of Tap Water Scenario Noncancer Hazard Results for Nonradiological Analytes in Groundwater

Analyte Name	90th Percentile Concentration in Groundwater C_w (mg/L)	Volatile[a]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Nickel	0.0095	--	0.013	<0.01	--(b)	0.013	0.094
Nitrate	70	--	0.27	<0.01	--(b)	0.27	1.9
Selenium	0.0044	--	0.024	<0.01	--(b)	0.024	0.17
Silver	0.00020	--	<0.01	<0.01	--(b)	<0.01	0.0083
Strontium	0.63	--	0.029	<0.01	--(b)	0.029	0.20
Tetrachloroethene	0.0010	Yes	<0.01	<0.01	<0.01	<0.01	0.031
Tin	0.039	--	<0.01	<0.01	--(b)	<0.01	0.013
Uranium	0.0041	--	0.038	<0.01	--(b)	0.038	0.27
Vanadium	0.026	--	0.14	<0.01	--(b)	0.15	1.0
Zinc	0.034	--	<0.01	<0.01	--(b)	<0.01	0.022
Total HI			10.4	3.81	<0.01	14.2	100

a. Volatile contaminants as defined by EPA, 2013a, "Regional Screening Levels for Chemical Contaminants at Superfund Sites."

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

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

Shading identifies analytes with a contribution of greater than 1 percent to HI.

Table 6-53. 100-H Source 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
Aluminum	0.041	--	--	--	--(b)	--	--
Antimony	0.00061	--	--	--	--(b)	--	--
Arsenic	0.0033	--	7.41E-05	3.99E-07	--(b)	7.45E-05	76
Barium	0.067	--	--	--	--(b)	--	--
Boron	0.037	--	--	--	--(b)	--	--
Bromoform	0.0010	--	1.17E-07	7.89E-09	--(b)	1.25E-07	0.13
Bromomethane	0.0010	Yes	--	--	--	--	--
Carbon disulfide	0.0010	Yes	--	--	--	--	--
Carbon tetrachloride	0.0010	Yes	1.93E-06	4.99E-07	7.45E-08	2.51E-06	2.6
Chloroform	0.0014	Yes	6.45E-07	--	1.60E-07	8.05E-07	0.8
Chloromethane	0.0010	Yes	--	--	--	--	--
Chromium	0.031	--	--	--	--(b)	--	--
Cobalt	0.00043	--	--	--	--(b)	--	--
Copper	0.0013	--	--	--	--(b)	--	--
Fluoride	0.11	--	--	--	--(b)	--	--
Cr(VI)	0.026	--	--	--	--(b)	--	--
Iron	0.44	--	--	--	--(b)	--	--
Lithium	0.014	--	--	--	--(b)	--	--
Manganese	0.035	--	--	--	--(b)	--	--
Mercury	0.00010	--	--	--	--(b)	--	--

Table 6-53. 100-H Source 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
Methylene chloride	0.0010	Yes	1.12E-07	4.04E-09	2.33E-09	1.18E-07	0.12
Molybdenum	0.0054	--	--	--	--(b)	--	--
Nickel	0.0089	--	--	--	--(b)	--	--
Nitrate	40	--	--	--	--(b)	--	--
Nitrite	1.6	--	--	--	--(b)	--	--
Selenium	0.0027	--	--	--	--(b)	--	--
Strontium	0.39	--	--	--	--(b)	--	--
Tin	0.039	--	--	--	--(b)	--	--
Toluene	0.0010	Yes	--	--	--	--	--
Uranium	0.0061	--	--	--	--(b)	--	--
Vanadium	0.012	--	--	--	--(b)	--	--
Zinc	0.016	--	--	--	--(b)	--	--
Strontium-90	14	--	1.48E-05	--	--(b)	1.48E-05	15
Technetium-99	8.8	--	4.57E-07	--	--(b)	4.57E-07	0.47
Tritium	3,900	Yes	3.74E-06	--	5.73E-07	4.31E-06	4.4
Total Cumulative ELCR			9.59E-05	9.10E-07	8.10E-07	9.76E-05	100

a. Volatile contaminants as defined by EPA, 2013a, "Regional Screening Levels for Chemical Contaminants at Superfund Sites," or as defined by EPA 540-R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update*, "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 contribution greater than 1 percent to total cumulative risk.

Table 6-54. 100-H Source Exposure Area - Summary of Tap Water Scenario Noncancer Hazard Results for Nonradiological Analytes in Groundwater

Analyte Name	90th Percentile Concentration in Groundwater C_w (mg/L)	Volatile[a]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Aluminum	0.041	--	<0.01	<0.01	--(b)	<0.01	0.070
Antimony	0.00061	--	0.042	<0.01	--(b)	0.043	2.6
Arsenic	0.0033	--	0.30	<0.01	--(b)	0.31	19
Barium	0.067	--	<0.01	<0.01	--(b)	<0.01	0.60
Boron	0.037	--	<0.01	<0.01	--(b)	<0.01	0.31
Bromoform	0.0010	--	<0.01	<0.01	--(b)	<0.01	0.090
Bromomethane	0.0010	Yes	0.020	<0.01	<0.01	0.022	1.4
Carbon disulfide	0.0010	Yes	<0.01	<0.01	<0.01	<0.01	0.021
Carbon tetrachloride	0.0010	Yes	0.039	0.011	<0.01	0.050	3.0
Chloroform	0.0014	Yes	<0.01	<0.01	<0.01	<0.01	0.27
Chloromethane	0.0010	Yes	--	--	<0.01	<0.01	0.008
Chromium	0.031	--	<0.01	<0.01	--(b)	<0.01	0.048
Cobalt	0.00043	--	0.039	<0.01	--(b)	0.039	2.4
Copper	0.0013	--	<0.01	<0.01	--(b)	<0.01	0.053
Fluoride	0.11	--	0.048	<0.01	--(b)	0.049	3.0
Cr(VI)	0.026	--	0.23	0.097	--(b)	0.33	20
Iron	0.44	--	0.017	<0.01	--(b)	0.018	1.1
Lithium	0.014	--	0.20	<0.01	--(b)	0.20	12
Manganese	0.035	--	0.040	<0.01	--(b)	0.046	2.8
Mercury	1.00E-04	--	<0.01	<0.01	--(b)	<0.01	0.60
Methylene chloride	0.0010	Yes	<0.01	<0.01	<0.01	<0.01	0.030
Molybdenum	0.0054	--	0.029	<0.01	--(b)	0.030	1.8
Nickel	0.0089	--	0.012	<0.01	--(b)	0.013	0.77
Nitrate	40	--	0.15	<0.01	--(b)	0.16	9.5
Nitrite	1.6	--	0.14	<0.01	--(b)	0.14	8.8

Table 6-54. 100-H Source Exposure Area - Summary of Tap Water Scenario Noncancer Hazard Results for Nonradiological Analytes in Groundwater

Analyte Name	90th Percentile Concentration in Groundwater C_w (mg/L)	Volatile[a]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Selenium	0.0027	--	0.015	<0.01	--(b)	0.015	0.91
Strontium	0.39	--	0.018	<0.01	--(b)	0.018	1.1
Tin	0.039	--	<0.01	<0.01	--(b)	<0.01	0.11
Toluene	0.0010	Yes	<0.01	<0.01	<0.01	<0.01	0.028
Uranium	0.0061	--	0.055	<0.01	--(b)	0.056	3.4
Vanadium	0.012	--	0.067	<0.01	--(b)	0.067	4.1
Zinc	0.016	--	<0.01	<0.01	--(b)	<0.01	0.090
Total HI			1.51	0.12	<0.01	1.63	100

a. Volatile contaminants as defined by EPA, 2013a, "Regional Screening Levels for Chemical Contaminants at Superfund Sites."
b. Nonvolatile constituents are not considered in the inhalation exposure route.
-- = Indicates toxicity criteria not available to quantify contaminant's hazard via this exposure route.
Shading identifies analytes with a contribution of greater than 1 percent to HI.

Table 6-55. Horn 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
1,2-Dichloroethane	0.0010	Yes	1.35E-06	6.41E-08	1.29E-07	1.55E-06	1.0
2-Butanone	0.0010	Yes	--	--	--	--	--
Acetone	0.0010	Yes	--	--	--	--	--
Aluminum	0.054	--	--	--	--(b)	--	--
Antimony	0.00074	--	--	--	--(b)	--	--
Arsenic	0.0055	--	1.23E-04	6.61E-07	--(b)	1.23E-04	83

Table 6-55. Horn 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
Barium	0.067	--	--	--	--(b)	--	--
Boron	0.024	--	--	--	--(b)	--	--
Carbon tetrachloride	0.0013	Yes	2.51E-06	6.49E-07	9.68E-08	3.26E-06	2.2
Chloroform	0.0010	Yes	4.61E-07	4.05E-08	1.14E-07	6.16E-07	0.41
Chromium	0.076	--	--	--	--(b)	--	--
Cobalt	0.00010	--	--	--	--(b)	--	--
Copper	0.0014	--	--	--	--(b)	--	--
Fluoride	0.26	--	--	--	--(b)	--	--
Cr(VI)	0.071	--	--	--	--(b)	--	--
Iron	0.42	--	--	--	--(b)	--	--
Lithium	0.012	--	--	--	--(b)	--	--
Manganese	0.011	--	--	--	--(b)	--	--
Methylene chloride	0.0010	Yes	1.12E-07	4.04E-09	2.33E-09	1.18E-07	0.079
Molybdenum	0.0085	--	--	--	--(b)	--	--
Nickel	0.0049	--	--	--	--(b)	--	--
Nitrate	30	--	--	--	--(b)	--	--
Nitrite	0.12	--	--	--	--(b)	--	--
Selenium	0.0032	--	--	--	--(b)	--	--
Silver	0.00020	--	--	--	--(b)	--	--
Strontium	0.36	--	--	--	--(b)	--	--

Table 6-55. Horn 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
Tetrachloroethene	0.0010	Yes	8.03E-06	4.62E-06	2.93E-08	1.27E-05	8.5
Tin	0.039	--	--	--	--(b)	--	--
Toluene	0.0010	Yes	--	--	--	--	--
Trichloroethene	0.0010	Yes	1.32E-06	2.21E-07	1.24E-07	1.67E-06	1.1
Uranium	0.0042	--	--	--	--(b)	--	--
Vanadium	0.022	--	--	--	--(b)	--	--
Xylenes (total)	0.0010	Yes	--	--	--	--	--
Zinc	0.012	--	--	--	--(b)	--	--
Strontium-90	0.90	--	9.51E-07	--	--(b)	9.51E-07	0.64
Technetium-99	1.9	--	9.88E-08	--	--(b)	9.88E-08	0.066
Tritium	4,350	Yes	4.17E-06	--	6.39E-07	4.81E-06	3.2
Total Cumulative ELCR			1.42E-04	6.26E-06	1.14E-06	1.49E-04	100

Note: Shading identifies analytes with a contribution greater than 1 percent to total cumulative risk.

a. Volatile contaminants as defined by EPA, 2013a, "Regional Screening Levels for Chemical Contaminants at Superfund Sites," or as defined by EPA 540-R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update*, "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.

Table 6-56. Horn Exposure Area - Summary of Tap Water Scenario Noncancer Hazard Results for Nonradiological Analytes in Groundwater

Analyte Name	90th Percentile Concentration in Groundwater C_w (mg/L)	Volatile[a]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
1,2-Dichloroethane	0.0010	Yes	<0.01	<0.01	<0.01	<0.01	0.063
2-Butanone	0.0010	Yes	<0.01	<0.01	<0.01	<0.01	0.0021
Acetone	0.0010	Yes	<0.01	--	<0.01	<0.01	0.0014
Aluminum	0.054	--	<0.01	<0.01	--(b)	<0.01	0.066
Antimony	0.00074	--	0.050	<0.01	--(b)	0.052	2.3
Arsenic	0.0055	--	0.50	<0.01	--(b)	0.50	22
Barium	0.067	--	<0.01	<0.01	--(b)	<0.01	0.43
Boron	0.024	--	<0.01	<0.01	--(b)	<0.01	0.14
Carbon tetrachloride	0.0013	Yes	0.051	0.014	<0.01	0.065	2.8
Chloroform	0.0010	Yes	<0.01	<0.01	<0.01	<0.01	0.14
Chromium	0.076	--	<0.01	<0.01	--(b)	<0.01	0.086
Cobalt	0.00010	--	<0.01	<0.01	--(b)	<0.01	0.40
Copper	0.0014	--	<0.01	<0.01	--(b)	<0.01	0.042
Fluoride	0.26	--	0.12	<0.01	--(b)	0.12	5.3
Cr(VI)	0.071	--	0.65	0.27	--(b)	0.92	40
Iron	0.42	--	0.017	<0.01	--(b)	0.017	0.73
Lithium	0.012	--	0.17	<0.01	--(b)	0.17	7.4
Manganese	0.011	--	0.013	<0.01	--(b)	0.015	0.64
Methylene chloride	0.0010	Yes	<0.01	<0.01	<0.01	<0.01	0.02
Molybdenum	0.0085	--	0.046	<0.01	--(b)	0.047	2.0

Table 6-56. Horn Exposure Area - Summary of Tap Water Scenario Noncancer Hazard Results for Nonradiological Analytes in Groundwater

Analyte Name	90th Percentile Concentration in Groundwater C_w (mg/L)	Volatile[a]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Nickel	0.0049	--	<0.01	<0.01	--(b)	<0.01	0.30
Nitrate	30	--	0.11	<0.01	--(b)	0.12	5.0
Nitrite	0.12	--	0.011	<0.01	--(b)	0.011	0.48
Selenium	0.0032	--	0.018	<0.01	--(b)	0.018	0.78
Silver	0.00020	--	<0.01	<0.01	--(b)	<0.01	0.052
Strontium	0.36	--	0.016	<0.01	--(b)	0.017	0.72
Tetrachloroethene	0.0010	Yes	<0.01	<0.01	<0.01	<0.01	0.19
Tin	0.039	--	<0.01	<0.01	--(b)	<0.01	0.078
Toluene	0.0010	Yes	<0.01	<0.01	<0.01	<0.01	0.020
Trichloroethene	0.0010	Yes	--	--	<0.01	<0.01	0.015
Uranium	0.0042	--	0.039	<0.01	--(b)	0.039	1.7
Vanadium	0.022	--	0.12	<0.01	--(b)	0.12	5.4
Xylenes (total)	0.0010	Yes	<0.01	<0.01	<0.01	<0.01	0.015
Zinc	0.012	--	<0.01	<0.01	--(b)	<0.01	0.048
Total HI			1.98	0.30	<0.01	2.28	100

Note: Shading identifies analytes with a contribution of greater than 1 percent to HI.

a. Volatile contaminants as defined by EPA, 2013a, "Regional Screening Levels for Chemical Contaminants at Superfund Sites."

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

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

HI – hazard index

100-D Source Exposure Area. The total ELCR is 1.1×10^{-5} for nonradiological analytes and 1.2×10^{-4} for radiological analytes. The radiological ELCR and nonradiological ELCRs are within the EPA range of 1×10^{-4} to 1×10^{-6}.

As shown in Table 6-51, the major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are tetrachloroethene (1.3×10^{-5}; 14 percent contribution), tritium (9.7×10^{-6}; 11 percent contribution), chloroform (3.1×10^{-6}; 3.6 percent contribution), carbon tetrachloride (2.5×10^{-6}; 2.8 percent contribution), and bromodichloromethane (1.2×10^{-6}; 1.3 percent contribution). Contribution to ELCR is elevated for arsenic (5.8×10^{-5}; 65 percent contribution) where measured concentrations are within natural background values.

As shown in Table 6-52, the HI is 14, which is greater than the EPA target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is Cr(VI) (HQ of 13; 90 percent contribution). All remaining individual analytes (arsenic, lithium, nitrate, and vanadium) that contribute greater than one percent of the HI also report a HQ less than 1.

100-H Source Exposure Area. The total ELCR is 7.8×10^{-5} for nonradiological analytes and 2.0×10^{-5} for radiological analytes. Both total ELCRs are within the EPA range of 1×10^{-4} to 1×10^{-6}.

As shown in Table 6-53, the major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are strontium-90 (1.5×10^{-5}; 15 percent contribution), tritium (4.3×10^{-6}; 4.4 percent contribution), and carbon tetrachloride (2.5×10^{-6}; 2.6 percent contribution). Contribution to ELCR is elevated for arsenic (7.4×10^{-5}; 76 percent contribution) where measured concentrations are within natural background values.

As shown in Table 6-54, the HI is 1.6, which is greater than the EPA target HI of 1.0. All individual analytes (antimony, arsenic, bromomethane, carbon tetrachloride, cobalt, fluoride, Cr(VI), iron, lithium, manganese, molybdenum, nitrate, nitrite, strontium, uranium, and vanadium) that contribute greater than one percent of the HI also report a HQ less than 1.

Horn Exposure Area. The total ELCR is 1.4×10^{-4} for nonradiological analytes and 5.9×10^{-6} for radiological analytes. The nonradiological ELCR is greater than the EPA upper target risk threshold of 1×10^{-4} and the radiological ELCR is within the EPA range of 1×10^{-4} to 1×10^{-6}.

As shown in Table 6-55, the major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are tetrachloroethene (1.3×10^{-5}; 8.5 percent contribution), tritium (4.8×10^{-6}; 3.2 percent contribution), carbon tetrachloride (3.3×10^{-6}; 2.2 percent contribution), trichloroethene (1.7×10^{-6}; 1.1 percent contribution), and 1,2-dichloroethane (1.6×10^{-6}; 1.0 percent contribution). Contribution to ELCR is elevated for arsenic (1.2×10^{-4}; 83 percent contribution) where measured concentrations are within natural background values.

As shown in Table 6-56, the HI is 2.3, which is greater than the EPA target HI of 1.0. All individual analytes (antimony, arsenic, carbon tetrachloride, fluoride, Cr(VI), iron, lithium, molybdenum, nitrate, uranium, and vanadium) that contribute greater than one percent of the HI also report a HQ less than 1.

6.3.8 Uncertainties in 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 Hanford Site-specific and general uncertainties.

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 (DOE/RL-2007-21) and the 100-D/H Work Plan (DOE/RL-2008-46-ADD1). 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 as a result of differing monitoring programs.

Current baseline conditions are presented by groundwater data collected over an 8-month period between October 7, 2009 and June 11, 2010. Three sampling events were used to capture the effects that temporal fluctuations of river stage have on groundwater conditions. The COPCs identified during the work plan phase were validated by using groundwater samples analyzed for the analytical methods documented in the 100-D/H SAP (DOE/RL-2009-40). The groundwater dataset used for COPC identification consists of sampling and analysis data collected from 52 monitoring wells within the 100-HR-3 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 to or less than the lowest action level. When analytical methods could not achieve the lowest action level, the action level defaulted to the MDL that could reasonably be achieved. These detection limits are documented in Table 2-19 of the 100-D/H SAP (DOE/RL-2009-40).

Technetium-99 was reported at a concentration of 2,100 pCi/L in sample number B257L3 at Well 199-D5-18 (collected on May 12, 2010). This result is flagged with a "Y" review qualifier and a subsequent review of the results indicates that samples were misidentified. The review indicates that an aliquot (either B24949 or B24952) from well 299-E27-24 was inadvertently substituted for B257L3 during sample preparation and analysis at the laboratory. Additionally, two previous sampling rounds (March 30, 2010 and October 21, 2009) reported nondetected concentrations and gross beta measurements at this well from all three results consistently report concentrations between 7.5 and 9.5 pCi/L. Technetium-99 results from 199-D5-18 reported in 1992 were also reported as nondetected concentrations. The technetium-99 result for sample B257L3 was not included in the data set used to calculate exposure point concentrations.

6.3.8.2 Uncertainties Associated with Exposure Point Concentrations

The protectiveness and groundwater risk assessment methodology uses an RME concentration for each COPC for the entire OU 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. *Data Quality Assessment: Statistical Methods for Practitioners* (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 greater than 1 and 50 percent or more observations that are BDL, *Data Quality Assessment: Statistical Methods for Practitioners* (EPA/240/B-06/003) 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. ProUCL contains computational methods for parametric and nonparametric UCL, upper prediction limits (UPLs) and upper tolerance limits for use with datasets without non-detects as well as datasets with BDL observations. These computational methods can address skewed datasets 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. *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 (*Guidelines for Exposure Assessment* [EPA/600/Z-92/001]), which is comparable to the definition of RME as defined in the risk assessment guide (EPA/540/1-89/002). Therefore, use of the 90th percentile as the basis for a groundwater EPC yields risk estimates that correspond to an RME.

To illustrate the problem with using the 95 percent UCL for the groundwater data sets described in this report, Table 6-57 presents a few statistics for each contaminant, including the frequency of detection, 90th percentile, mean, and 95 percent UCL (or ProUCL value). The mean in Table 6-57 is calculated (by the ProUCL software) using only the detected concentration values; nondetect results are not used. The Kaplan-Meier mean is also provided in Table 6-57 which includes both detected concentration values and nondetected results. For the 95 percent UCL recommended by ProUCL for censored datasets (i.e., some concentrations were below the detection limit), the nondetect results were used (by the same software, ProUCL) in the calculation of the 95 percent UCL using a Kaplan-Meier statistical method (a nonparametric method) (these values are shown in Table 6-57). For highly skewed and/or highly censored datasets (i.e., those when the frequency of detection is low), these differing statistical approaches with respect to the dataset can lead to large differences between the two calculated values. This is especially true when the frequency of nondetects exceeds 40 percent. For example, the calculated mean concentration value for aluminum in the 100-D Source Exposure Area is 19 μg/L. This mean value is based on only the 19 detected values. When ProUCL used its algorithms to calculate the 95 percent UCL, the recommended calculated value was 13 μg/L, which is smaller than the mean value calculated by the software. This is due to the consideration of the 41 nondetect values in calculating the 95 percent UCL, for which the method detection limit is used as the observed concentration for these measurements. This situation occurs for many of the contaminants in the 100-HR-3 Groundwater OU. A similar situation exists for the other exposure areas in Table 6-57.

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Table 6-57. Percentile Concentrations and Summary Statistics for the 100-HR-3 Groundwater OU Dataset

COPC	Units	Number of Detections	Number of Nondetects	Frequency of Nondetects	Coefficient of Variation	90th Percentile of RI Data	Max	Mean	Kaplan Meier Mean	Kaplan Meier UCL	Recommended 95% UCL or ProUCL Value	Is 95% UCL or ProUCL Value > 90th Percentile?	Action Level*
100-D Source Exposure Area													
Acetone	µg/L	1	59	98%	N/A	1	0.82	0.82	Not Calculated	Not Calculated	Not Calculated	N/A	7,200
Aluminum	µg/L	19	41	68%	0.55	24	42	19	10	13	13	No	87
Arsenic	µg/L	56	4	7%	0.29	2.6	2.9	1.8	1.7	19	1.9	No	0.058 (4.0)
Barium	µg/L	60	0	0%	0.28	100	133	73	Not Calculated	Not Calculated	78	No	2,000
Beryllium	µg/L	5	55	92%	0.46	0.1	0.31	0.17	0.11	0.17	0.17	Yes	4.0
Boron	µg/L	19	28	60%	0.50	67	102	49	31	38	38	No	3,200
Bromodichloromethane	µg/L	2	58	97%	0.011	1	0.68	0.68	0.67	0.68	0.68	No	0.71 (5.0)
Cadmium	µg/L	2	58	97%	0.46	0.2	0.22	0.17	0.12	0.12	0.12	No	0.25
Carbon tetrachloride	µg/L	2	58	97%	0.027	1	2.7	2.7	2.6	2.7	2.7	Yes	0.63 (1.0)
Chloride	µg/L	60	0	0%	0.41	30,000	37,300	18,800	Not Calculated	Not Calculated	20,473	No	230,000
Chloroform	µg/L	50	10	17%	0.99	5.1	8.3	2.2	1.9	3.1	3.1	No	1.4 (5.0)
Chromium	µg/L	60	0	0%	2.0	925	4,460	412	Not Calculated	Not Calculated	905	No	65
Cobalt	µg/L	23	37	62%	1.4	1.3	3	0.82	0.38	0.55	0.55	No	4.8 (4.0)
Copper	µg/L	38	22	37%	0.78	0.73	2.3	0.48	0.35	0.47	0.47	No	9.0
Fluoride	µg/L	13	47	78%	0.35	115	148	86	66	70	70	No	960
Gross alpha	pCi/L	7	53	88%	0.38	3.5	6.8	4.3	2.4	4.1	4.1	Yes	15
Gross beta	pCi/L	44	16	27%	0.65	14	35	8.9	7.5	8.8	8.8	No	--
Cr(VI)	µg/L	60	0	0%	2.3	992	6,390	494	Not Calculated	Not Calculated	1,534	Yes	10
Iron	µg/L	39	21	35%	0.84	106	265	70	53	66	66	No	1,000
Lead	µg/L	14	46	77%	0.30	0.35	0.52	0.34	0.23	0.26	0.26	No	2.1
Lithium	µg/L	42	5	11%	1.4	21	133	15	14	26	26	Yes	32
Manganese	µg/L	3	57	95%	1.2	4	47	19	6.2	47	47	Yes	384
Methylene chloride	µg/L	6	54	90%	0.18	1	0.27	0.22	0.17	0.22	0.22	No	5.0
Molybdenum	µg/L	43	4	9%	0.78	4.4	8.7	2.1	2.1	3.1	3.1	No	80
Nickel	µg/L	13	47	78%	0.91	9.5	39	14	6.2	7.8	7.8	No	52
Nitrate	µg/L	60	0	0%	0.44	69,500	99,200	45,011	Not Calculated	Not Calculated	49,284	No	45,000
Selenium	µg/L	56	4	7%	0.49	4.4	6.5	2.8	2.6	3	3	No	5.0
Silver	µg/L	4	56	93%	0.32	0.2	0.26	0.19	0.13	0.23	0.23	Yes	2.6
Strontium	µg/L	60	0	0%	0.36	629	938	452	Not Calculated	Not Calculated	488	No	9,600
Strontium-90	pCi/L	3	57	95%	0.27	0.67	3.7	2.8	2.3	3.7	3.7	Yes	8.0
Sulfate	µg/L	60	0	0%	0.66	161,500	438,000	118,847	Not Calculated	Not Calculated	162,675	Yes	250,000
Technetium-99	pCi/L	2	57	97%	0.20	16	16	14	12	13	13	No	900
Tetrachloroethene	µg/L	1	59	98%	N/A	1	0.14	0.14	Not Calculated	Not Calculated	Not Calculated	N/A	5.0 (5.0)
Thallium	µg/L	4	56	93%	1.1	0.1	1	0.38	0.14	0.17	0.17	Yes	0.5 (2.0)

Table 6-57. Percentile Concentrations and Summary Statistics for the 100-HR-3 Groundwater OU Dataset

COPC	Units	Number of Detections	Number of Nondetects	Frequency of Nondetects	Coefficient of Variation	90th Percentile of RI Data	Max	Mean	Kaplan Meier Mean	Kaplan Meier UCL	Recommended 95% UCL or ProUCL Value	Is 95% UCL or ProUCL Value > 90th Percentile?	Action Level*
Tin	µg/L	9	38	81%	2.9	39	43	5	1.0	11	11	No	9,600
Tritium	pCi/L	48	12	20%	0.91	8,800	12,000	3,808	3,082	5,854	5,854	No	20,000
Uranium	µg/L	60	0	0%	0.38	4.1	4.8	2.8	Not Calculated	Not Calculated	3	No	30
Vanadium	µg/L	30	30	50%	0.30	26	33	20	16	17	17	No	80
Zinc	µg/L	18	42	70%	1.5	34	260	57	22	37	37	Yes	91
100-H Source Exposure Area													
Aluminum	µg/L	13	26	67%	1.2	41	188	49	21	35	35	No	87
Antimony	µg/L	4	35	90%	0.28	0.61	1	0.72	0.62	0.65	0.65	Yes	6.0
Arsenic	µg/L	39	0	0%	0.26	3.3	3.7	2.3	Not Calculated	Not Calculated	2.5	No	0.058 (4.0)
Barium	µg/L	39	0	0%	0.29	67	72	45	Not Calculated	Not Calculated	48	No	2,000
Boron	µg/L	17	15	47%	0.33	37	56	29	24	27	27	No	3,200
Bromoform	µg/L	1	38	97%	N/A	1	0.58	0.58	Not Calculated	Not Calculated	Not Calculated	N/A	5.5
Bromomethane	µg/L	1	38	97%	N/A	1	0.97	0.97	Not Calculated	Not Calculated	Not Calculated	N/A	11
Carbon disulfide	µg/L	1	38	97%	N/A	1	0.076	0.076	Not Calculated	Not Calculated	Not Calculated	N/A	800
Carbon tetrachloride	µg/L	2	37	95%	1.3	1	2	1	0.14	0.82	0.82	No	0.63 (1.0)
Chloride	µg/L	39	0	0%	0.24	37,600	44,900	27,013	Not Calculated	Not Calculated	28,774	No	230,000
Chloroform	µg/L	31	8	21%	0.27	1.4	1.7	1	0.99	1.1	1.1	No	1.4 (5.0)
Chloromethane	µg/L	1	38	97%	N/A	1	0.1	0.1	Not Calculated	Not Calculated	Not Calculated	N/A	--
Chromium	µg/L	39	0	0%	0.44	31	34	17	Not Calculated	Not Calculated	19	No	65
Cobalt	µg/L	16	23	59%	0.81	0.43	0.9	0.29	0.15	0.2	0.2	No	4.8 (4.0)
Copper	µg/L	21	18	46%	0.79	1.3	2.8	0.8	0.50	0.65	0.65	No	9.0
Fluoride	µg/L	8	31	79%	0.23	106	114	91	67	89	89	No	960
Gross alpha	pCi/L	10	29	74%	0.41	4	7.9	4	2.8	3.3	3.3	No	15
Gross beta	pCi/L	34	5	13%	0.76	30	58	19	17	27	27	No	4.0
Cr(VI)	µg/L	34	5	13%	0.62	26	29	13	11	14	14	No	10
Iron	µg/L	29	10	26%	3.5	444	7,840	414	313	1,575	1,575	Yes	1,000
Lead	µg/L	5	34	87%	0.58	0.23	0.71	0.37	0.24	0.29	0.29	Yes	2.1
Lithium	µg/L	27	5	16%	0.54	14	23	8.6	7.9	11	11	No	32
Manganese	µg/L	8	31	79%	0.81	35	120	47	19	25	25	No	384
Mercury	µg/L	1	38	97%	N/A	0.1	0.11	0.11	Not Calculated	Not Calculated	Not Calculated	N/A	0.012 (0.5)
Methylene chloride	µg/L	5	34	87%	2.0	1	11	2.4	0.42	2.3	2.3	Yes	5.0
Molybdenum	µg/L	29	3	9%	1.1	5.4	7.8	1.9	1.8	3.3	3.3	No	80
Nickel	µg/L	12	27	69%	0.58	8.9	18	8.3	4.2	6.3	6.3	No	52
Nitrate	µg/L	38	0	0%	0.20	39,800	46,900	30,037	Not Calculated	Not Calculated	31,686	No	45,000
Nitrite	µg/L	8	31	79%	0.22	1,560	2,270	1,609	1,236	1,485	1,485	No	3,300
Selenium	µg/L	38	1	3%	0.37	2.7	3.2	1.7	1.7	1.8	1.8	No	5.0
Strontium	µg/L	39	0	0%	0.18	391	477	321	Not Calculated	Not Calculated	337	No	9,600

Table 6-57. Percentile Concentrations and Summary Statistics for the 100-HR-3 Groundwater OU Dataset

COPC	Units	Number of Detections	Number of Nondetects	Frequency of Nondetects	Coefficient of Variation	90th Percentile of RI Data	Max	Mean	Kaplan Meier Mean	Kaplan Meier UCL	Recommended 95% UCL or ProUCL Value	Is 95% UCL or ProUCL Value > 90th Percentile?	Action Level*
Strontium-90	pCi/L	12	27	69%	0.77	14	27	11	5.6	7.2	7.2	No	8.0
Sulfate	µg/L	39	0	0%	0.19	79,700	88,700	62,613	Not Calculated	Not Calculated	65,752	No	250,000
Technetium-99	pCi/L	5	34	87%	0.82	8.8	35	14	8.7	16	16	Yes	900
Thallium	µg/L	2	37	95%	0.64	0.1	0.28	0.19	0.11	0.28	0.28	Yes	0.50 (2.0)
Tin	µg/L	1	31	97%	N/A	39	0.11	0.11	Not Calculated	Not Calculated	Not Calculated	N/A	9,600
Toluene	µg/L	1	38	97%	N/A	1	0.062	0.062	Not Calculated	Not Calculated	Not Calculated	N/A	640
Tritium	pCi/L	39	0	0%	0.29	3,900	4,400	2,636	Not Calculated	Not Calculated	2,843	No	20,000
Uranium	µg/L	39	0	0%	1.0	6.1	13	2.6	Not Calculated	Not Calculated	3.4	No	30
Vanadium	µg/L	6	33	85%	0.52	12	23	12	7.0	13	13	Yes	80
Zinc	µg/L	9	30	77%	0.67	16	30	14	5.4	9.3	9.3	No	91
Horn Exposure Area													
1,2-Dichloroethane	µg/L	1	56	98%	N/A	1	0.67	0.67	Not Calculated	Not Calculated	Not Calculated	N/A	0.48
2-Butanone	µg/L	1	56	98%	N/A	1	10	10	Not Calculated	Not Calculated	Not Calculated	N/A	4,800
Acetone	µg/L	1	56	98%	N/A	1	6.9	6.9	Not Calculated	Not Calculated	Not Calculated	N/A	7,200
Aluminum	µg/L	33	24	42%	1.0	54	150	34	22	30	30	No	8
Antimony	µg/L	9	48	84%	0.13	0.74	0.95	0.77	0.67	0.75	0.73	No	6.0
Arsenic	µg/L	52	5	9%	0.51	5.5	7.5	3.2	2.9	3.4	3.4	No	0.058 (4.0)
Barium	µg/L	57	0	0%	0.27	67	80	48	Not Calculated	Not Calculated	51	No	2,000
Boron	µg/L	8	35	81%	0.43	24	35	23	12	21	21	No	3,200
Carbon tetrachloride	µg/L	10	47	82%	0.35	1.3	1.7	1.2	0.34	1.1	1.1	No	0.63 (1.0)
Chloride	µg/L	57	0	0%	0.30	23,600	26,600	15,768	Not Calculated	Not Calculated	16,798	No	230,000
Chloroform	µg/L	32	25	44%	0.53	1	1	0.44	0.39	0.45	0.45	No	1.4 (5.0)
Chromium	µg/L	57	0	0%	0.65	76	88	37	Not Calculated	Not Calculated	43	No	65
Cobalt	µg/L	5	52	91%	0.41	0.1	0.21	0.15	0.080	0.14	0.14	Yes	4.8 (4.0)
Copper	µg/L	45	12	21%	0.84	1.4	2.8	0.68	0.56	0.7	0.7	No	9.0
Fluoride	µg/L	42	15	26%	0.45	263	343	167	140	159	159	No	960
Gross alpha	pCi/L	17	40	70%	0.31	3.5	5.6	3.4	2.4	3.5	3.5	No	15
Gross beta	pCi/L	38	19	33%	0.46	12	21	8	6.5	7.3	7.3	No	4.0
Cr(VI)	µg/L	50	7	12%	0.64	71	90	40	35	51	51	No	10
Iron	µg/L	42	15	26%	2.1	422	2,490	271	204	498	498	Yes	1,000
Lead	µg/L	4	53	93%	0.56	0.2	0.66	0.38	0.22	0.43	0.43	Yes	2.1
Lithium	µg/L	33	10	23%	0.38	12	16	8.1	6.8	8	8	No	32
Manganese	µg/L	13	44	77%	1.4	11	122	33	8.1	24	24	Yes	384
Methylene chloride	µg/L	7	50	88%	0.65	1	0.62	0.33	0.16	0.25	0.25	No	5.0
Molybdenum	µg/L	43	0	0%	0.57	8.5	12	4.7	Not Calculated	Not Calculated	5.4	No	80
Nickel	µg/L	8	49	86%	0.31	4.9	7.9	5.5	3.1	5.1	5.1	Yes	52
Nitrate	µg/L	57	0	0%	0.33	29,550	33,900	20,073	Not Calculated	Not Calculated	21,558	No	45,000

Table 6-57. Percentile Concentrations and Summary Statistics for the 100-HR-3 Groundwater OU Dataset

COPC	Units	Number of Detections	Number of Nondetects	Frequency of Nondetects	Coefficient of Variation	90th Percentile of RI Data	Max	Mean	Kaplan Meier Mean	Kaplan Meier UCL	Recommended 95% UCL or ProUCL Value	Is 95% UCL or ProUCL Value > 90th Percentile?	Action Level*
Nitrite	µg/L	2	55	96%	0.13	118	1,380	1,265	1,154	1,380	1,380	Yes	3,300
Selenium	µg/L	56	1	2%	0.50	3.2	7.1	2	2.1	2.3	2.3	No	5.0
Silver	µg/L	2	55	96%	0.79	0.2	1	0.64	0.29	1	1	Yes	2.6
Strontium	µg/L	57	0	0%	0.21	360	409	280	Not Calculated	Not Calculated	293	No	9,600
Strontium-90	pCi/L	4	53	93%	0.32	0.9	4.2	2.9	2.2	2.7	2.7	Yes	8.0
Sulfate	µg/L	57	0	0%	0.20	78,350	97,300	62,219	Not Calculated	Not Calculated	65,061	No	250,000
Technetium-99	pCi/L	1	56	98%	N/A	1.9	12	12	Not Calculated	Not Calculated	Not Calculated	N/A	900
Tetrachloroethene	µg/L	7	50	88%	0.71	1	0.43	0.2	0.12	0.14	0.14	No	5.0 (5.0)
Tin	µg/L	1	42	98%	N/A	39	1.3	1.3	Not Calculated	Not Calculated	Not Calculated	N/A	9,600
Toluene	µg/L	2	55	96%	0.34	1	0.18	0.15	0.11	0.18	0.18	No	640
Trichloroethene	µg/L	3	54	95%	0.13	1	0.33	0.31	0.26	0.27	0.27	No	0.95 (1.0)
Tritium	pCi/L	55	2	4%	0.52	4,350	4,700	2,569	2,485	3,286	3,286	No	20,000
Uranium	µg/L	57	0	0%	0.43	4.2	5	2.6	Not Calculated	Not Calculated	2.8	No	30
Vanadium	µg/L	30	27	47%	0.28	22	29	17	15	16	16	No	80
Xylenes (total)	µg/L	2	55	96%	0.031	1	0.46	0.45	0.44	0.44	0.44	No	1,600
Zinc	µg/L	9	48	84%	0.82	12	46	17	3.5	10	10	No	91

* Value in parentheses () represents the estimated quantitation limit reported in *Sampling and Analysis Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study* (DOE/RL-2009-40).

Other situations exist for which the recommended 95 percent UCL value is either not calculated (because the frequency of detection is too small) or where the UCL value is higher than the mean but only nominally higher and within less than a single significant digit. For example, the chloroform EPC calculation in the Horn Exposure Area has a 95 percent UCL of 0.45 against a mean value of 0.44.

This discussion only highlights the limits of the 95 percent UCL calculations and the need to use judgment in the establishment of the final EPCs. One advantage of using the 90th percentile is that fewer assumptions are used in the calculation and it can be consistently used for data sets regardless of skewness, frequency of detection issues, multiple detection limits, and other similar factors that can influence the 95 percent UCL calculation. Finally, future monitoring efforts should facilitate the calculation of the 95 percent UCL value to allow future compliance monitoring to provide the requisite data.

A comparison of the 90th percentile values used for the protectiveness and groundwater risk assessments, the recommended 95 percent UCLs (or ProUCL value), and the Kaplan-Meier UCL are presented in Table 6-57. Table 6-57 also shows the frequency of detection and CVs for the COPCs in groundwater. It should be noted that in most cases, the recommended 95 percent UCL is the same as the Kaplan-Meier UCL. As shown in Table 6-57, 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 (or ProUCL value) for COPCs that are risk drivers in groundwater, such as Cr(VI), nitrate, and strontium-90 in the 100-D and 100-H Areas.

6.3.8.2.1 *100-D Source Exposure Area*

The 90th percentile concentrations of RI data are greater than the 95 percent UCL (or ProUCL value) for 26 of 35 analytes reported on Table 6-57. The 95 percent UCL (or ProUCL value) is greater than the 90th percentile concentration for beryllium, carbon tetrachloride, gross alpha, Cr(VI), lithium, manganese, silver, strontium-90, sulfate, thallium, and zinc. Although the 90th percentile concentrations are less than the 95 percent UCL (or ProUCL value) concentration for beryllium, gross alpha, lithium, manganese, silver, strontium-90, sulfate, thallium, and zinc, both concentrations were less than the action level or EQL (as applicable) and use of the 95 percent UCL (or ProUCL value) would not result in a different conclusion. Although the 90th percentile concentrations are less than the 95 percent UCL (or ProUCL value) concentration for carbon tetrachloride and Cr(VI), both concentrations were greater than the action level or EQL (as applicable) and use of the 95 percent UCL (or ProUCL value) would not result in a different conclusion.

A 95 percent UCL was not calculated for acetone and tetrachloroethene because only one detection was reported for each of these analytes. Therefore, a comparison could not be made.

6.3.8.2.2 *100-H- Source Exposure Area*

The 90th percentile concentrations of RI data are greater than the 95 percent UCL (or ProUCL value) for seven of 41 analytes reported on Table 6-57. The 95 percent UCL (or ProUCL value) is greater than the 90th percentile concentration for antimony, iron, lead, methylene chloride, technetium-99, thallium and vanadium. Although the 90th percentile concentration is less than the 95 percent UCL (or ProUCL value) concentration for iron, both concentrations were greater than the action level and use of the 95 percent UCL (or ProUCL value) would not result in a different conclusion. The 95 percent UCL (or ProUCL value) is greater than the 90th percentile concentration for iron. Although the 90th percentile concentrations are less than the 95 percent UCL (or ProUCL value) concentration for antimony, lead, methylene chloride, technetium-99, thallium, and vanadium, both concentrations were less than the action level or EQL (as applicable) and use of the 95 percent UCL (or ProUCL value) would not result in a different conclusion.

A 95 percent UCL was not calculated for bromoform, bromomethane, carbon disulfide, chloromethane, mercury, tin, and toluene, because only one detection was reported for each of these analytes. Therefore, a comparison could not be made.

6.3.8.2.3 *Horn Exposure Area*

The 90th percentile concentrations of RI data are greater than the 95 percent UCL (or ProUCL value) for eight of 42 analytes reported on Table 6-57. The 95 percent UCL (or ProUCL value) is greater than the 90th percentile concentration for cobalt, iron, lead, manganese, nickel, nitrite, silver, and strontium-90. Although the 90th percentile concentration is less than the 95 percent UCL (or ProUCL value) concentration for iron, both concentrations were greater than the action level and use of the 95 percent UCL (or ProUCL value) would not result in a different conclusion. The 95 percent UCL (or ProUCL value) is greater than the 90th percentile concentration for iron. Although the 90th percentile concentrations are less than the 95 percent UCL (or ProUCL value) concentration for cobalt, iron, lead, manganese, nickel, nitrite, silver, and strontium-90, both concentrations were less than the action level or EQL (as applicable) and use of the 95 percent UCL (or ProUCL value) would not result in a different conclusion.

A 95 percent UCL was not calculated for 1,2-dichloroetane, 2-butanone, acetone, technetium-99, and tin, because only one detection was reported for each of these analytes. Therefore, a comparison could not be made.

For the 100-D Source exposure area, the 90th percentile concentrations for chloroform, chromium, and nitrate are greater than the 95 percent UCL (or ProUCL value) values. For Cr(VI), the 95 percent UCL of 1,534 μg/L is greater than the 90th percentile value of 992 μg/L. Both Cr(VI) concentrations are similar, indicating that Cr(VI) is distributed throughout the 100-D Source exposure area and both are greater than the freshwater CCC value of 10 μg/L.

For the 100-H Source exposure area, the 90th percentile value for Cr(VI), nitrate, and strontium-90 are greater than the 95 percent UCL (or ProUCL value). For Cr(VI), both the 95 percent UCL (or ProUCL value) value of 14 μg/L and the 90th percentile value of 34 μg/L are greater than the freshwater CCC value of 10 μg/L. For strontium-90, the 90th percentile value of 14 pCi/L is greater than the MCL value of 8 pCi/L, whereas the 95 percent UCL (or ProUCL value) value of 7.2 is not greater than the MCL. For nitrate, both the 90th percentile value of 39,800 μg/L and the 95 percent UCL (or ProUCL value) value of 31,868 μg/L are less than the MCL value of 45,000 μg/L.

For the Horn exposure area, the 90th percentile values for carbon tetrachloride, chromium, and Cr(VI) are greater than the 95 percent UCL (or ProUCL value). For carbon tetrachloride, the 95 percent UCL (or ProUCL value) value of 1.1 μg/L and the 90th percentile value of 1.3 μg/L are greater than the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) groundwater cleanup level of 0.23 μg/L. For chromium, the 90th percentile value of 76 μg/L is greater than the freshwater CCC value of 65 μg/L, whereas the 95 percent UCL (or ProUCL value) value of 54 μ/L is not greater than the criterion. For Cr(VI), the 95 percent UCL value (or ProUCL value) of 51 μg/L and the 90th percentile value of 71 μg/L are greater than the freshwater CCC value of 10 μg/L.

6.3.8.3 *Uncertainties Associated with Exposure Assessment*

The exposure assumptions used to develop the action levels 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 ("Guidance on Risk Characterization for Risk Managers and Risk Assessors"

[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.

6.3.8.3.1 *Uncertainties Associated with Inhalation of Aersols Containing Hexavalent Chromium*

A study by Finley et al (1996) determined that cancer risk from exposure during showering with Cr (VI) aerosols from tapwater ranged from 9.0E-07 to 5.5E-06 from water containing 2 to 10 Cr(VI) mg/L. Average air-borne concentrations of Cr(VI) at breathing-zone height ranged from 0.087 μg/m3 to 0.324 μg/m3 which was measured over 24 hours of use. The air concentrations of 0.087 μg/m3 to 0.324 μg/m3 were directly correlated to water concentrations of 0.89 mg/L to 11.5 mg/L. This study concluded that exposure to indoor aerosols containing up to 10 mg/L is unlikely to create a health hazard. Finley et al (1996) also determined that ambient (outdoor) concentrations of Cr(VI) were about the same as those calculated from indoor shower aerosols (suggesting no difference between indoor and ambient air concentrations). Cr(VI) is identified as a COPC for the 100-HR-3 groundwater OU and warrants evaluation of remedial alternatives in the feasibility study. Cr(VI) is identified as a COPC because groundwater concentrations are greater than WAC 173-340-720 groundwater cleanup level of 48 μg/L and the ambient water quality criteria of 10 μg/L. Although there may be some potential for health hazards from exposure to Cr(VI) during showering at concentrations at 2 mg/L, this concentration would result in risk approximately equal to 1×10^{-6} and is considerably greater than the levels identified for protection of human health and aquatic receptors.

6.3.8.3.2 *Uncertainties Associated with Dermal Contact Exposure*

The action levels for use as a drinking water source consider ingestion and inhalation of vapors as complete and significant pathways for exposure. For the action levels, 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 action levels 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 carbon tetrachloride, chromium, and Cr(VI). The ratio of the dermal absorbed dose from dermal to oral is 40 percent for chromium, 42 percent for Cr(VI), and 17 percent for carbon tetrachloride. Based on this comparison, the action level concentrations may have the potential to underestimate exposure to these COPCs.

6.3.8.3.3 *Uncertainties Associated with Action Levels that include the Fish Consumption Exposure Pathway*

Water quality standards used as action levels to identify COPCs have been developed to include exposure to groundwater contaminants through direct contact (groundwater ingestion and fish consumption). These specific action levels are:

- "Water Quality Standards" (40 CFR 131) for states not complying with Section 303 of the *Clean Water Act of 1977*, Human Health Water + organism
- National Recommended Water Quality Criteria, Ambient Water Quality Criteria (AWQC) established under Section 304 of the *Clean Water Act of 1977*, Human Health Water + organism

These water quality standards were used to identify COPCs in groundwater based on the potential for impacts to surface water. While groundwater adjacent to the Columbia River can discharge to the river through the hyporheic zone, contaminants potentially in groundwater undergo dilution in the river flows to concentrations indistinguishable from levels upstream. Correspondingly, this limits potential accumulation of groundwater contaminants into fish to levels indistinguishable from levels upstream. Based on these factors, potential exposure pathways from groundwater through fish consumption along the Hanford Site are considered incomplete.

6.3.8.3.4 *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 guide (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.

6.3.8.3.5 *Slope Factors for Cr(VI)*

The oral RfD of 0.003 mg/kg-day published by IRIS is used to develop the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level for Cr(VI). An oral carcinogenic potency factor has

recently been published (*Derivation of an Ingestion-Based Soil Remediation Criterion for Cr^{+6} Based on the NTP Chronic Bioassay Data for Sodium Dichromate Dihydrate* [NJDEP, 2009]). The oral carcinogenic potency factor derived is 0.5 $(mg/kg\text{-}day)^{-1}$, 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 were used to calculate the 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level, the groundwater concentration would decrease from 48 to 0.18 µg/L.

6.3.8.4 Uncertainties Associated with Risk Characterization

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 Ra-226, but excluding uranium and radon), and 5 pCi/L combined for Ra-226 and Ra-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 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720(4)(iii) (B)]) and radionuclide slope factors from HEAST (EPA 540-R-97-036). Exposure inputs and equation 720-2 were selected to calculate risks to be consistent with the risk evaluation section for 100-H Source exposure area that is presented in Section 6.3.6.2.3. Cancer risks for strontium-90 in the 100-H Source exposure area were also calculated using the tap water scenario and presented in Table 6-58. Table 6-58 shows the MCL concentration for strontium-90, and the EPC reported in the 100-H Source exposure area does not individually exceed the 10^{-4} ELCR end of the NCP (40 CFR 300) risk range. Although the 90th percentile value for strontium-90 does not exceed the upper end of the risk range, strontium-90 was retained as a contaminant of potential concern for further evaluation in the FS because it was present in localized areas at concentrations greater than the DWS.

Table 6-58. Summary of 90th Percentile Current Groundwater Concentrations, Associated Cancer Risk, and Associated Sum of Fractions for Radioactive COPCs

COPC	90th Percentile Value (pCi/L)	Federal or State MCL (pCi/L)	ELCR at Federal MCL	Individual Fraction	Individual ELCR
Strontium-90	14	8	8.5×10^{-6}	1.8	1.5×10^{-5}
Sum of Fractions				**1.8**	**-**
Cumulative ELCR for Radioactive COPCs				**-**	**1.5×10^{-5}**

6.3.8.4.1 Uncertainties Associated with the Native American Risk Assessments

As discussed in Section 6.1.3, the RCBRA (DOE/RL-2007-21, Volume II) evaluated three residential scenarios that describe exposure related to rural land-use patterns that involved exposure assumptions that represented subsistence use. Of the three residential scenarios, two Native American scenarios were evaluated including CTUIR and the Yakama Nation. Although groundwater within the 100-D/H 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 Regional Screening Levels (EPA, 2013a), 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 (DOE/RL-2007-21, Volume II) (see Section 6.3.2). The uncertainties in the RCBRA (DOE/RL-2007-21, Volume II) 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 than the EPA Tap Water scenario. Depending on the contaminants and pathways involved, as described in the following paragraphs, ELCR and HI for the Native American scenarios may be 4- to 5-fold greater than for the Tap Water scenario, 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. EPCs 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 *Exposure Scenario for CTUIR Traditional Subsistence Lifeways* (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.

As described in Section 6.1.4, the RCBRA (DOE/RL-2007-21) presents the risks and hazards calculated for both Native American exposure scenarios from direct contact, external gamma exposure, inhalation, and food chain pathways at remediated waste sites. The groundwater risk assessment presents the risks and hazards calculated for groundwater used as a source of drinking water and as a source of steam for sweat lodge use. The results from the RCBRA (DOE/RL-2007-21, Volume II) for remediated waste sites and the results from the groundwater risk assessment are presented in Table 6-59. The risks and hazards

can be summed to obtain a cumulative estimate of risk and hazard for all exposure pathways included in the CTUIR and Yakama Nation exposure scenarios.

Groundwater within the 100-HR-3 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

Human health risks were assessed in areas outside the footprints of waste sites as part of the RCBRA (DOE/RL-2007-21, Volume II) and the CRC risk assessment (DOE/RL-2010-117, Volume II). The following sections summarize the conclusions obtained from these two risk assessments. Table 6-60 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 in the following sections.

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, and fish tissue. The exposure scenarios considered for riparian and nearshore areas were avid angler, casual user, and Tribal scenarios, including nonresident Tribal scenario, and ingestion of fish in the CTUIR and Yakama Nation Resident scenarios. The Casual Recreational User scenario addresses occasional recreational use and 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.

EPCs in soil in the riparian environment were calculated using MULTI INCREMENT® sampling from riparian locations in 100-D/H OU (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) 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-D/H OU area for the Casual Recreational User and Avid Angler scenarios showed that lifetime cancer risks generally were near 1×10^{-6} and were below a noncancer HI of 1 for direct exposures to soil, sediment, and surface water.

Risks for riparian soils were higher than a 1×10^{-4} cancer risk and above a noncancer HI of 1 for the nonresident Tribal scenario. Modeled concentrations of arsenic from riparian soil into native vegetation provided the largest contribution to cancer risks and noncancer HIs. However, as discussed in the RCBRA (DOE/RL-2007-21, Volume II), uncertainties in the food chain modeling methods considerably overstate risks from plant ingestion exposure pathways for arsenic. There were no cancer risks estimated

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from fish ingestion for any of the scenarios evaluated, because no carcinogenic COPCs were detected in fish tissue samples in 100-D/H. The noncancer HI for fish ingestion with the nonresident Tribal scenario exceeded 1. In the 100-D/H OU, nickel detected in sculpin was the driver for noncancer risks from fish ingestion. The RCBRA (DOE/RL-2007-21, Volume II) concluded that sculpin caught close to the OUs would not be expected to reflect risks potentially associated with food fish with large home ranges. Noncancer HIs calculated with the combination of localized concentrations in sculpin with subsistence ingestion rates are probably overstated.

Based on the results from this analysis, there are no additional COPCs identified in riparian soils, nearshore sediments, and surface water that warrant further evaluation in the FS. The COPCs identified for waste sites are inclusive of the riparian area. Uncertainties in the estimation of human health risks, as described in the RCBRA, suggest that these risks have been considerably overstated.

6.4.2 Risk Assessment Conclusions from the Columbia River Component

The CRC HHRA (DOE/RL-2010-117, Volume II) provides a comprehensive assessment of human health risks for the Hanford Reach. The intent of the CRC HHRA (DOE/RL-2010-117, Volume II) was to complete the assessment of the "bank-to-bank" Hanford Reach and downstream areas (that is, Lake Wallula) of the Columbia River, characterizing risk in areas not previously addressed under the RCBRA. Human exposure scenarios addressed in the CRC HHRA (DOE/RL-2010-117, Volume II) 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 specifically created to support the CRC HHRA (DOE/RL-2010-117, Volume II) 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 (Prosopium williamsoni)
- Walleye (*Sander vitreus*)
- Smallmouth bass (Micropterus dolomieui)
- Bridgelip sucker (Catostomus columbianus)
- White sturgeon (Acipenser transmontanus)

Table 6-59. Summary of Cancer Risks and Noncancer Hazards for Soil and Groundwater Exposure Pathways Associated with the CTUIR and the Yakama Nation Exposure Scenarios

Environmental Medium/ Exposure Pathway	CTUIR Total ELCR	CTUIR Risk Drivers (Contributes > 1×10^{-6})	CTUIR Hazard Index	CTUIR Hazard Drivers	Yakama Nation Total ELCR	Yakama Nation Risk Drivers (Contributes > 1×10^{-6})	Yakama Nation Hazard Index	Yakama Nation Hazard Drivers
100-DSource								
Remediated Waste Sites (Direct Contact and Food Chain Pathways)	4.0×10^{-2} to 2×10^{-5}	Arsenic, cesium-137, europium-152, strontium-90, technetium-99	0.048 to 380	Arsenic, mercury	4.0×10^{-2} to 3×10^{-5}	Arsenic, cesium-137, europium-152, strontium-90, technetium-99	0.16 to 430	Arsenic, mercury
Groundwater as a Potential Drinking Water Source	3.4×10^{-4}	Bromodichloro-methane, carbon tetrachloride, chloroform, tetrachloroethene, tritium,	23	Cr(VI)	3.7×10^{-4}	Bromodichloro-methane, carbon tetrachloride, chloroform, tetrachloroethene, tritium,	23	Cr(VI)
Groundwater as a Potential Source of Steam from Sweat Lodge Use (Includes Vaporized Nonvolatiles)	5.0×10^{-1}	Cr(VI)	99	Cr(VI)	1.0×10^{-0}	Cr(VI)	716	Arsenic, barium, cadmium, cobalt, Cr(VI), manganese, nickel
Groundwater as a Potential Source of Steam from Sweat Lodge Use (Excludes Vaporized Nonvolatiles)	--	--	--	--	1.6×10^{-4}	Arsenic, bromodichloro-methane, carbon tetrachloride, tetrachloroethene, tritium	48	Cr(VI)
100-HSource								
Remediated Waste Sites (Direct Contact and Food Chain Pathways)	4.0×10^{-2} to 2×10^{-5}	Arsenic, cesium-137, europium-152, strontium-90, technetium-99	0.048 to 380	Arsenic, mercury	4.0×10^{-2} to 3×10^{-5}	Arsenic, cesium-137, europium-152, strontium-90, technetium-99	0.16 to 430	Arsenic, mercury
Groundwater as a Potential Drinking Water Source	4.0×10^{-4}	Carbon tetrachloride strontium-90, tritium.	3.3	Cr(VI)	4.3×10^{-4}	Strontium-90, tritium. carbon tetrachloride	3.3	Cr(VI)
Groundwater as a Potential Source of Steam from Sweat Lodge Use (Includes Vaporized Nonvolatiles)	1.8×10^{-2}	Cr(VI)	13	Cr(VI), arsenic, barium	1.3×10^{-1}	Cr(VI)	96	Arsenic, barium, cobalt, Cr(VI), manganese, nickel, uranium
Groundwater as a Potential Source of Steam from Sweat Lodge Use (Excludes Vaporized Nonvolatiles)	--	--	--	--	6.7×10^{-5}	Arsenic, carbon tetrachloride, chloroform, tritium	1.5	--
Horn Area								
Soil (Direct Contact and Food Chain Pathways)	4.0×10^{-2} to 2×10^{-5}	Arsenic, cesium-137, europium-152, strontium-90, technetium-99	0.048 to 380	Arsenic, mercury	4.0×10^{-2} to 3×10^{-5}	Arsenic, cesium-137, europium-152, strontium-90, technetium-99	0.16 to 430	Arsenic, mercury
Groundwater as a Potential Drinking Water Source	5.7×10^{-4}	1,2-dichloroethane, tetrachloroethene, trichloroethene, tritium	4.4	Cr(VI)	6.2×10^{-4}	1,2-dichloroethane, tetrachloroethene, trichloroethene, tritium	4.4	Cr(VI)
Groundwater as a Potential Source of Steam from Sweat Lodge Use (Includes Vaporized Nonvolatiles)	4.9×10^{-2}	Cr(VI)	14	Cr(VI), arsenic, barium, manganese	3.1×10^{-1}	Cr(VI)	100	Arsenic, barium, cobalt, fluoride, Cr(VI), manganese, nickel
Groundwater as a Potential Source of Steam from Sweat Lodge Use (Excludes Vaporized Nonvolatiles)	--	--	--	--	9.6×10^{-5}	1,2-dichloroethane, arsenic, carbon tetrachloride, chloroform, tetrachloroethene, trichloroethene, tritium	3.6	Cr(VI)

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Table 6-60. Summary of Total Risks and Noncancer Hazards for the Riparian and Nearshore Areas in the 100-D/H 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	0.02	None	--	RCBRA - DOE/RL-2007-21, Tables 4-14 and 4-16
Avid Angler Scenario						
Nearshore – sediment, river water, dust	2.0×10^{-6}	None	0.006	None	--	RCBRA - DOE/RL-2007-21, Tables 4-17 and 4-19
Fish ingestion - Sculpin	0	None	4.3	Metals	Screening-level result employing nearshore COPC concentrations in sculpin, a small fish with a limited home range.	
Nonresident Tribal Scenario						
Soil, sediment, water	6.0×10^{-5}	Arsenic	0.78	None	--	RCBRA - DOE/RL-2007-21, Tables 4-24 and 4-26
Plants and game	1.0×10^{-2}	Arsenic	80	Arsenic	Ingestion of contaminants in plants and game were modeled using high end biotransfer factors, which overstated concentrations accumulated from soil. Uncertainties associated with the large range of published bio-transfer factors.	
Fish Ingestion - Sculpin	0	None	25	Metals	Screening-level result employing nearshore COPC concentrations in sculpin, a small fish with a limited home	

Table 6-60. Summary of Total Risks and Noncancer Hazards for the Riparian and Nearshore Areas in the 100-D/H OUs

Environment/Exposure Media	Excess Lifetime Cancer Risk	Primary Risk Drivers	Noncancer Hazard Index	Primary Noncancer Hazards	Comment	Source
					range.	
Casual User Scenario (Child - Columbia River)						
100-A Study Area COPCs in Surface Water	0	None	0.005	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	5×10^{-7}	None	0.02	None		
100-B Study Area COPCs in Surface Water	0	None	0.003	None		
100-B Study Area COPCs in Sediment	4×10^{-7}	None	0.02	None		
100-B Study Area COPCs in Island Soil	8×10^{-7}	None	0.02	None		
Casual User Scenario (Adult - Columbia River)						
100-A Study Area COPCs in Surface Water	0	None	0.001	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	3×10^{-6}	None	0.003	None		
100-B Study Area COPCs in Surface Water	0	None	0.0009	None		
100-B Study Area COPCs in Sediment	2×10^{-6}	None	0.002	None		
100-B Study Area COPCs in Island Soil	5×10^{-7}	None	0.003	None		
Avid Angler Scenario (Child - Columbia River)						
100 Area, Fish Ingestion	1×10^{-6}	Carbon-14	7	PCBs (dioxin and non-dioxin like)	--	CRC - DOE/RL-2010-117, Table 6-25
Avid Angler Scenario (Youth - Columbia River)						
100-A Study Area COPCs in Surface Water	0	None	0.001	None	Risks in each media summed across chemical carcinogens and	CRC - DOE/RL-2010-117, Tables 6-28 and 6-29.
100-A Study Area COPCs in Sediment	7×10^{-7}	None	0. 005	None		

Table 6-60. Summary of Total Risks and Noncancer Hazards for the Riparian and Nearshore Areas in the 100-D/H OUs

Environment/Exposure Media	Excess Lifetime Cancer Risk	Primary Risk Drivers	Noncancer Hazard Index	Primary Noncancer Hazards	Comment	Source
100-A Study Area COPCs in Fish	4×10^{-6}[a]	Carbon-14	7	PCBs (dioxin and non-dioxin like)	radionuclides.	
100-B Study Area COPCs in Surface Water	0	None	0.0008	None		
100-B Study Area COPCs in Sediment	5×10^{-7}	None	0.003	None		
100-B Study Area COPCs in Island Soil	3×10^{-7}	None	0.006	None		
100-B Study Area COPCs in Fish	4×10^{-6}[a]	Carbon-14	7	PCBs (dioxin and non-dioxin like)		
Avid Angler Scenario (Adult - Columbia River)						
100-A Study Area COPCs in Surface Water	0	None	0.0007	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	3×10^{-6}	None	0. 003	None		
100-A Study Area COPCs in Fish	3×10^{-5}[a]	Carbon-14	7	PCBs (dioxin and non-dioxin like)		
100-B Study Area COPCs in Surface Water	0	None	0.0005	None		
100-B Study Area COPCs in Sediment	2×10^{-6}	None	0.002	None		
100-B Study Area COPCs in Island Soil	5×10^{-7}	None	0.003	None		
100-B Study Area COPCs in Fish	3×10^{-5}[a]	Carbon-14	7	PCBs (dioxin and non-dioxin like)		

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

Table 6-60. Summary of Total Risks and Noncancer Hazards for the Riparian and Nearshore Areas in the 100-D/H OUs

Environment/Exposure Media	Excess Lifetime Cancer Risk	Primary Risk Drivers	Noncancer Hazard Index	Primary Noncancer Hazards	Comment	Source
PCBs 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 values indicate that there were no COPCs for that medium; therefore, no risks or noncancer hazards were calculated.						
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 *River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment* (DOE/RL-2007-21) and *Columbia River Component Risk Assessment, Volume II: Baseline Human Health Risk Assessment* (DOE/RL-2010-117) risk assessment reports.						

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, because the 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, respectively. PCBs, chlorinated pesticides (notably dieldrin and beta-hexachlorocyclohexane), cobalt, lithium, and mercury were the primary risk drivers through fish ingestion. Throughout the 100 Area sub-area (where the 100-D/H OU is located), all of the risk drivers in fish also were identified as COPCs in upstream reference areas. Carbon 14 was the only radionuclide consistently detected among fish tissue samples although at a very low (1 percent) frequency of detection. Carbon-14 was also only sporadically detected in abiotic media.

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 L 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 for these contaminants from the 100-D/H OU sites or groundwater, coupled with comparable risks associated with fish caught in reference areas, it is unlikely that Hanford Site activities in the 100-D/H OU are associated with the fish ingestion risks projected in the CRC HHRA (DOE/RL-2010-117, Volume II).

Results from the risk characterization indicate that the risks related to exposure to surface water and sediment are very small relative to that from the fish ingestion pathway. Cumulative risks for the Casual Recreational User scenario (which included direct contact exposure pathways to sediment and surface

water) were 7×10^{-6} in the 100 Area sub-area. Arsenic in sediment within most of the exposure points accounted for over half of the cumulative risk. It is noted that nickel concentrations in surface water displayed a different pattern of concentration across the Hanford Site study area; however, it does not exceed the human health benchmark. Of the radionuclides, cobalt-60, europium-152, and cesium-137 constitute the majority of radiation cancer risk. Concentrations of cesium-137 and europium-152 measured in sediment samples from the 100 Area Sub-Area showed spatial variation. Although cesium-137 and europium-152 were detected and EPCs were calculated they were not identified as primary risk drivers for the Casual User scenario. It should be noted that cesium-137 is a known constituent of worldwide atmospheric fallout and was found largely in reference areas.

Risks from island soil exposures were relatively minor compared to risks from other abiotic media, cobalt-60 in soils collected from island soils was a contributor to risk; however, it was reported at a low frequency of detection (1 of 69 island soils) and at low concentration (0.016 pCi/g) (the residential PRG for cobalt-60 is 3.3 pCi/g). Cobalt-60 was not detected in the soils collected from the 100 Area sub area.

In the early 1990s, the upstream half (12.5 acres) of 100-D Island (100-D-67) was surveyed using the Ultrasonic Ranging and Data System (USRADS) (*100-D Island USRADS Radiological Surveys Preliminary Report – Phase II* [BHI-00134]). Areas of elevated radiation readings were found to be discrete radioactive particles (specks) that were in the silt 10.1 to 25.4 cm (4 to 10 in.) beneath the surface and between the 4-6 inch diameter cobbles that make up the bulk of the soil on 100-D Island. During the USRADS surveys in April 1992, the specks that were found were removed and a portion of them were counted in the laboratory. The only radionuclide found in the majority of the specks was cobalt-60. In 1992, the highest activity speck contained 22 micro-Curies of cobalt-60 with the average specks containing 2.5 micro-Curies. Calculations based on the maximum number of specks found in a volume of soil show that the soil activity due to cobalt-60 in 1992 was 0.45 pCi/g.

The WDOH conducted a risk assessment on cobalt-60 present in particulates on 100-D Island (*100-D Island Radiological Survey* [WDOH/ERS-96-1101]). The carcinogenic risk associated with the cobalt-60 particles was stated to be the result of two pathways: external exposure and ingestion. The maximum potential dose rate from external exposure was estimated to be 0.04 mrem/year based on a recreational scenario. The WDOH study (*100-D Island Radiological Survey* [WDOH/ERS-96-1101]) also reported the carcinogenic risk from external exposure and ingestion of soil to be 2.7×10^{-8} and 2.3×10^{-11}, respectively, and concluded that the risks from radioactive specks were not sufficient to justify further surveys to locate and remove them. Since 1993, cobalt-60 has decayed through almost four halflives resulting in present day risks that are considerably less than these values. In 2004, the 100-D Island was surveyed using Laser-Assisted Ranging and Data System (LARADS). The results of the survey showed that levels of gamma-emitting radionuclides were present at or slightly above background levels, with maximum readings between background and 5,000.

Based on conclusions from previous studies and because of radioactive decay, it is concluded that no further remedial action is warranted for 100-D Island.

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, the three inactive 100-D/H 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) 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 human health risk assessment determined that elevated human radiological exposure could occur if portions of the river pipelines became dislodged and washed ashore (RCBRA [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.

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 that pipelines present no unacceptable risks; 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 due to decay (radioactivity would be less than 15 mrem/yr above background by Year 2022)
- 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 these pipelines.

6.5 Summary and Conclusions

The soil and groundwater risk assessments for the 100-D/H source and groundwater OUs accomplish the following objectives:

- Proposes direct contact PRGs in soil for use in the FS consistent with values presented in the RCBRA (DOE/RL-2007-21).
- Evaluates the effectiveness of source interim actions for the 100-D/H Source OU.
- Qualitatively evaluates soil data from RI and LFI soil borings and wells to determine whether results could be useful for risk management decisions.
- Confirms that previously remediated waste sites meet RAOs and remedial action goals published in the 100 Area RDR/RAWP (DOE/RL-96-17) in accordance with 1996 MTCA.
- Confirms that previously remediated waste sites achieve the 2007 MTCA 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 direct contact for nonradionuclides.
- Proposes soil PRGs protective of groundwater and surface water for use in the FS in accordance with 2007 MTCA [WAC 173-340-747(5)] procedure, presented in Chapter 5.
- Evaluates previously remediated waste sites to determine if residual concentrations are predicted to impact groundwater in accordance with 2007 MTCA [WAC 173-340-747(5)] procedures (as reported in Section 5.7.3). The results of this comparison are provided in Section 5.7.3 of this report.
- 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.
- Proposes PRGs in groundwater in accordance with 2007 MTCA (WAC 173-340-720).

The methodology used to assess risks for the RI/FS uses PRGs developed in the RCBRA 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 the most recent regulatory guidance and 2007 MTCA regulations. 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 (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. In addition, risks from contaminants in groundwater were assessed using Tribal scenarios based on assumptions provided by the CTUIR and Yakama Nation. The EPA Tap Water scenario is also evaluated to provide a similar scenario using exposure assumptions that represent a RME.

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. Soil samples collected from depth intervals ranging from 0 to 4.6 m (15 ft) bgs were combined and compared to PRGs, including those that represent the RAOs (Residential scenario) and reasonably anticipated future land use (Resident Monument Worker and Casual Recreational User). Soil samples collected from depth intervals greater than 4.6 m (15 ft) bgs 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 primary contaminants in the vadose zone of previously remediated waste sites are radionuclides and arsenic. 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 Shallow Zone Results for Closeout Verification Data

Cancer risks associated with all radionuclides at remediated waste sites within the top 4.6 m (15 ft) of soil are in the 10^{-4} range for both the 100-D and 100-H Source OUs, based on the Residential exposure scenario. Two waste sites in the 100-D Source OU and one waste site in the 100-H Source OU were reported with individual COPCs greater than 1×10^{-4}. Cancer risks associated with the Resident Monument Worker scenario are similar to the Residential scenario. Cancer risks for the Resident Monument worker have a cumulative ELCR approximately 0.75 times lower than the unrestricted (resident). Cancer risks for a Casual Recreational User scenario are approximately two orders of magnitude lower than the Residential scenarios. This slight exceedance of target risk thresholds is a result of health protective levels being 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). In addition, the radionuclides related to waste disposal have relatively short half-lives. It is anticipated that concentrations would decay to levels corresponding to EPA's target risk range within 50 years.

Concentrations of strontium-90 in the 100-D-48:3 shallow decision unit, concentrations of cobalt-60 and nickel-63 in the 100-D-42, 100-D-43, and 100-D-45 shallow focused decision unit, and concentrations of europium-152 and strontium-90 in the 100-D-47 shallow focused decision unit have decayed to residential RBSLs and do not warrant further evaluation in the FS. The following waste sites contain Hanford Site-related COPCs in the top 4.6 m (15 ft) and warrant further evaluation as COCs in the FS:

- 116-D-8 shallow focused 2 decision unit contained cesium-137 at a concentration of 7.63 pCi/g, resulting in a risk of 1.7×10^{-4}, when sampled in 2011. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2035.
- 116-DR-9 shallow decision unit contained cesium-137 at a concentration of 10 pCi/g, resulting in a risk of 2.0×10^{-4}, when sampled in 1999. Cesium-137 concentrations will decay to levels less than the residential RBSL of 4.4 pCi/g by year 2035. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2038.

- 118-D-6:4 shallow 2 decision unit contained cesium-137, europium-152, and strontium-90 at concentrations of 2.9 pCi/g, 1.4 pCi/g, and 0.36 pCi/g resulting in a risk of 1.2×10^{-4}, when sampled in 2010. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2022.
- 118-DR-2:2 shallow decision unit contained technetium-99 at a concentration of 2 pCi/g when sampled in 2000, resulting in a risk of 2.2×10^{-4}. The technetium-99 concentration is greater than the residential RBSL of 1.5 pCi/g and does not decay to the residential RBSL within a reasonable period.
- 116-H-5 shallow 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 2011. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2016.
- 118-H-1:1 shallow 2 decision unit contained strontium-90 at a concentration of 2.3 pCi/g, resulting in a risk of 1.2×10^{-4}, when sampled in 2010. Activities of all radionuclides will decay to a total ELCR of less than 1.0×10^{-4} by year 2016.

For nonradiological contaminants, the COPCs that are the largest contributors to calculated risks and HIs are metals at the 100-D Source OU and metals, PCBs, and PAHs at the 100-H Source OU. For all exposure scenarios, for waste sites that have been remediated under interim action RODs, the cancer risks and noncancer HIs for nonradioactive contaminants fell within EPA's target risk ranges. Concentrations of arsenic in vadose zone material are associated with cancer risks higher than 10^{-6} under unrestricted (residential) exposure assumptions. Two waste sites were reported with PAH concentrations, and one waste site was reported with Aroclor-1260 greater than the acceptable risk value of 1×10^{-6} for individual carcinogens but less than the 2007 MTCA (HHRA Procedures [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5} for multiple contaminants and multiple pathways. The concentrations of arsenic in vadose zone material posing risks greater than 10^{-6} are consistent with Sitewide naturally occurring background in vadose zone material. No waste sites require further evaluation in the FS based on the presence of nonradiological COPCs.

6.5.1.2 Shallow Zone Results for RI and LFI Data

Soil samples were collected from depths ranging between 0 to 4.6 m (15 ft) bgs for two RI soil borings (both from 100-H Source OU), five RI test pits (three from 100-D Source OU and two from 100-H Source OU), and seven LFI test pits (all from 100-D Source OU). The conclusions from the evaluation of the shallow zone RI and LFI data are consistent with the conclusions of the soil risk assessment.

For the 100-D Source OU, four LFI sample locations (116-D-1A Trench, 116-D-7 Retention Basin, 116-DR-9 Retention Basin, and 116-D-2 Crib) report soil concentrations greater than residential RBSLs. These four 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. At the 108-D/Sodium Dichromate Tanks test pit, benzo(a)pyrene was reported as an estimated concentration of 180 µg/kg in the 1.5 m (5 ft) bgs depth interval. The benzo(a)pyrene concentration of 180 µg/kg is slightly greater than the residential RBSL of 137 µg/kg. Benzo(a)pyrene is the only analyte reported at a concentration greater than a RBSL at this location. In addition, the 108-D/Sodium Dichromate Tanks test pit is located within the footprint of the 100-D-101 waste site that is identified as an accepted WIDS waste site.

For the 100-H Source OU, three LFI sample locations (116-H-1 Trench, 116-H-7 Retention Basin, and 116-H-9 Crib) report soil concentrations greater than residential RBSLs. 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.

6.5.1.3 Deep Zone Results for Closeout Verification Data

Deep vadose zone samples were evaluated to identify remediated waste sites where exposure to residual contamination could present a potential risk from an inadvertent exposure through deep excavation activities. While this exposure would be industrial in nature, the RBSLs (developed for the Residential exposure scenario) were used for convenience as screening values to identify such sites in order to allow institutional controls to be established to control access to deep contamination.

Eighteen waste sites represented by the following 20 decision units are reported with concentrations of one or more radioisotopes (cesium-137, cobalt-60, europium-152, europium-154, nickel-63, or strontium-90) in the deep zone. These waste sites will decay to residential RBSLs within 2 and 185 years:

- 100-D-18 deep decision unit
- 100-D-19 deep focused decision unit
- 100-D-48:1 deep decision unit
- 100-D-48:2 deep decision unit
- 100-D-48:3 deep decision unit
- 100-D-49:2 deep decision unit
- 100-D-49:4 deep decision unit
- 116-D-1A deep decision unit
- 116-D-7 deep decision unit
- 116-DR-1&2 deep decision unit
- 116-DR-6 deep decision unit
- 116-DR-9 deep decision unit
- 118-D-6:4 deep decision unit
- 118-D-6:4 deep focused decision unit
- 118-DR-2:2 deep decision unit
- 116-H-1 deep decision unit
- 116-H-3 deep decision unit
- 116-H-7 deep decision unit
- 118-H-6:2, 118-H-6:3, 118-H-6:6, 100-H-9, 100-H-10, 100-H-11, 100-H-12, 100-H-13, 100-H-14, and 100-H-31 deep 2 decision unit
- 118-H-6:2, 118-H-6:3, 118-H-6:6, 100-H-9, 100-H-10, 100-H-11, 100-H-12, 100-H-13, 100-H-14, and 100-H-31 deep 3 decision unit

6.5.1.4 Deep Zone Results for RI and LFI Data

Soil samples were collected from depths greater than 4.6 m (15 ft) bgs from the following locations:

- Twelve RI soil borings (seven from 100-D Source OU and five from 100-H Source OU)
- Fifteen of the RI wells (seven from 100- D Source OU and eight from 100-H Source OU)
- Five RI test pits (three from 100-D Source OU and two from 100-H Source OU)
- Twenty-three LFI soil borings (18 from 100-D Source OU and five from 100-H Source OU)
- Six LFI wells (all from 100-H Source OU)

The conclusions from the evaluation of the deep zone RI and LFI data are consistent with the conclusions of the soil risk assessment.

For the 100-D Source OU, RI soil boring/well samples from 116-D-1B Trench (C7855), 116-D-7 Retention Basin (C7851), and the 118-D-6 Reactor Fuel Storage Basin (C7857) and 100-D RUM Well R5 redrill (C8668) report radionuclide concentrations greater than residential RBSLs. LFI soil boring samples from 116-D-1A Trench (199-D5-21), 116-D-1B Trench (199-D5-29), 116-DR-1&2 Trench (199-D8-62), 116-D-2 Crib (199-D5-22), 116-D-9 Crib (199-D5-26), and the 132-D-3 Pumping Station (199-D5-28) also report radionuclide concentrations greater than residential RBSLs. 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 RBSL. The following summarizes the results of the comparisons for the previously listed waste sites:

- LFI data, CVP/RSVP closeout data, and RI soil boring data are available for the 116-D-1A Trench. This site is a potential source for groundwater contamination in the D northern Cr(VI) groundwater plume. The RI data indicate that individual risks from all detected analytes are less than the risk threshold of 1×10^{-4}. The results of the LFI data analysis and the risk assessment for the deep decision unit identify similar radioisotopes as contributors to risk (cesium-137, cobalt-60, europium-152, europium-154, and strontium-90). These radioisotopes are present at depths ranging between 5.2 and 16.2 m (17 and 53.2 ft) bgs. Concentrations of all isotopes decay to levels less than residential RBSLs between years 2174 and 2196.

- LFI and RI soil boring data are available for the 116-D-1B Trench. The results of the RI data analysis and the LFI data analysis identify similar radioisotopes as contributors to risk (cesium-137, cobalt-60, europium-152, europium-154, and strontium-90) and concentrations of all isotopes decay to levels less than residential RBSLs between years 2092 and 2177. Cesium-137 and europium-152 radioisotopes are present at depths ranging between 4.8 and 7.1 m (15.7 and 23.2 ft) bgs and strontium-90 is present at depths ranging between 6.3 and 15.8 m (20.7 and 52 ft) bgs in the RI soil boring. Cesium-137, cobalt-60, europium-152, europium-154, and strontium-90 are present at depths ranging between 4.3 and 8.1 m (14 and 26.7 ft) bgs. The 116-D-1B Trench is a consolidated waste site associated with the 116-D-1A Trench; therefore, the risk assessment results reported for the 116-D-1A Trench apply to the 116-D-1B Trench.

- LFI data, CVP/RSVP closeout data, and RI soil boring data are available for the 116-D-7 Retention Basin. The RI data analysis identifies cesium-137 as a contributor to risk and the risk assessment for the 116-D-7 waste site (deep decision unit) identifies cesium-137, cobalt-60, europium-152, europium-154, and nickel-63 as contributors to risk. Cesium-137 is present at depths ranging between 6.1 and 9.8 m (19.9 and 32 ft) bgs. 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 RBSLs by year 2063 and year 2083, respectively.

- LFI data, CVP/RSVP closeout data, and RI soil boring data are available for the 116-DR-1&2 Trench. This site is historically a source for groundwater contamination in the D northern and Horn Cr(VI) groundwater plumes. However, the RI data indicate that individual risks from all detected analytes remaining in the soil at the present day are less than the risk threshold of 1×10^{-4}. The results of the LFI data analysis and the risk assessment for the deep decision unit identify similar radioisotopes as contributors to risk (cesium-137, cobalt-60, europium-152, europium-154, and strontium-90). Concentrations of all isotopes decay to levels less than residential RBSLs between years 2163 and 2122. These radioisotopes are present at depths ranging between 4.5 and 6.8 m (14.8 and 22.3 ft) bgs.

- LFI data, CVP/RSVP closeout data, and RI soil boring data are available for the 116-DR-9 Retention Basin. The RI data and LFI data indicate that individual risks from all detected analytes are less than the risk threshold of 1×10^{-4}. The risk assessment for the 116-DR-9 waste site (deep decision unit) identifies cesium-137 and europium-152 as contributors to risk. Concentrations of these isotopes decay to levels less than residential RBSLs by year 2037.

- RI soil boring data are available for the 118-D-6 Reactor Fuel Storage Basin. The RI data analysis identifies cesium-137 as a contributor to risk. Concentrations of cesium-137 decay to activity levels less than the residential RBSL by year 2120. Cesium-137 is present at depths ranging between 5.9 and 8.2 m (19.5 and 27 ft) bgs.

- RI soil boring data are available for the 100-D RUM Well R5 Redrill. The RI data analysis identifies strontium-90 as a contributor to risk. Concentrations of strontium-90 decay to activity levels less than the residential RBSL by year 2012. Strontium-90 is present at depths ranging between 24 and 24.7 m (78.6 and 81.1 ft) bgs.

- LFI data and CVP/RSVP closeout data are available for the 116-D-2 Crib. The LFI data analysis identifies cesium-137 and strontium-90 as contributors to risk. Cesium-137 and strontium-90 were present at depths ranging between 5.2 and 6.1 m (17 and 20 ft) bgs. This waste site was subsequently remediated under the interim action ROD. The soil risk assessment did not identify risks associated with this site based on current conditions.

- LFI data and CVP/RSVP closeout data are available for the 116-D-9 Crib. The LFI data analysis identifies strontium-90 as a contributor to risk. Strontium-90 was present at depths ranging between 5.3 and 6.4 m (17.3 and 20.9 ft) bgs. The soil risk assessment did not identify risks associated with this site based on current conditions.

- LFI data are available for the 132-D-3 Pumping Station; soil samples were not collected from this site as part of the closeout documentation because this is a facility. The LFI data analysis identifies strontium-90 as a contributor to risk. Strontium-90 is present at depths ranging between 7.6 and 8.2 m (25 and 27 ft) bgs. Concentrations of strontium-90 decayed to activity levels less than the residential RBSL by year 1999.

- LFI data and CVP/RSVP closeout data are available for the 116-DR-7 Crib. The LFI data analysis identifies europium-152 as a contributor to risk. Europium-152 is present at depths ranging between 7.6 and 9.0 m (25 and 29.5 ft) bgs. Concentrations of strontium-90 decayed to activity levels less than the residential RBSL by year 2006. The soil risk assessment did not identify risks associated with this site based on current conditions.

For the 100-H Source OU, RI soil boring samples from the 116-H-1 Trench (C7864) report radionuclide concentrations greater than residential RBSLs. LFI soil boring samples from the 116-H-1 Trench (199-H4-58), the 116-H-7 Retention Basin (199-H4-61), and Well 199-H4-49 also report radionuclide concentrations greater than residential RBSLs. 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 RBSL.

- LFI data, CVP/RSVP closeout data, and RI soil boring data are available for the 116-H-1 Trench. The RI and LFI data analysis identifies cesium-137 and europium-152 as contributors to risk. These radioisotopes are present at depths ranging between 4.6 and 6.6 m (15.1 and 21.6 ft) bgs. The risk assessment for 116-H-1 Trench waste site (deep decision unit) identifies cesium-137, europium-152, europium-154, and strontium-90 as contributors to risk. Concentrations of radioisotopes decay to activity levels less than the residential RBSL between year 2065 (RI and LFI data) and year 2101 (CVP/RSVP closeout data).
- LFI data, CVP/RSVP closeout data, and RI soil boring data are available for the 116-H-7 Retention Basin. The RI data indicate that individual risks from all detected analytes are less than the risk threshold of 1×10^{-4}. Europium-152 concentrations in LFI data are reported above the residential RBSL and are present at depths ranging between 4.5 and 5.0 m (14.8 and 16.4 ft) bgs. Concentrations of europium-152 in LFI data decayed to activity levels less than the residential RBSL in year 1994. The risk assessment for 116-H-7 Retention Basin waste site (deep decision unit) identifies cesium-137, cobalt-60, europium-152, europium-154, and strontium-90 as contributors to risk. Cesium-137, cobalt-60, europium-152, europium-154, and strontium-90 concentrations at 116-H-7 decay to levels less than residential RBSLs by year 2070.
- LFI data are available for 199-H4-49 monitoring well. The LFI data analysis identifies technetium-99 as a contributor to risk and is present at depths ranging between 10.7 and 11.4 m (35 and 37.5 ft) bgs. Concentrations of technetium-99 do not decay within a reasonable timeframe because the half-life for this isotope is 213,000 years.

The results from several of the waste sites are based on small datasets, which creates uncertainties in obtaining reliable EPCs in vadose zone material. The uncertainties relating to small datasets could result in risks either being over- or understated. EPCs selected for shallow zone and deep zone decision units represent verification data collected from the floor and sidewalls of the excavated waste site. EPCs developed from the floor and sidewalls of the excavated waste site overstate risk because the contaminant is assumed to be uniformly distributed across the entire decision unit, and exposure is assumed to occur at the surface. However, only the sidewalls intersect the surface. If the contaminants are disturbed in the future, their distribution within the decision unit would be blended with the clean backfill, resulting in an overall reduction of the EPC for the decision unit. The approach for identifying COPCs is conservative because it excludes few contaminants and, therefore, probably overstates risks. The exposure factors and toxicity values used to develop the PRGs generally are conservative and tend to provide upper-bound estimates of risks in vadose zone material.

Based on the results of the soil risk assessment for the 100-D/H Source OU, cleanups in vadose zone material conducted as part of the interim actions appear to have been effective in reducing human health risks to within EPA's target risk range. In some cases, residual risks are higher than the State of Washington's cancer risk threshold; however, in all 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 those for a casual recreational

user and a resident Monument worker. Deep vadose zone samples (from remediated waste sites) were used to identify locations where institutional controls should be implemented to prevent in advertent exposure through deep excavation activities. While this exposure would be industrial in nature, the RBSLs (developed for the Residential exposure scenario) were used for convenience to identify sites where institutional controls should be established to control access to deep contamination. These sites do not pose significant risks because there is no current exposure pathway for deep contamination. Concentrations in deep vadose material will decay to the Residential RBSLs within185 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 provides 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-HR-3 Groundwater OU was evaluated as three separate exposure areas including the 100-D Source, 100-H Source, and Horn exposure areas. The 100-D Source exposure area represents the plume sources in 100-D, including the northern and southern Cr(VI) plumes. The 100-H Source exposure area represents the plume sources in 100-H. The Horn exposure area represents the portion of the Cr(VI) plume that is located in the Horn area where 100-D Sources have dispersed over time.

100-D Source Exposure Area. The contaminants in groundwater that are the largest contributors to calculated risks, dose, and HIs are Cr(VI) and total chromium, chloroform, and nitrate. The EPCs in groundwater were compared with AWQC and state water quality standards for protection of human health and aquatic organisms, federal and state primary and secondary DWSs, and state groundwater cleanup levels.

The EPC for nitrate is greater than the federal and state DWSs developed for the protection of human health. Nitrate is retained as a COPC, indicating the need to evaluate potential remedial technologies for these analytes in the FS.

Metals concentrations in groundwater higher than ambient water quality standards are chromium and Cr(VI). The EPCs for chromium and Cr(VI) are both higher than the AWQC for protection of aquatic receptors. In addition, the EPC for chromium is greater than the federal DWS. Therefore, the EPCs for both chromium species are greater than the DWS or developed for the protection of human health or AWQC and State water quality criteria (WAC 173-201A) developed to protect aquatic organisms, indicating the need to evaluate potential remedial technologies for these analytes in the FS.

Strontium-90 was reported at a concentration above the DWS at well 199-D5-32, this is the only result reported at this well. Additionally, well 199-D5-12, located south of the 116-D-1A liquid waste stream, historically reported strontium-90 concentrations above the DWS until it was decommissioned in 2002. Strontium-90 is retained as a COPC, indicating the need to evaluate potential remedial technologies in the FS.

The EPC for chloroform is greater than the 2007 MTCA Method B groundwater cleanup level, which is based on a 1×10^{-6} target cancer risk level. However, the cumulative risk for chloroform is less than the 2007 MTCA (HHRA Procedures [WAC 173-340-708]) cumulative risk level of 1×10^{-5} for multiple contaminants. The EPC for chloroform is also less than federal DWS developed for the protection of human health. The results of this evaluation for chloroform do not indicate the need to evaluate potential remedial technologies in the FS.

Based on the results of the groundwater risk assessment, chromium, Cr(VI), strontium-90, and nitrate are retained as COCs in the 100-D Source exposure area and indicate the need to evaluate potential remedial technologies in the FS.

The COPC identification process identified six analytes for the 100-D source exposure area that are retained as COPCsfor further monitoring. The occurrence of antimony, cadmium, cobalt, copper, lead, and silver, and their nature and extent evaluation, indicates these analytes historically have been detected in groundwater at concentrations above their respective action level, but their presence was not associated with a specific location or a trend. Therefore, these analytes warrant further monitoring.

The COPC identification process identified 12 analytes for the 100-D ISRM that are retained as COPCs for further monitoring. Seven of the 12 analytes (fluoride, iron, lead, manganese, nitrite, sulfate, and zinc) occur in a limited number of wells within the ISRM and their presence is associated with the reducing conditions created by the presence of zero valence iron. The remaining five analytes (antimony, cadmium, cobalt, copper, and silver) historically have been detected in groundwater at concentrations above their respective action level, but their presence was not associated with a specific location or a trend. Therefore, these analytes warrant further monitoring.

In addition to comparison to action levels, risks were evaluated using the Native American scenarios and the EPA Tap Water scenario. The total cumulative ELCRs for the 100-D Source exposure area for the CTUIR and Yakama Nation exposure scenarios are 3.0×10^{-4} and 3.2×10^{-4}, respectively, when groundwater is used as a drinking water source. The total cumulative ELCRs for both Native American scenarios are greater than the EPA upper target risk threshold of 1×10^{-4}. The primary contributors to risk for the CTUIR and Yakama Nation scenarios are carbon tetrachloride, chloroform, bromodichloromethane, strontium-90, technetium-99, and tritium. The total ELCR for the EPA Tap Water scenario is 7.5×10^{-5}, which is within the EPA range of 1×10^{-4} to 1×10^{-6}. The primary contributors to risk for the Tap Water scenario are carbon tetrachloride, chloroform, bromodichloromethane, technetium-99, and tritium. Arsenic is a primary contributor to risk for each of the scenarios (approximately 75 percent); however, levels of arsenic in groundwater are considered naturally occurring. The remaining analytes that are reported contribute approximately 25 percent of the total cumulative risk. The total HI for the 100-D Source exposure area is 26 for both the CTUIR and Yakama Nation exposure scenarios. The HI for the EPA tap water equations is 13. Cr(VI) is the primary contributor to the noncancer HI for the Native American scenarios, as well as the primary contributor to the EPA Tap Water exposure scenario.

The cumulative ELCR is 5.0×10^{-1} for the CTUIR scenario and 1.0×10^{-0} 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 primary contributor to risk is Cr(VI) for both of the scenarios (greater than 99 percent contribution). The HI for the 100-D Source exposure area is 99 for the CTUIR scenario and 716 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. The primary contributors to the noncancer HI are Cr(VI), cobalt, nickel, and barium.

100-H Source Exposure Area. The contaminants in groundwater that are the largest contributors to risks, dose, and HIs are strontium-90 and Cr(VI). The EPCs in groundwater were compared with AWQCs and state water quality standards for protection of human health and aquatic organisms, federal and state primary and secondary DWSs, and state groundwater cleanup levels.

The EPC for strontium-90 is greater than the federal 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.

The EPC for Cr(VI) is greater than the State water quality standard (WAC 173-201A) developed for the protection of aquatic receptors. Cr(VI) is identified as a COPC, indicating the need to evaluate potential remedial technologies for Cr(VI) in the FS.

Although the EPC for nitrate is less than the DWS developed for the protection of human health, it is present at concentrations above the DWS in localized areas. Nitrate is retained as a COPC; its presence warrants design considerations for any engineered controls or remedial actions performed in this OU.

Although the EPC for chromium is less than the AWQC developed for the protection of aquatic receptors, it is present at concentrations above the AWQC in localized areas. Chromium is identified as a COPC that warrants further monitoring.

Although the EPC for uranium is less than the DWS developed for the protection of human health, it is present at concentrations above the DWS at a single well within the 100-H area. Uranium is retained as a COPC for further monitoring.

Based on the results of the groundwater risk assessment, the following COPCs are identified as COCs in the 100-H Source exposure area and indicate the need to evaluate potential remedial technologies in the FS: Cr(VI), nitrate, and strontium-90.

The COPC identification process identified six analytes for the 100-H source exposure area that are retained as COPCs for further monitoring. The analytes in the 100-H source exposure area include antimony, cadmium, cobalt, copper, lead, and silver. The nature and extent evaluation indicates these analytes historically have been detected in groundwater at concentrations above their respective action level, but their presence was not associated with a specific location or a trend. Therefore, these analytes warrant further monitoring.

In addition to comparison to action levels, risks were evaluated using the Native American scenarios and the EPA Tap Water scenario. The total cumulative ELCRs for the 100-H Source exposure area for the CTUIR and Yakama Nation exposure scenarios are 4.0×10^{-4} and 4.2×10^{-4}, respectively, when groundwater is used as a drinking water source. The total cumulative ELCRs for both Native American scenarios are greater than the EPA upper target risk threshold of 1×10^{-4}. The primary contributors to risk for the CTUIR and Yakama Nation scenarios are carbon tetrachloride, strontium-90, technetium-99, and tritium. The total ELCR for the EPA Tap Water scenario is 9.6×10^{-5}, which is within the EPA range of 1×10^{-4} to 1×10^{-6}. The primary contributors to risk for the Tap Water scenario are carbon tetrachloride, strontium-90, and tritium. Arsenic is a primary contributor to risk for each of the scenarios (approximately 75 percent); however, levels of arsenic in groundwater are considered naturally occurring. The remaining analytes that are reported contributeapproximately 25 percent of the total cumulative risk. The total HI for the 100-H Source exposure area is 3.3 for both the CTUIR and Yakama Nation exposure scenarios. The HI for the EPA tap water equations is 1.6. No individual COPC in the 100-H Source exposure area had a HQ greater than the EPA target HI of 1 for the Native American scenarios or the EPA Tap Water exposure scenario.

The cumulative ELCR is 1.8×10^{-2} for the CTUIR scenario and 1.3×10^{-1} 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 value for Cr(VI) is greater than the EPA upper target risk threshold of 1×10^{-4}. The HI for the 100-H Source exposure area is 13 for the CTUIR scenario and 96 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. The primary contributors to the noncancer HI are Cr(VI), cobalt, nickel and barium.

Horn Exposure Area. The principal contaminants in groundwater are chromium and Cr(VI). The EPCs in groundwater were compared with AWQC and state water quality standards for protection of human health and aquatic organisms, federal and state primary and secondary DWSs, and state groundwater cleanup levels.

Metals concentrations in groundwater higher than ambient water quality standards are chromium (AWQC) and Cr(VI) (WAC 173-201A). Chromium and Cr(VI) are COPCs, indicating the need to evaluate potential remedial technologies for chromium and Cr(VI) in the FS.

Based on the results of the groundwater risk assessment the following COPCs are identified as COCs and indicate the need evaluate potential remedial technologies in the FS: chromium and Cr(VI).

The COPC identification process identified five analytes for the Horn exposure area that are retained as COPCsfor further monitoring. The analytes in the Horn exposure area include antimony, cadmium, cobalt, copper, and silver. The nature and extent evaluation indicates these analytes historically have been detected in groundwater at concentrations above their respective action level, but their presence was not associated with a specific location or a trend. Therefore, these analytes warrant further monitoring.

In addition to comparison to action levels, risks were evaluated using the Native American scenarios and the EPA Tap Water scenario. The total cumulative ELCRs for the Horn exposure area for the CTUIR and Yakama Nation exposure scenarios are 5.3×10^{-4} and 5.7×10^{-4}, respectively, when groundwater is used as a drinking water source. The total cumulative ELCRs for both Native American scenarios are greater than the EPA upper target risk threshold of 1×10^{-4}. The primary contributors to risk for the CTUIR and the Yakama Nation scenarios are 1,2-dichloroethane, carbon tetrachloride, chloroform, trichloroethene, strontium-90, and tritium. The total ELCR for the EPA Tap Water scenario is 1.3×10^{-4}, which is greater than the EPA upper target risk threshold of 1×10^{-4}. The primary contributors to risk for the Tap Water scenario are 1,2-dichloroethane, carbon tetrachloride, and tritium. Arsenic is a primary contributor to risk for each of the scenarios (approximately 90 percent); however, levels of arsenic in groundwater are considered naturally occurring. The remaining analytes that are reported contribute less than 10 percent of the total cumulative risk. The total HI or the Horn exposure area is 4.6 for both the CTUIR and Yakama Nation exposure scenarios. The HI for the EPA tap water equations is 2.4. Cr(VI) is the primary contributor to the noncancer HI for the Native American scenario. No individual COPCs had a HQ greater than the EPA target HI of 1 for the EPA Tap Water exposure scenario.

The cumulative ELCR is 4.9×10^{-2} for the CTUIR scenario and 3.1×10^{-1} 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 value for Cr(VI) is greater than the EPA upper target risk threshold of 1×10^{-4}. The HI for the Horn exposure area is 14 for the CTUIR scenario and 101 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. The primary contributors to the noncancer HI are Cr(VI) and barium.

The key uncertainties in the assessment of groundwater risks are with the assessment of dermal contact exposure pathways, selection of the toxicity value for carbon tetrachloride, and recent developments with the toxicity value for Cr(VI). The evaluation of potential risks from VOCs is based on ingestion and inhalation exposure pathways and does not consider exposure through dermal contact with water. Not including the dermal contact exposure pathway potentially results in risks from these contaminants being understated. TIngestion exposure to Cr(VI) is currently assessed as a noncarcinogen for purposes of developing groundwater cleanup levels for protection of human health, and Cr(VI) currently does not have a federal MCL. However, some state agencies, particularly the NJDEP, have developed a cancer slope factor for Cr(VI). Assessing ingestion of Cr(VI) in groundwater as a carcinogen is not yet incorporated into regulatory requirements or guidance at this time; however, groundwater standards for protection of human health for Cr(VI) would be considerably lower if these were based on carcinogenic effects.

The results from the groundwater risk assessment were based on three additional rounds of groundwater sampling across the 100-HR-3 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 work plan. The results of the groundwater risk assessment identified total chromium, Cr(VI), strontium-90, and nitrate as contaminants warranting further evaluation in the FS.

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-D/H 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 evaluated soil contaminant concentrations at 142 interim closed and no action waste sites.
- The ERA relied on ecological PRGs presented in the RCBRA that protect 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-D/H under interim action ROD remedial action goals protect 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 chromium and Cr(VI) in the 100-HR-3 Groundwater OU contribute to potential ecological risks.
- 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 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 protect 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 assumptions that attainment of standards for protection of human health or that reduced contaminant leaching would protect 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 (DOE/RL-2007-21)[1] was prepared to address the regulatory requirement to perform a baseline risk assessment. The RCBRA (DOE/RL-2007-21) was a comprehensive examination of current and potential risks in areas potentially affected by Hanford Site processes within the 100 Area and 300 Area OUs. One of the objectives of the RCBRA (DOE/RL-2007-21) was to determine whether the interim actions protected 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 (DOE/RL-2007-21) 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 southern and western shorelines of the Columbia River on the Hanford Site.
- Groundwater and areas of groundwater emergence on the southern and western shorelines of the Columbia River on the Hanford Site

[1] All citations to the RCBRA (DOE/RL-2007-21) in this chapter are referring to *Volume I: Ecological Risk Assessment*.

The RCBRA (DOE/RL-2007-21) 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 interim action RODs. Based on this set of study sites, the results from the RCBRA (DOE/RL-2007-21) identified contaminants in soil as contaminants of ecological concern (COECs). The principal COECs were metals and pesticides.

The study design of the ERA in the RCBRA (DOE/RL-2007-21) provided risk conclusions that applied across the entire River Corridor. The study design, coupled with results that identified COECs across the River Corridor, required development of an ERA approach for the RI/FS that allowed evaluation of risks on a site-by-site basis as well as supported development of preliminary remediation goals (PRGs). That approach incorporates the use of ecological (SSLs) [2] 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, found in Appendix H. This tiered process allows the incorporation of more sophisticated ERA methods and increasing levels of ecological site-specific and site relevant 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 75 waste sites in the 100-D (100-DR-1 and 100-DR-2) OUs and 36 waste sites in the 100-H (100-HR-1 and 100-HR-2) OUs, with verification sampling and analytical information, to provide site-specific ecological risk information for each site.

The CRC (DOE/RL-2010-117)[3] used analytical chemistry collected from surface water, sediment, pore water, and island soil 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 using refined toxicity and distributional data, the CRC (DOE/RL-2010-117) identified contaminants in soil as contaminants of potential ecological concern (COPECs). COPECs principally were metals. The potential for these contaminants to have originated from 100-D or 100-H is discussed later in this chapter. Three of the 75 waste sites in the 100-D Source OU and 5 of the 36 waste sites in the 100-H Source OU report only deep-zone data and therefore are not included in the evaluation.

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

- **Updating the identification of COPCs (Section 7.1).** The RCBRA (DOE/RL-2007-21) 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-D/H waste sites.

[2] SSLs were used for initial screening to eliminate chemicals, for which there is little likelihood of risk, while PRGs were used to provide both more refined risk screen and characterization as well as to aid risk management decisions (Section 7.6).

[3] All citations to the CRC (DOE/RL-2010-117) in this chapter are referring to *Volume I: Screening-Level Ecological Risk Assessment*.

- **Presenting the problem formulation (Section 7.2).** This section summarizes the problem formulation used in developing the risk-based concentration values used in this ERA as ecological SSLs. This problem formulation reflects conditions in upland environments across the Hanford Site and incorporates information developed from the RCBRA (DOE/RL-2007-21).

- **Presenting effects and exposure assessments (Section 7.3).** This section summarizes the quantitative assessments used in developing the Tier 1 and Tier 2 risk-based concentration values, including the wildlife exposure factors, biotransfer factors, and wildlife toxicity reference values (TRVs) (Appendix H, Tables H-1 and H-2). The data and methods used to develop risk-based concentrations that protect 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 incorporated into the RCBRA (DOE/RL-2007-21).

- **Updating the ecological risk characterization for 100-D/H waste sites (Section 7.4).** Verification sampling and analysis data for the 95 waste sites in the 100-D and 47 waste sites in the 100-H 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 COECs to determine the need for further action at 100-D/H 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 COECs in riparian and island soil 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 the 100-D/H nearshore area.

- **Presenting 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 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 of which, if any, risks should be addressed further in the FS. The process for developing final remediation goals was also discussed along with recommendations for the SMDP for evaluating waste sites as follows:

  - Size of the waste site relative to the home range of wildlife receptors (for example, developing and applying an area use factor [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 the area of adjacent uncontaminated habitat

  - Nature and extent of residual contamination following remediation

  - Potential presence of exposure pathways following remediation

  - Number and frequency of exceedances of the risk thresholds (PRGs)

- Location of the samples exceeding thresholds, sample frequency, and proximity of other exceedances
- Depth at which exceedances of the risk thresholds (PRGs) occur

Section 6.4 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 6.3 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 evaluation 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 evaluation 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 (DOE/RL-2010-117). Appendix L evaluates ecological risks identified within the Columbia River and the relationship among potential sources to the Columbia River in the 100-D/H 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 RCBRA (DOE/RL-2007-21) has been supplemented through the development of a conceptual model depicting the relationships among sources in the 100-D/H OUs and riparian and nearshore media (soil, sediment, pore water, and surface water). This conceptual model is presented as Appendix L.

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 process for identifying COPCs in soil. CVP and RSVP data collected within 95 waste sites in the 100-D Source OU and 47 waste sites in the 100-H Source OU were used to identify COPCs. This chapter presents the risk assessment for individual waste sites using CVP/RSVP data. During this ERA, COPCs were examined to identify a refined list of COPECs estimated to pose site-related ecological risks to receptor populations.

7.1.1 Data Summary

Remediation of waste sites in the 100-D/H Source OUs began in 1996. Ninety-five 100-D Source OU waste sites have verification sampling data and are included in this soil risk assessment. Twenty-eight of these 100-D Source OU waste sites were evaluated in the RCBRA (DOE/RL-2007-21). An additional thirteen 100-D Source OU sites, referred to as associated waste sites, have been remediated, but are included in another waste site's sampling and closeout documentation.

Forty-seven 100-H Source OU waste sites have verification sampling and analysis data and are included in this soil risk assessment. Eight of these thirty-six 100-H Source OU waste sites were evaluated in the RCBRA (DOE/RL-2007-21). An additional ten 100-H Source OU sites, referred to as consolidated sites, have been remediated but are included in another waste site's sampling and closeout documentation. A summary of the waste sites, associated decision unit(s), and reclassification status for the 100-D and 100-H Source OUs is provided in Tables G-1 and G-2, respectively (Appendix G). Waste site decision units are defined in Section 6.2.2.2. The waste sites listed in Tables G-1 and G-2 (Appendix G) are

a subset of the waste sites that were listed in Appendix C, Table C-1, of the 100-D/H Work Plan (DOE/RL-2008-46-ADD1).

7.1.2 Data Quality Assessment

A 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 whether the data are of the right type, quality, and quantity to support site cleanup verification decisions within specified error tolerances. The DQA also determines whether the analytical data are acceptable for decision-making purposes and whether the sample design was sufficient for clean site verification. The cleanup verification sample analytical data and detailed DQA are 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 quality assurance 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 100-D/H SAP (DOE/RL-2009-40) 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 waste sites in the 100-D/H OUs, included in the risk assessment, are 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 elevated background concentrations and their contribution to site risks and naturally occurring elements that are not CERCLA hazardous substances, pollutants, and contaminants, but exceed the risk-based screening levels.

The RCBRA (DOE/RL-2007-21) identifies a subset of analytes excluded from consideration as COPCs by agreement among the Tri-Parties based on relevant Hanford Site data. The following exclusion list used in the RCBRA (DOE/RL-2007-21) was 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 result from historical Hanford Site operation because radioactive decay would have occurred since operations ceased.
- **Essential nutrients:** Essential nutrients present at relatively low concentrations and 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 (for example, grain size for soil, 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 (DOE/RL-2007-21), these background radionuclides were identified by consensus of Tri-Party managers as not directly related to Hanford Site operations or processes.

A list of the analytes that meet the exclusion criteria for the soil risk assessment are listed in Section 6.2.2.2 and presented in Appendix G (Table G-3). The RCBRA (DOE/RL-2007-21) includes the following two additional steps to identify COPCs that the soil risk assessment did not apply:

- Analytes 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.
- Remaining analytes evaluated as candidate COPCs, based on comparisons to Hanford Site background, reference areas, and an analyte-specific evaluation.

As a result of not applying the last two steps used in the RCBRA (DOE/RL-2007-21) to identify COPCs, more analytes are identified as COPCs in this risk assessment than were identified in the RCBRA (DOE/RL-2007-21). Identifying all detected analytes (except those on the exclusion list) as COPCs is a more streamlined approach 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-D/H Area OUs. The EcoSSLs for aluminum and iron are based on soil pH (*Ecological Soil Screening Level for Aluminum: Interim Final* [OSWER Directive 9285.7 60] and *Ecological Soil Screening Level for Iron: Interim Final* [OSWER Directive 9285.7-69). The potential for aluminum toxicity is only identified in soils when the pH is 5.5 or less. While iron is essential for plant growth and is generally considered to be a micronutrient (*Soils and Soil Fertility* [Thompson and Troeh, 1973]), the potential for iron bioavailability is only identified when the pH is less than 5 or greater than 8 (*Ecological Soil Screening Level for Iron: Interim Final* [OSWER Directive 9285.7-69]). Oxidized environments (upland or well-aerated soils, such as those at the Hanford Site) promote the precipitation of ferric-oxide compounds, which are not available to plants for uptake. The main concern from an ecological risk perspective for iron is not direct chemical toxicity per se, but the effect of iron as a mediator in the geochemistry of other (potentially toxic) metals and the potential physical hazard of depositing flocculent (*Ecological Soil Screening Level for Iron: Interim Final* [OSWER Directive 9285.7-69]). These other COPECs are being evaluated with the screening levels identified in Section 7.3. Data collected during the 2011 Hanford-wide field study indicated that pH in soils range between 5.8 and 8.7 (*Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site* [ECF-HANFORD-11-0158]). The range of soil pH in the River Corridor indicates that aluminum would not be bioavailable. While most measurements of soil pH also suggest that iron would not be bioavailable, iron may be bioavailable at the limited number of locations where the soil pH exceeds 8. Thus, while aluminum concentrations are not bioavailable and do not pose a risk to terrestrial ecological receptors, iron may be bioavailable and has the potential to mediate toxicity in limited areas.

The COPC list for these OUs was 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 to identify 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 an ecological conceptual site exposure model that evaluates potential exposure pathways and identifies the representative species used to assess ecological risk to those and other similar species. The problem formulation includes identification of the important aspects of the 100-D/H Source OUs 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-D/H Area is in the northern portion of the Hanford Site adjacent to the Columbia River. The 100 Area reactors and associated facilities are on steep bluffs overlooking the river. The topography of the 100-D/H OU area is relatively flat inland from the Columbia River. The area has been disturbed and graded extensively by human activity since reactor construction began in the 1940s and through present-day waste site remedial activities. The surface elevation ranges from approximately 116 m (380 ft) above mean sea level at the Columbia River to 135 m (443 ft) above mean sea level on the eastern edge of 100-D. The upland environment is described in this section. The riparian and nearshore habitats are described in Appendix L, which evaluates the potential for exposures in the riparian and nearshore environments to be of concern and to have originated from 100-D or 100-H OU waste sites.

The predominant plant community in the 100 Area 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*). These plant species are restricted to wetlands in the riparian zone of the Columbia River (NEPA Characterization Report [PNNL-6415]). Table 3-22 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. Wildlife use of the remaining disturbed and developed areas is expected to be reduced because these areas are less attractive and provide fewer of the needs of wildlife than do natural habitats. However, even these areas can be frequented by wildlife. 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.

No species that regularly frequent the Hanford Site are listed 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. Fauna previously identified at the site are listed in Appendix H, Table H-21. Table H-22 in Appendix H lists the Flora and Fauna on the Threatened and Endangered Species List and its state status.

Bats have been found at the 183-H Clearwell and at 183-D Water Filtration Facility. A survey conducted in April 2009 and published in June 2011 concluded that there was no indication of bats at the 183-H Clearwell (WCH-450, *Bat Surveys of Retired Facilities Scheduled for Demolition by Washington Closure Hanford*). A similar survey during the same time frame was conducted at the 183-D Facility. Three types of bats were observed Yuma myotis (*Myotis yumanensis)*, pallid bats (*Antrozous pallidus*), and a small number of canyon bats *(Parastrellus hesperus)*. Pallid bats are a state-monitored species. A mitigation plan per Hanford Site Biological Resources Management Plan (DOE/RL-96-32) was carried out to provide an alternative roost. If needed, future mitigation plans will also follow Hanford Site Biological Resources Management Plan (DOE/RL-96-32).

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 continues to protect nest and roost sites on the Hanford Site under the *Bald Eagle Site Management Plan for the Hanford Site, South-Central Washington* (DOE/RL-94-150). Changes have been made to reduce the buffer zones surrounding winter night roosts and nest sites from 800 to 400 m (875 to 437.5 ft).

Bald eagles have generally been observed at the Hanford Site from November to March ("A Congregation of Wintering Bald Eagles" [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 Site Management Plan for the Hanford Site, South-Central Washington* [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 are found. Two roosting sites are in this same area (*Bald Eagle Site Management Plan for the Hanford Site, South-Central Washington* [DOE/RL-94-150]). Although these areas along the Columbia River are primarily between 100-D and 100-H, additional consideration of these species is not required for this risk assessment. Additional discussion on site setting and site history is included in Sections 3.10 and 1.2, respectively.

Although upland environments remain the focus of this discussion, it should be noted that the section of Columbia River adjacent to the Hanford Site is within the Hanford Reach, which extends from Priest Rapids Dam downstream to the slack waters of Lake Wallula, created by McNary Dam. The Hanford Reach contains three species listed as threatened or endangered under the *Endangered Species Act of 1973*, including Upper Columbia River spring-run Chinook salmon (*Oncorhynchus tshawytscha*), Upper Columbia River steelhead trout (*Oncorhynchus mykiss*), and bull trout (*Salvelinus confluentus*). The occurrence of these species within the Hanford Reach is discussed in detail in Appendix H.

7.2.2 Simplified Ecological Exposure Model for Upland Sites

Development of the ecological exposure model for this ERA involved characterizing the exposure pathways and ecological receptors associated with the habitat types in the upland environment of the waste sites within the 100-D/H OUs. Appropriate exposure pathways and representative endpoint species for the upland environment of the 100-D/H OUs were developed based on information from the RCBRA (DOE/RL-2007-21) and are discussed below. A full risk assessment 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 used here as in those documents. The aquatic exposure models are described in Section L.2.4 (Appendix L) with the evaluation of the aquatic exposure pathways. Appendix H evaluates the potential for the exposure of threatened and endangered species to site-related chemicals in the Hanford Reach. Results of those exposure and effects evaluations (that is, the risk characterization) are discussed in Chapter 4, Appendix L, and Section 7.6 of this chapter with respect to the potential for the 100-D/H 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-D/H Source OUs upland environments, the ecological exposure pathways considered most plausible are shown on Figure 7-1 and include the following:

- Direct contact of vegetation with analytes in surface soil.
- Direct contact with, or ingestion of, surface soil by terrestrial invertebrates (for example, 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 (for example, 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 soil below the biologically active zone. Therefore, deep soil was not evaluated in this ERA.

A food web model for the upland environment of the Hanford Site (Figure 7-2) was developed based upon 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 micro-organisms 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[4]

Some endpoints 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 because of acute, chronic, and reproductive effects, or disruption in

[4] 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.

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 protecting 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 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, protecting that population would be acceptable. However, the measurement endpoints described in the next section that 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 observed effect concentration (LOEC) or lowest observed adverse effect level (LOAEL) endpoints for the protection of populations and communities is appropriate. Section III in *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."

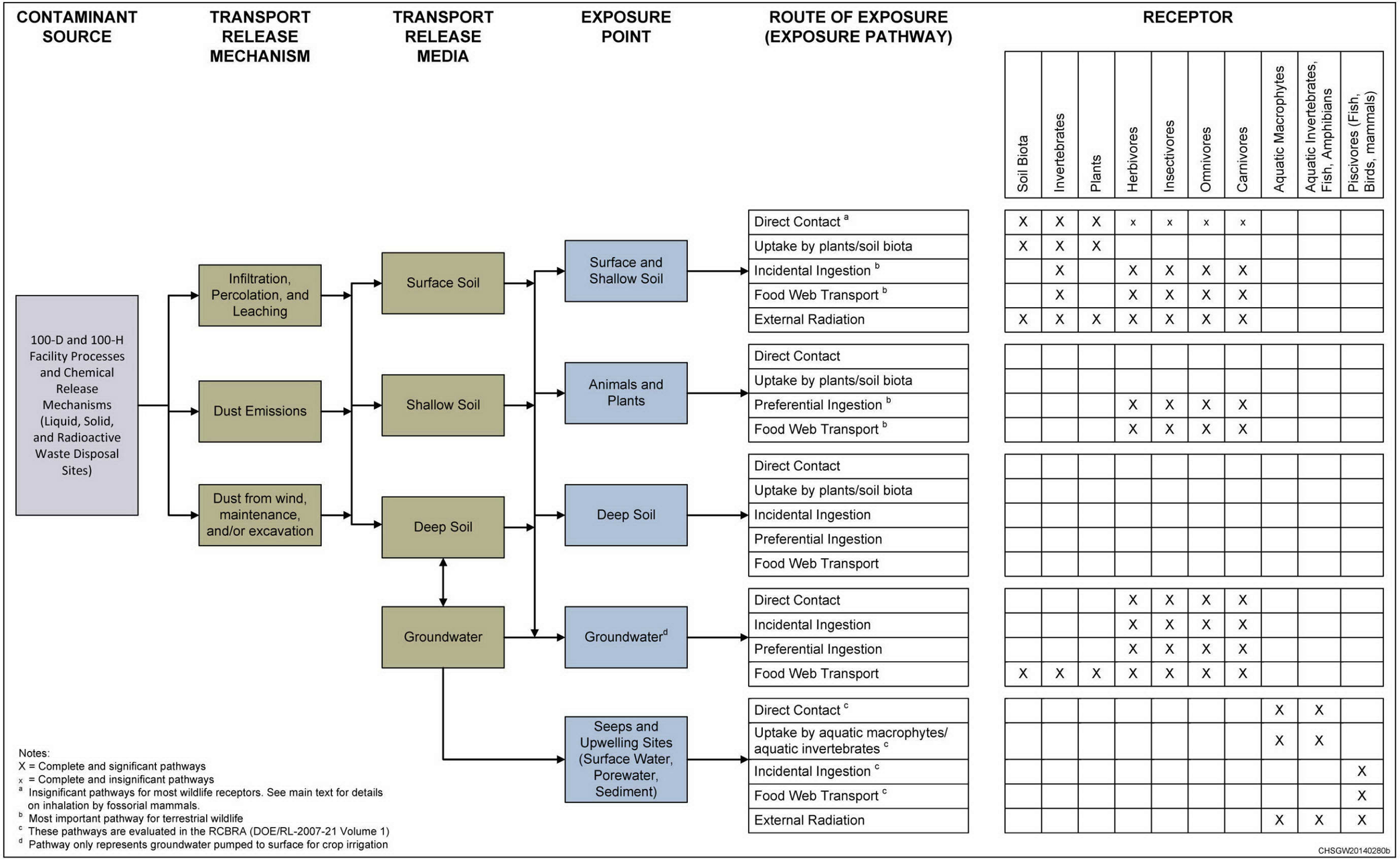

Figure 7-1. Ecological Conceptual Site Model for Terrestrial Habitats in Hanford Site Upland Environment

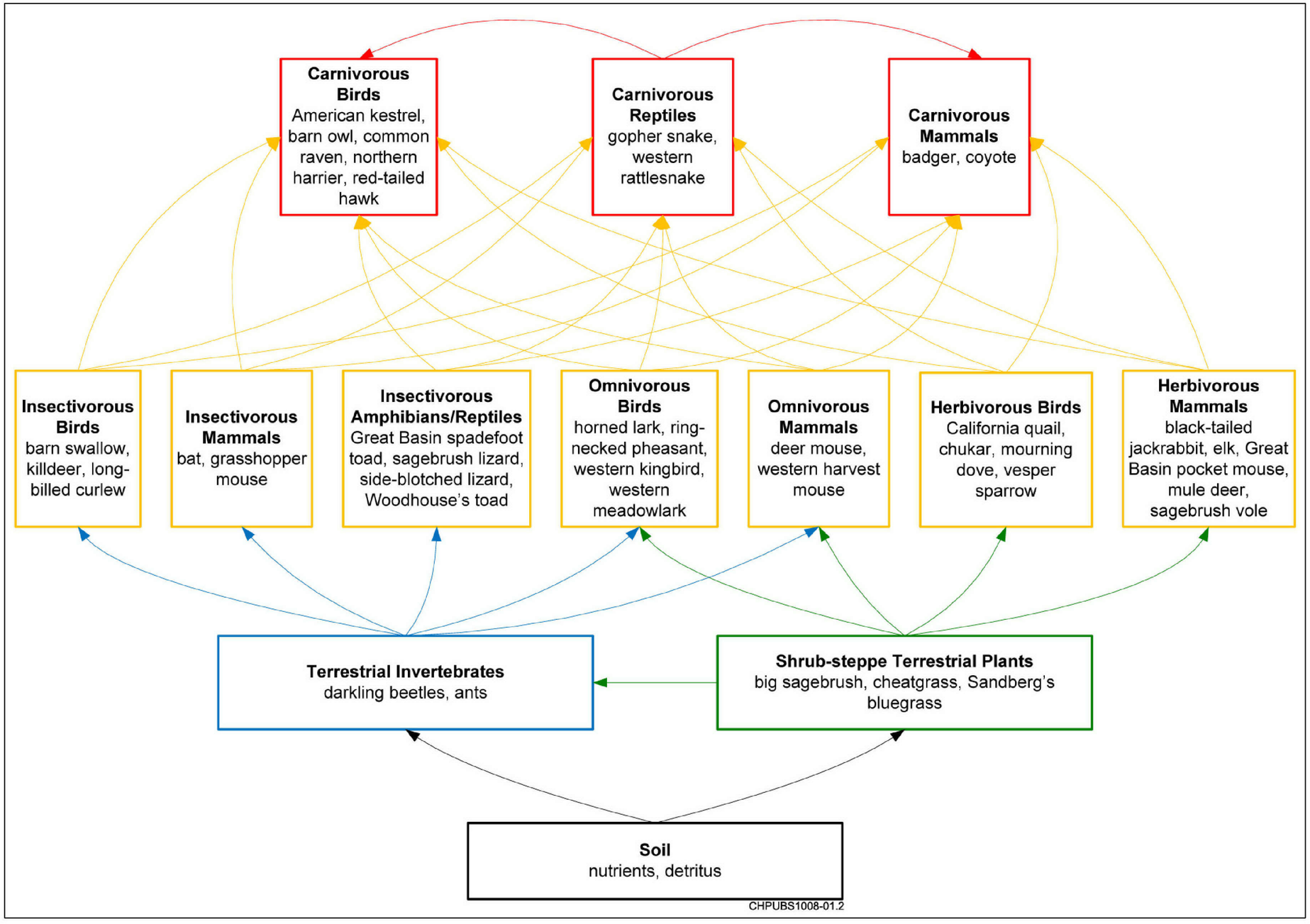

Figure 7-2. Hanford Site Upland Environment Terrestrial Food Web

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 2007 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 evaluation. 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 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. The three components to each assessment endpoint are as follows: 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-D/H Source OUs 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 used to select it. Entities and attributes were selected for community and population levels of assessment.

7.2.4 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 are as follows:

- Measures of exposure are used to evaluate intake of a contaminant from contact with environmental media (for example, 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. The 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 (for example, a wildlife population) throughout its exposure area (for example, the entire home range of the target species). Thus, the average exposure to multiple individuals (for example, 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 used in this evaluation include TRVs for wildlife (Appendix H, Tables H-1 and H-2) and LOECs in soil for plants and soil invertebrates (Section 7.3.1). The maximum acceptable adverse effect levels generally selected for population- and community-level assessment endpoints are the 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 ecological risk assessment or evaluation. This ecological information was 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 integrated to develop two levels of thresholds for evaluating the 100-D/H 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 evaluation on those COPEC-receptor-waste sites combinations that might require further evaluation. The additional evaluation completed with a comparison to PRGs helps identify which COPEC-receptor-waste sites combinations should be brought forward to the SMDP in Section 7.6. Comparisons to SSLs were used to identify COPEC receptor waste sites combinations for the SMDP in cases where the second tier of effect level (PRG) was not available or recommended (e.g., organics, radionuclides, and a few inorganics).

For wildlife, the effects assessment presents TRVs derived from literature-based toxicity information on COPCs that can be used in determining the potential for adverse effects to ecological receptors. The following two types of effects-based values are presented in this ERA: initial conservative values from published literature (for example, Ecology, EPA, and DOE guidance or compendiums), and more Hanford Site-specific values (values established using data collected at the Hanford Site). These values are 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. The exposure assessment uses the following 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. The development of the nonradionuclide and radionuclide SSLs and PRGs is summarized in the exposure assessment for each receptor group (that is, 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.

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 sections, effects for plants and invertebrates are discussed separately from wildlife. For radionuclides, the effects assessment includes values that correspond to effects from a dose of radiation. For nonradionuclides, plant and invertebrate effects are described relative to direct exposure, whereas for wildlife, the effects are described relative to the ingested dose.
- 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 7.3.2.3 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 describes wildlife exposure through drinking from seeps along the Columbia River.
- Section 7.3.4 describes 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 comparisons with the SSLs and PRGs.

7.3.1 Effects Assessment

The ecological effects assessment consists of an evaluation of available toxicity or other effects information 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 (for example, soil) that protect plant and invertebrate communities and wildlife populations.

7.3.1.1 Effects Assessment of Radionuclides

Radionuclide toxicity data for plants and wildlife are represented by DOE's Biota Concentration Guides (BCG) for radionuclides, presented in *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE-STD-1153-2002), hereinafter called Graded Approach for Radiation Doses to Biota. 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]), *Proliferation Resistance Fundamentals for Future Nuclear Energy Systems* (IAEA STR-332), and *Sources and Effects of Ionizing 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), which includes the following screening method and three 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 (that is, soil) with a set of BCGs to evaluate compliance with the biota dose limits.
- Site-specific screening using more realistic site- representative lumped parameters (for example, bioaccumulation factors [BAFs]) in place of conservative default parameters, using mean radionuclide concentrations in place of maximum values, and considering time dependence and spatial extent of contamination.
- Site-specific analysis using 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 presented in Graded Approach for Radiation Doses to Biota (DOE-STD-1153-2002). The values in soil, calculated using these default methods, are included in Table 6-4 of 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, 2009a) 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 that protect 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 the following 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 receptor-specific SSLs were developed using RESRAD-BIOTA for Windows, Version 1.5 (ANL, 2009a) with Level 3 assumptions. Values were established for eight species representing feeding guilds at the site. However, Hanford Site-specific tissue residue of radionuclides was insufficient for developing models so values from relevant published literature were used ("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 listed 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 sum of fractions (SOF) method. With the SOF method, the contributions of radionuclides were reviewed to determine their contribution to dose. Contributions were considered significant if the radionuclide EPC was greater than the SSL and 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 used and an explanation of the selection of effects data. The overarching theme was to use the most recent of relevant toxicological information available as described within ERAGS (EPA 540-R-97-006) and 2007 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 EcoSSLs (http://www.epa.gov/ecotox/ecossl/)
- Screening benchmark concentrations in soil developed by ORNL; many of the ecological indicator soil concentrations published by Ecology were drawn from ORNL screening benchmark concentrations
- Washington State Department of Ecology's ecological indicator soil concentrations, found in "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. Each source is summarized 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 soil. 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 the following four ecologically relevant endpoints: reproduction, population characteristics, growth, or physiological changes. Toxicity parameters used in deriving the EcoSSLs 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 NOAEC and LOAEC. Studies that reported only a LOAEC or only a NOAEC (for example, unbound studies) 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 equivalent to NOAECs. The EcoSSL for plants and soil invertebrates instead represent a level where effects have been observed but to a percent of individuals that is considered acceptable within the ERA practice and to be protective of populations or communities, 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 selecting a value that approximated the 10th percentile.

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 of 2007 MTCA (WAC 173-340), represent soil concentrations expected to be protective at any 2007 MTCA (WAC 173-340) site and are provided for use in eliminating hazardous substances from further consideration under 2007 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 Potential 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 Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision* (ES/ER/TM-126/R2).

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

			EPA EcoSSLs			ORNL - ES/ER/TM-85/R3, ES/ER/TM-126/R2		DOE BCGs		Washington State Dept. of Ecology – 2007 MTCA (WAC 173-340, Table 749-3)		Lowest Screening Benchmark by Receptor Type					
Group	Soil Constituent	Units	Plants	Invertebrate	Reference	Plants	Invertebrate	Terrestrial Plant	Terrestrial Animal	Plant	Soil Biota	Plant	Inverts	Overall Lowest Screening Benchmark	Background Soil Concentrations[a]	SSL for Plants and Soil Invertebrates[b]	Basis
Radionuclides	Americium-241	pCi/g	---	---	---	---	---	21,500	3,890	---	---	21,500	---	21,500	---	21,500	Benchmark
	Antimony-125	pCi/g	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Carbon-14	pCi/g	---	---	---	---	---	60,700	4,760	---	---	60,700	---	60,700	---	60,700	Benchmark
	Cesium-134	pCi/g	---	---	---	---	---	1,090	11.3	---	---	1,090	---	1,090	---	1,090	Benchmark
	Cesium 137	pCi/g	---	---	---	---	---	2,210	20.8	---	---	2,210	---	2,210	1.05	2,210	Benchmark
	Cobalt-60	pCi/g	---	---	---	---	---	6,130	692	---	---	6,130	---	6,130	0.00842	6,130	Benchmark
	Curium-244	pCi/g	---	---	---	---	---	153,000	4,060	---	---	153,000	---	153,000	---	153,000	Benchmark
	Europium-152	pCi/g	---	---	---	---	---	14,700	1,520	---	---	14,700	---	14,700	---	14,700	Benchmark
	Europium-154	pCi/g	---	---	---	---	---	12,500	1,290	---	---	12,500	---	12,500	0.0334	12,500	Benchmark
	Europium-155	pCi/g	---	---	---	---	---	153,000	15,800	---	---	153,000	---	153,000	0.0539	153,000	Benchmark
	Hydrogen-3 (tritium)	pCi/g	---	---	---	---	---	1,680,000	174,000	---	---	1,680,000	---	1,680,000	---	1,680,000	Benchmark
	Neptunium-237	pCi/g	---	---	---	---	---	8,150	3,860	---	---	8,150	---	8,150	---	8,150	Benchmark
	Nickel-63	pCi/g	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Plutonium-238	pCi/g	---	---	---	---	---	17,500	5,270	---	---	17,500	---	17,500	0.00378	17,500	Benchmark
	Plutonium-239/240	pCi/g	---	---	---	---	---	12,700	6,110	---	---	12,700	---	12,700	0.0248	12,700	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	---	---	---	---	---	3,580	22.5	---	---	3,580	---	3,580	0.178	3,580	Benchmark
	Technetium-99	pCi/g	---	---	---	---	---	21,900	4,490	---	---	21,900	---	21,900	---	21,900	Benchmark
	Thorium-232	pCi/g	---	---	---	---	---	23,500	1,510	---	---	23,500	---	23,500	1.32	23,500	Benchmark
	Uranium-234	pCi/g	---	---	---	---	---	51,600	5,130	---	---	51,600	---	51,600	1.1	51,600	Benchmark
	Uranium-235	pCi/g	---	---	---	---	---	27,400	2,770	---	---	27,400	---	27,400	0.109	27,400	Benchmark
	Uranium-238	pCi/g	---	---	---	---	---	15,700	1,580	---	---	15,700	---	15,700	1.06	15,700	Benchmark

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

			EPA EcoSSLs			ORNL - ES/ER/TM-85/R3, ES/ER/TM-126/R2		DOE BCGs		Washington State Dept. of Ecology – 2007 MTCA (WAC 173-340, Table 749-3)		Lowest Screening Benchmark by Receptor Type					
Group	Soil Constituent	Units	Plants	Invertebrate	Reference	Plants	Invertebrate	Terrestrial Plant	Terrestrial Animal	Plant	Soil Biota	Plant	Inverts	Overall Lowest Screening Benchmark	Background Soil Concentrations[a]	SSL for Plants and Soil Invertebrates[b]	Basis
Metals	Aluminum	mg/kg	Narrative Statement		OSWER Dir. 9285.7-60	50	---	---	---	50	---	50	---	50	11,800	11,800	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(III)	mg/kg	---	---	OSWER Dir. 9285.7-66	1	0.4	---	---	42	42	1	0.4	0.4	---	0.4	Benchmark
	Chromium(VI)	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	---	---	---	1,100	---	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	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	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

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

			EPA EcoSSLs			ORNL - ES/ER/TM-85/R3, ES/ER/TM-126/R2		DOE BCGs		Washington State Dept. of Ecology – 2007 MTCA (WAC 173-340, Table 749-3)		Lowest Screening Benchmark by Receptor Type					
Group	**Soil Constituent**	**Units**	**Plants**	**Invertebrate**	**Reference**	**Plants**	**Invertebrate**	**Terrestrial Plant**	**Terrestrial Animal**	**Plant**	**Soil Biota**	**Plant**	**Inverts**	**Overall Lowest Screening Benchmark**	**Background Soil Concentrations[a]**	**SSL for Plants and Soil Invertebrates[b]**	**Basis**
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	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	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	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

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

			EPA EcoSSLs			ORNL - ES/ER/TM-85/R3, ES/ER/TM-126/R2		DOE BCGs		Washington State Dept. of Ecology – 2007 MTCA (WAC 173-340, Table 749-3)		Lowest Screening Benchmark by Receptor Type					
Group	Soil Constituent	Units	Plants	Invertebrate	Reference	Plants	Invertebrate	Terrestrial Plant	Terrestrial Animal	Plant	Soil Biota	Plant	Inverts	Overall Lowest Screening Benchmark	Background Soil Concentrations[a]	SSL for Plants and Soil Invertebrates[b]	Basis
	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
	Pyrene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	18	18	---	18	Benchmark
	Total PAHs	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Low molecular weight PAHs[e]	mg/kg	---	29	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	29	29	---	29	Benchmark
	High molecular weight PAHs[f]	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	---	18	18	---	18	Benchmark

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

			EPA EcoSSLs			ORNL - ES/ER/TM-85/R3, ES/ER/TM-126/R2		DOE BCGs		Washington State Dept. of Ecology – 2007 MTCA (WAC 173-340, Table 749-3)		Lowest Screening Benchmark by Receptor Type					
Group	Soil Constituent	Units	Plants	Invertebrate	Reference	Plants	Invertebrate	Terrestrial Plant	Terrestrial Animal	Plant	Soil Biota	Plant	Inverts	Overall Lowest Screening Benchmark	Background Soil Concentrations[a]	SSL for Plants and Soil Invertebrates[b]	Basis
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 (o-cresol)	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	4-methylphenol (p-cresol)	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	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Dichlorodiphenyltrichloroethane	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Dieldrin	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Endosulfan I	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Endosulfan II	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Endosulfan sulfate	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

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

			EPA EcoSSLs			ORNL - ES/ER/TM-85/R3, ES/ER/TM-126/R2		DOE BCGs		Washington State Dept. of Ecology – 2007 MTCA (WAC 173-340, Table 749-3)		Lowest Screening Benchmark by Receptor Type					
Group	Soil Constituent	Units	Plants	Invertebrate	Reference	Plants	Invertebrate	Terrestrial Plant	Terrestrial Animal	Plant	Soil Biota	Plant	Inverts	Overall Lowest Screening Benchmark	Background Soil Concentrations[a]	SSL for Plants and Soil Invertebrates[b]	Basis
	Endrin aldehyde	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Methoxychlor	mg/kg	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

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

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

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

2007 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 chromium (total) not available, the lower of either Cr(III) or Cr(VI) as available was used as a surrogate.

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

e. The low molecular weight 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 PAHs. For the purposes of this assessment, the benchmark was also applied to the individual low molecular weight PAHs.

f. The high molecular weight 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 ES/ER/TM-126/R2.

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

m. MTCA values based on chlordane.

--- = value not available

ORNL = Oak Ridge National Laboratory

TPH = total petroleum hydrocarbons

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	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
Radionuclides	Americium-241	pCi/g	--	--	--	--	--	--	--	--	--	28,900	25,000	11,900	17,800	72,100	48,700	41,400	4,840	4,840
	Carbon-14	pCi/g	--	--	--	--	--	--	--	--	--	54	60	56	50	61	60	135	32	32
	Curium-244	pCi/g	--	--	--	--	--	--	--	--	--	389,000	252,000	105,000	207,000	2,300,000	722,000	499,000	50,800	50,800
	Cobalt-60	pCi/g	--	--	--	--	--	--	--	--	--	805	805	805	863	805	805	806	1,000	805
	Cesium-134	pCi/g	--	--	--	--	--	--	--	--	--	1,140	1,190	1,200	854	1,160	1,180	1,270	562	562
	Cesium 137	pCi/g	--	--	--	--	--	--	--	--	--	2,390	2,700	2,800	1,430	2,510	2,630	3,280	924	924
	Europium-152	pCi/g	--	--	--	--	--	--	--	--	--	1,740	1,740	1,740	1,880	1,740	1,740	1,740	2,220	1,740
	Europium-154	pCi/g	--	--	--	--	--	--	--	--	--	1,610	1,610	1,610	1,740	1,610	1,610	1,610	2,060	1,610
	Europium-155	pCi/g	--	--	--	--	--	--	--	--	--	33,400	33,400	33,400	37,300	33,400	33,400	33,400	48,600	33,400
	Hydrogen-3 (tritium)	pCi/g	--	--	--	--	--	--	--	--	--	1,430	1,280	936	1,130	3,270	2,290	2,830	420	420
	Neptunium-237	pCi/g	--	--	--	--	--	--	--	--	--	8,190	8,140	7,880	9,150	8,250	8,170	8,180	11,200	7,880
	Nickel-63	pCi/g	--	--	--	--	--	--	--	--	--									
	Plutonium-238	pCi/g	--	--	--	--	--	--	--	--	--	36,300	56,200	20,900	26,800	291,000	161,000	161,000	5,980	5,980
	Plutonium-239/240	pCi/g	--	--	--	--	--	--	--	--	--	38,800	60,300	22,300	28,400	324,000	175,000	176,000	6,270	6,270
	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	--	--	--	--	--	--	--	--	--	4,580	4,580	4,580	5,040	4,580	4,580	4,580	6,130	4,580
	Strontium-90	pCi/g	--	--	--	--	--	--	--	--	--	521	302	151	112	706	519	413	91	91
	Technetium-99	pCi/g	--	--	--	--	--	--	--	--	--	5,360	11,500	137,000	280,000	8,670	12,100	412,000	128,000	5,360
	Thorium-232	pCi/g	--	--	--	--	--	--	--	--	--	5,070	12,900	5,340	12,400	34,400	32,500	86,200	4,560	4,560
	Uranium-234	pCi/g	--	--	--	--	--	--	--	--	--	12,700	21,800	6,370	40,900	30,300	24,800	51,600	14,200	6,370
	Uranium-235	pCi/g	--	--	--	--	--	--	--	--	--	6,340	7,810	4,360	10,200	8,600	8,130	9,630	8,060	4,360
	Uranium-238	pCi/g	--	--	--	--	--	--	--	--	--	8,020	10,400	5,150	22,100	11,900	11,000	13,900	13,400	5,150

NOAEL = no observed adverse-effect level

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Wildlife (Birds and Mammals). Bird and mammal TRVs for both the no observed adverse-effect levels (NOAEL) and LOAELs were used in the SSL and PRG development. The TRVs were used within models relating the ingested dose of the chemicals (Section 7.3.2, Exposure Assessment) with the TRVs to establish SSLs or PRGs that represent adverse effects thresholds. The TRVs were obtained from various sources, with a focus on the most recent sources and those derived or endorsed by EPA and Ecology (as evidenced by their use in either EcoSSLs or the 2007 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:

- 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*
- 2007 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 the 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 (for example, 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 use the work of this expert panel. Thus, for analytes that EPA has developed EcoSSLs for birds and mammals, those same NOAELs were used for wildlife SSL and PRG development for Hanford (see *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-00784], in Appendix H). 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 EcoSSL. In these cases, the LOAEL for Hanford SSL and PRG development was selected as the lowest LOAEL from the EcoSSL dataset above the geometric mean NOAEL.

One 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 study "Main and Interactive Effects of Arsenic and Selenium on Mallard Reproduction and Duckling Growth and Survival" (Stanley et al., 1994), conducted by USFWS at Patuxent wildlife research center over a 92- to 173-day period, resulted in both a NOAEL and a 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. All of these studies were conducted over 70 days or less. "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. "Main and Interactive Effects of Arsenic and Selenium on Mallard Reproduction and Duckling Growth and Survival" (Stanley et al., 1994) was conducted by a reliable research group over a much longer time frame and produced bound results (that is, the NOAEL was bound by a LOAEL). The intent of the EcoSSLs is to provide a value that can 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.

The other exception to this TRV selection process was for the uranium TRV for mammalian receptors. The TRV was selected based on detailed reviews of available toxicity literature conducted by both Ecology and CHPRC. Ecology recommended a LOAEL of 1.3 mg/U/kg/d based on analyses in "Derivation of Ecotoxicity Thresholds for Uranium" (Sheppard et al., 2005). However, significant uncertainties and inconsistencies were identified with the derivation of this 1.3 mg/kg/d TRV. Consequently, the dose of 2.8 mg U/kg/d from "The Developmental Toxicity of Uranium in Mice" (Domingo et al., 1989) was identified as the most appropriate LOAEL TRV for application at the Hanford Site as it was consistent with WAC 173-340-7493(4)(a). Details of these reviews are presented in Appendix H of *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311).

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 the following criteria:

- Studies were of chronic exposures or exposures during a critical stage of life (for example, reproduction).
- Exposure was oral through food ingestion to ensure data were representative of oral exposures expected for wildlife in the field.
- Emphasis was placed on studies of reproductive effects to ensure 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 (for example, growth, reproduction, or survival). If multiple studies for a given COPC met 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 included in Appendix H (*Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-00784] for SSLs and *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-01311] for PRGs).

7.3.2 Exposure Assessment

The exposure assessment for plants and invertebrates, wildlife, and radionuclides is summarized 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 sections for nonradionuclide SSLs, radionuclide SSLs, and nonradionuclide PRGs, which include 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 (that is, receptors are directly exposed to COPCs). Although other exposure pathways (for example, 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, biotic media (food), inhalation, and dermal contact. Modeling is often used 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].

Following is the general form of the model used to estimate exposure of birds and mammals to chemicals in environmental media (*Ecological Risk Assessment for Contaminated Sites* [Suter et al., 2000]):

$$E_t = E_o + E_d + E_i$$

where:

E_t = total chemical exposure experienced by wildlife

E_o = oral exposure

E_d = dermal exposure

E_i = 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-93/187]). Similarly, methods and data necessary to estimate wildlife inhalation exposures are poorly developed (*Wildlife Exposure Factors Handbook*, Vol. I and II [EPA/600/R-93/187]) or limited.[4] Recent publications have suggested the inclusion of inhalation and dermal pathways for developing TRVs for VOCs in fossorial mammals ("Efforts to Standardize Wildlife Toxicity Values Remain Unrealized," [Mayfield and Fairbrother, 2012]; "Wildlife Ecological Screening Levels for Inhalation of Volatile Organic Chemicals" [Gallegos et al., 2007]); and pesticides in birds ("A Comprehensive Re-Analysis of Pesticide Dermal Toxicity in Birds and Comparison with the Rat" [Mineau, 2012]), respectively. Olfactory bulb uptake in fossorial mammals affords a significant exposure route to Mn and Cd in soils was noted in "Olfactory Bulb Intake and Determination of Biotransfer Factors in the California Ground Squirrel (Spermophilus Beecheyi) Exposed to Manganese and Cadmium in Environmental Habitats," (Bench et al., 2001). However, VOCs and pesticides were not the primary COPECs identified for the 100-D/H OUs in past investigations, and methods for olfactory exposure and risk characterization are not well established. Additionally, a wildlife receptor's exposure to contaminants by inhalation and dermal contact usually contributes little to its overall exposure. Dermal exposure also is likely to be low, even in burrow dwelling animals, because of the presence of protective dermal layers (for example, feathers, fur, or scales). Therefore, for the purposes of developing the SSL values, both dermal and inhalation exposure were assumed to be negligible[5]. 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-D/H Areas move down to the Columbia River riparian area and drink from the freshwater seeps and from the 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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[5] If the CSM had indicated that VOCs are a significant COPEC, focused analyses of the inhalation pathway may have been warranted, but VOCs were not significant at 100-D or 100-H. Risk-based concentrations or PRGs for this pathway, however, are beyond the scope of this report.

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

where:

Et =

total exposure (mg/kg/day)

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

P_s = proportion of total food intake that is soil (kg soil/kg food)

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 [Appendix H, Table H-6] 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 PRGs for nonradionuclides. These SSLs and PRGs consist of soil concentrations associated with estimated dietary exposures equivalent to a selected effect level and were calculated using the following basic equation:

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

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 weight)

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

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

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

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

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

$Frac_s$ = 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 levels. 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 BAFs or bioaccumulation regression models to extrapolate to the food source. This equation is solved for wildlife SSLs or PRGs using the 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-D/H Source OUs remediated waste sites. The SSLs and PRGs were compared to EPCs developed for the 100-D/H OUs 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, wildlife was assumed to forage exclusively within the waste site being evaluated, resulting in an AUF of 1. In other words, the resulting SSLs and PRGs did not account for wildlife home range instead of 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 detailed 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 included as part of the total dietary composition, as reflected by the $Frac_s$ term in the dietary equation,
- All animals were assumed to be year-round residents, and migration away from areas contaminated with COPCs was not assumed.
- 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 (EPC) were assumed 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, 2001]). These allometric conversions are detailed in *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-00784) included in Appendix H.

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 (that is, the SSL or PRG). Bioaccumulation models and assumptions used within the calculation of wildlife SSLs and PRGs are described below. While some of them are the same as those within MTCA ("Site-Specific Terrestrial Ecological Evaluation Procedures" [WAC 173-340-7493]) promulgated in 2001, advancements in estimating bioaccumulation into food items were published as part of the initial (2003) and subsequent updates (2005 and 2007) to *Guidance for Developing Ecological Soil Screening Levels* (OSWER Directive 92857-55). These models and assumptions represent the most recent equations used in ERA and are now the standard of practice; thus they were employed for developing SSLs and PRGs for Hanford.

- **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 used 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 1 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 Table H-4 (Appendix H). 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 the existing bioaccumulation models (that is, 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 more site-specific and site-relevant bioaccumulation models.[6] A discussion of the uncertainty around the site-specificity associated with pooling Hanford-specific data with data from a broader range outside Hanford is found in Section 7.4.9. The following Hanford Site-specific and literature-based datasets were used to develop these bioaccumulation models presented in Appendix H (Table H-5):

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 individual 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 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.

Literature Derived Bioaccumulation Data for Plants and Small Mammals. 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 databases from *Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants* (BJC/OR-133) and "Uptake of Inorganic Chemicals from Soil by Plant Leaves: Regressions of Field Data" (Efroymson et al., 2001) were used. In addition, the small mammal bioaccumulation database from *Development and Validation of Bioaccumulation Models for Small Mammals* (ES/ER/TM-219) was used. These datasets were used in their entirety; no observations were excluded, and no additional data, other than that used in the EcoSSLs, were included. These data also represent the primary bioaccumulation data for inorganics integrated into *Guidance for Developing Ecological Soil Screening Levels* (OSWER Directive 9285.7-55). Electronic copies of the original databases were obtained from the authors to facilitate integration with Hanford Site-specific data.

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

The development of the plant bioaccumulation database is described in "Uptake of Inorganic Chemicals from Soil by Plant Leaves: Regressions of Field Data" (Efroymson et al., 2001) as follows:

> "Field and greenhouse studies in which concentrations of arsenic, cadmium, copper, lead, mercury, nickel, selenium, or zinc in both surface soil and collocated, aboveground plant tissue were analyzed were identified. Information regarding soil and plant concentrations, soil parameters, exposure time, chemical form, dry or wet weight, extraction method, plant species, and plant part was compiled in a spreadsheet. The database included the following number of observations per growth form: 525, graminoid; 544, forb/herb; 4, forb/herb or vine; 69, forb/herb or shrub; 16, shrub; 18, tree or shrub; 49, tree; and 107 unknown or composited samples. Approximately thirty percent of the data represented chemical concentrations in plant leaves, excluding stems, fruits and seeds; and the remaining aboveground samples included clippings, unspecified aboveground parts or shoots. Samples of fruits or seeds alone were excluded from the database. Tests in which salts (e.g., cadmium chloride, copper sulfate, sodium selenate) were added in solution to soil were excluded because of preliminary results that suggested regressions of concentrations in plants on concentrations in soil were different for field and salt chemical forms.
>
> Only studies in which concentrations were expressed on an air- or oven-dry weight basis were used. Although most studies reported that plant material was washed, studies were not excluded if the extent of washing was not stated in the paper. Studies were used even if the individual investigators observed no correlation between concentrations of contaminants in soils and plants. Concentrations of chemicals in soil or plants were sometimes estimated from a figure, but only if estimates could be made within about ten percent. Data for species that are known to hyperaccumulate metals were excluded. Data for which measured concentrations were below detection thresholds were excluded.
>
> Each plant species or variety, soil type, location, and concentration of the test element in soil represented an independent observation in the dataset. Differences in exposure duration or above-ground plant part did not constitute separate observations; concentrations in soils or plants that differed on the basis of one of these two variables were averaged. The number of observations in these means, which ranged between 1 and 6, was not retained in the subsequent statistical analysis.
>
> Concentrations of contaminants in soil at the time of plant sampling were used if known. If these concentrations were not measured (as was often the case in pot studies), the initial concentration of the element measured in or added to soil was assumed to be equivalent to the final concentration. In field experiments, the change in soil concentration of an element over time was assumed to be minimal.
>
> Observations were included in the database if the total chemical concentration in soil was measured, either by extraction with strong acid or by extraction with moderately strong acid (e.g., 4N sulfuric acid) sometimes accompanied by heat. Studies in which concentrations of contaminants in soil were determined by a partial extraction with DTPA (diethylene triamine pentaacetic acid), weak acids, or water were excluded from analysis.
>
> For studies in which contaminant concentrations at multiple depths were measured, the concentration at the 0-10, 0-15, or 0-20 cm depth interval was recorded. Where only a single soil depth was measured, it ranged from 5 to 70 cm.

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	Meadowlark	Killdeer	Red-Tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	NOAEL Lowest	California Quail	Meadowlark	Killdeer	Red-Tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	LOAEL Lowest
Metals	Aluminum	mg/kg	22,019.89	18,601.60	4,920.58	61,782.28	687.18	270.79	380.00	710.10	270.79	--	--	--	--	6,871.78	2,707.93	3,798.53	7,100.99	2,707.93
	Antimony	mg/kg	--	--	--	--	8.82	0.66	0.60	16.66	**0.60**	--	--	--	--	96.64	6.61	5.98	166.64	**5.98**
	Arsenic, Total all valence states	mg/kg	1,799.96	1,980.65	425.03	10,343.53	264.76	104.92	170.75	549.25	**104.92**	8,103.60	10,558.64	2,131.65	45,439.07	459.41	189.51	318.36	880.60	**189.51**
	Arsenic (III)	mg/kg	1,799.96	1,980.65	425.03	10,343.53	264.76	104.92	170.75	549.25	**104.92**	8,103.60	10,558.64	2,131.65	45,439.07	459.41	189.51	318.36	880.60	**189.51**
	Arsenic (V)	mg/kg	1,799.96	1,980.65	425.03	10,343.53	264.76	104.92	170.75	549.25	**104.92**	8,103.60	10,558.64	2,131.65	45,439.07	459.41	189.51	318.36	880.60	**189.51**
	Barium	mg/kg	1,228.88	1,270.92	659.91	14,442.04	2,081.99	1,889.09	4,605.48	18,842.90	**659.91**	2,463.67	2,547.94	1,323.00	28,953.51	3,469.98	3,148.48	7,675.79	31,404.83	**1,323.00**
	Beryllium	mg/kg	--	--	--	--	13.95	17.96	100.83	282.51	**13.95**	--	--	--	--	--	--	--	--	**--**
	Bismuth	mg/kg	--	--	--	--	--	--	--	--	**--**	--	--	--	--	--	--	--	--	**--**
	Boron	mg/kg	63.94	86.46	139.66	796.74	39.76	49.95	284.01	766.77	**39.76**	222.00	300.21	484.92	2,766.47	132.92	166.97	949.39	2,563.21	**132.92**
	Cadmium	mg/kg	151.07	2.77	0.89	1,374.94	76.19	1.47	1.30	455.47	**0.89**	277.98	5.08	1.63	2,335.22	2,065.15	27.54	23.57	5,228.02	**1.63**
	Chromium (total)	mg/kg	334.34	96.52	36.52	1,286.46	320.38	74.72	77.98	752.34	**36.52**	349.42	100.88	38.17	1,355.27	1,284.17	299.49	312.56	3,535.56	**38.17**
	Chromium (III)	mg/kg	334.34	96.52	36.52	1,286.46	320.38	74.72	77.98	752.34	**36.52**	349.42	100.88	38.17	1,355.27	1,284.17	299.49	312.56	3,535.56	**38.17**
	Chromium (VI)	mg/kg	--	--	--	--	1,233.45	287.66	300.21	3,379.86	**287.66**	--	--	--	--	5,339.59	1,245.29	1,299.60	16,583.35	**1,245.29**
	Cobalt	mg/kg	1,425.33	305.33	108.78	1,601.40	2,174.40	260.93	250.06	1,346.06	**108.78**	1,460.92	312.95	111.50	1,632.76	3,233.42	388.02	371.85	1,868.88	**111.50**
	Copper	mg/kg	485.15	85.30	35.84	3,727.67	872.95	99.95	109.38	2,640.09	**35.84**	1,914.48	271.87	107.07	13,020.77	1,893.59	175.77	182.42	4,672.45	**107.07**
	Lead	mg/kg	247.02	48.68	15.51	978.92	1,204.17	151.05	153.49	2,005.03	**15.51**	537.35	114.72	35.58	2,433.19	2,544.20	331.98	336.43	4,108.35	**35.58**
	Lithium	mg/kg	--	--	--	--	3,189.29	1,258.37	1,749.15	257.42	**257.42**	--	--	--	--	6,378.59	2,516.73	3,498.30	514.83	**514.83**
	Manganese	mg/kg	16,368.56	24,183.51	9,588.41	113,951.05	4,227.40	4,115.32	18,430.08	20,464.11	**4,115.32**	31,822.67	48,820.09	19,635.66	221,536.11	5,828.07	5,798.20	27,720.38	28,212.66	**5,798.20**
	Mercury	mg/kg	3.09	0.35	0.04	24.60	0.49	0.03	0.03	8.67	**0.03**	35.51	21.26	3.59	133.86	7.98	1.87	3.25	43.36	**1.87**
	Molybdenum	mg/kg	34.51	27.03	17.90	97.66	1.67	1.40	2.77	7.12	**1.40**	345.10	270.35	179.02	976.56	16.67	13.96	27.66	71.20	**13.96**
	Nickel	mg/kg	1,080.61	79.37	30.84	6,037.33	303.26	17.77	16.29	637.16	**16.29**	1,911.91	136.40	52.86	11,078.24	675.83	35.81	32.58	1,438.31	**32.58**
	Selenium	mg/kg	5.57	3.72	1.72	157.63	2.05	1.19	1.83	32.28	**1.19**	10.47	8.17	4.29	417.07	2.97	1.90	3.19	59.89	**1.90**
	Silver	mg/kg	345.30	12.76	4.96	2,043.71	1,441.77	34.55	30.00	3,096.93	**4.96**	3,452.99	127.57	49.62	20,437.07	14,417.68	345.55	299.96	30,969.35	**49.62**
	Strontium	mg/kg	--	--	--	--	9,442.09	4,849.22	6,476.09	4,227.51	**4,227.51**	--	--	--	--	--	--	--	--	**--**
	Thallium	mg/kg	--	--	--	--	5.09	1.84	2.43	2.63	**1.84**	--	--	--	--	25.45	9.21	12.16	13.14	**9.21**
	Tin	mg/kg	82.17	127.93	231.25	1,852.26	186.81	251.72	2,690.84	5,107.00	**82.17**	204.21	317.95	574.73	4,603.40	279.41	376.51	4,024.76	7,638.67	**204.21**
	Uranium	mg/kg	2,501.56	2,690.66	785.38	18,729.66	55.61	35.89	68.23	154.53	**35.89**	--	--	--	--	556.10	358.88	682.29	1549.29	**358.88**
	Vanadium	mg/kg	66.97	58.21	15.56	268.46	1,363.15	577.09	834.81	1,863.83	**15.56**	133.95	116.42	31.13	536.92	2,723.03	1,152.80	1,667.60	3,723.18	**31.13**
	Zinc	mg/kg	4,973.24	714.12	66.60	70,825.06	4,611.56	633.13	794.24	38,590.44	**66.60**	5,015.41	725.66	67.80	71,293.85	4,660.81	643.92	810.09	38,865.84	**67.80**
General Inorganics	Ammonia/ Ammonium	mg/kg	--	--	--	--	--	--	--	--	**--**	--	--	--	--	--	--	--	--	**--**
	Chloride	mg/kg	--	--	--	--	--	--	--	--	**--**	--	--	--	--	--	--	--	--	**--**

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	Meadowlark	Killdeer	Red-Tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	NOAEL Lowest	California Quail	Meadowlark	Killdeer	Red-Tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	LOAEL Lowest
	Cyanide	mg/kg	--	--	--	--	27,970.79	20,692.77	78,122.51	38,060.72	**20,692.77**	--	--	--	--	--	--	--	--	**--**
	Fluoride	mg/kg	1,492.00	2,812.00	556.00	9,206.00	9,824.70	8,216.34	35,672.53	17,379.40	**556.00**	6,123.00	11,539.00	2,281.00	37,771.00	16,520.65	13,816.13	59,984.89	29,224.21	**2,281.00**
	Iodine	mg/kg	--	--	--	--	159.37	183.40	1,557.90	759.00	**159.37**	--	--	--	--	1,593.68	1,834.00	15,579.01	7,589.98	**1,593.68**
	Nitrate/Nitrite	mg/kg	--	--	--	--	206,421.95	152,710.84	576,537.26	280,884.80	**152,710.84**	--	--	--	--	460,072.60	340,361.45	1,284,984.44	626,035.16	**340,361.45**
	Phosphate	mg/kg	--	--	--	--	--	--	--	--	**--**	--	--	--	--	--	--	--	--	**--**
	Sulfate/Sulfite	mg/kg	--	--	--	--	--	--	--	--	**--**	--	--	--	--	--	--	--	--	**--**
	Total Organic Carbon	%	--	--	--	--	--	--	--	--	**--**	--	--	--	--	--	--	--	--	**--**
Volatile Organics	1,1-dichloroethane	mg/kg	3,614.96	217.36	82.67	13,954.67	20,357.19	573.95	502.38	22,894.29	**82.67**	7,229.93	434.72	165.33	27,909.35	--	--	--	--	**165.33**
	1,1-dichloroethene	mg/kg	3,614.96	217.02	82.54	11,432.85	12,214.32	343.83	300.94	12,238.43	**82.54**	7,229.93	434.04	165.08	22,865.71	--	--	--	--	**165.08**
	1,1,1-trichloroethane	mg/kg	3,614.96	216.69	82.42	8,935.68	407,143.89	11,443.76	10,015.86	349,074.28	**82.42**	7,229.93	433.38	164.84	17,871.35	--	--	--	--	**164.84**
	1,1,2-trichloroethane	mg/kg	3,614.96	217.23	82.62	12,031.27	407,143.89	11,472.08	10,041.41	420,572.26	**82.62**	7,229.93	434.46	165.24	24,062.54	--	--	--	--	**165.24**
	1,1,2,2-tetrachloroethane	mg/kg	3,614.96	216.67	82.41	9,548.86	3,635.79	102.18	89.43	3,255.35	**82.41**	7,229.93	433.33	164.82	19,097.72	36,357.95	1,021.81	894.31	32,553.53	**164.82**
	1,2-dichlorobenzene	mg/kg	87.76	90.99	82.05	4,343.45	282.35	294.23	854.29	17,612.27	**82.05**	175.53	181.99	164.11	8,686.89	--	--	--	--	**164.11**
	1,2-dichloroethane (DCA)	mg/kg	3,614.96	221.88	84.32	16,083.77	20,357.19	585.79	513.07	24,709.56	**84.32**	7,229.93	443.75	168.64	32,167.55	--	--	--	--	**168.64**
	1,3-dichlorobenzene	mg/kg	96.13	95.93	82.03	4,051.47	309.75	313.74	853.99	16,651.92	**82.03**	192.26	191.85	164.05	8,102.94	--	--	--	--	**164.05**
	2-butanone (Methyl Ethyl Ketone/MEK)	mg/kg	2,101.72	1,040.62	312.32	11,538.19	721,051.83	159,713.07	176,661.35	970,850.97	**312.32**	21,017.23	10,406.18	3,123.19	115,381.89	1,861,054.73	412,223.86	455,967.83	2,505,793.22	**3,123.19**
	2-hexanone	mg/kg	2,101.72	548.27	185.63	9,653.17	2,035.72	243.60	236.58	2,511.81	**185.63**	21,017.23	5,482.66	1,856.29	96,531.69	14,697.89	1,758.76	1,708.10	18,135.29	**1,708.10**
	Benzene	mg/kg	8,554.00	513.00	195.00	27,053.00	285.00	8.02	7.02	285.56	**7.02**	--	--	--	--	2,850.01	80.23	70.22	2,855.63	**70.22**
	Butanol	mg/kg	--	--	--	--	50,892.99	2,906.16	2,625.73	67,048.62	**2,625.73**	--	--	--	--	203,571.95	11,624.66	10,502.90	268,194.47	**10,502.90**
	Carbon Tetrachloride	mg/kg	3,614.96	216.30	82.28	7,382.46	6,514.30	182.77	159.96	4,903.54	**82.28**	7,229.93	432.60	164.56	14,764.92	--	--	--	--	**164.56**
	Chlorobenzene	mg/kg	3,614.96	216.31	82.28	6,672.38	7,939.31	222.77	194.96	5,560.69	**82.28**	7,229.93	432.63	164.57	13,344.76	15,756.47	442.11	386.93	11,035.82	**164.57**
	Chloroform	mg/kg	3,614.96	217.17	82.60	13,002.94	6,107.16	172.03	150.58	6,600.19	**82.60**	7,229.93	434.33	165.19	26,005.89	16,692.90	470.22	411.58	18,040.51	**165.19**
	Cis-1,2-dichloroethylene	mg/kg	3,614.96	217.05	82.55	13,446.00	18,402.90	518.11	453.49	20,270.86	**82.55**	7,229.93	434.10	165.11	26,892.00	--	--	--	--	**165.11**
	Dichloromethane (Methylene Chloride)	mg/kg	3,614.96	217.95	82.88	17,281.03	2,381.79	67.33	58.94	2,999.00	**58.94**	7,229.93	435.91	165.77	34,562.06	20,357.19	575.50	503.78	25,632.44	**165.77**
	Ethyl Benzene	mg/kg	159.00	182.00	194.00	12,721.00	342.00	383.68	1,357.00	33,025.00	**159.00**	--	--	--	--	1,027.00	1,151.00	4,073.00	99,076.00	**1,027.00**
	Methyl Isobutyl Ketone	mg/kg	2,101.72	572.87	192.73	10,211.45	721,051.83	90,039.69	87,995.70	915,291.62	**192.73**	21,017.23	5,728.72	1,927.26	102,114.45	1,861,054.73	232,394.92	227,119.32	2,362,392.98	**1,927.26**
	n-butyl Benzene	mg/kg	301.00	263.25	193.00	7,857.00	529.53	484.77	1,091.54	18,135.28	**193.00**	--	--	--	--	1,588.60	1,454.30	3,274.62	54,405.85	**1,454.30**
	Tetrachloroethylene	mg/kg	3,614.96	215.72	82.07	7,733.34	570.00	15.95	13.96	443.18	**13.96**	7,229.93	431.44	164.13	15,466.68	2,850.01	79.75	69.79	2,215.89	**69.79**
	Toluene	mg/kg	8,554.00	512.13	195.00	17,200.00	21,171.48	594.37	520.19	15,763.32	**195.00**	--	--	--	--	211,714.82	5,943.66	5,201.85	157,633.17	**5,201.85**

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	Meadowlark	Killdeer	Red-Tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	NOAEL Lowest	California Quail	Meadowlark	Killdeer	Red-Tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	LOAEL Lowest
	Trans-1,2-dichloroethylene	mg/kg	3,614.96	217.05	82.55	11,881.41	18,402.90	518.11	453.49	18,869.15	**82.55**	7,229.93	434.10	165.11	23,762.81	--	--	--	--	**165.11**
	Trichloroethylene (TCE)	mg/kg	3,614.96	216.77	82.45	7,497.82	285.00	8.01	7.01	216.87	**7.01**	7,229.93	433.53	164.90	14,995.63	2,850.01	80.13	70.14	2,168.73	**70.14**
	Xylene	mg/kg	149.00	174.99	194.00	13,419.00	422.29	480.57	1,787.19	45,266.25	**149.00**	--	--	--	--	825.70	939.65	3,494.50	88,509.43	**825.70**
Polycyclic Aromatic Hydrocarbons	Acenaphthene	mg/kg	6,830.60	284.90	109.59	38,361.66	71,250.18	1,396.31	1,210.97	96,952.35	**109.59**	68,306.01	2,849.00	1,095.94	383,616.62	142,500.36	2,792.63	2,421.93	193,904.70	**1,095.94**
	Acenaphthylene	mg/kg	3,505.79	18.59	7.36	38,361.66	24,320.69	91.39	77.90	96,952.35	**7.36**	43,765.65	186.19	73.61	383,616.62	54,131.54	182.92	155.81	193,904.70	**73.61**
	Anthracene	mg/kg	3,405.23	169.72	67.83	38,361.66	178,810.67	4,783.60	4,213.42	554,013.42	**67.83**	43,404.77	1,716.22	678.31	383,616.62	--	--	--	--	**678.31**
	Benzo(a)pyrene	mg/kg	47.19	5.97	2.41	767.23	60.38	8.08	7.64	554.01	**2.41**	--	--	--	--	634.65	81.16	76.43	5,540.13	**76.43**
	Benzo(a)anthracene	mg/kg	117.98	5.21	2.03	767.23	306.81	7.26	6.40	554.01	**2.03**	--	--	--	--	3,635.53	73.37	64.00	5,540.13	**64.00**
	Benzo(b)fluoranthene	mg/kg	22.46	3.04	1.27	767.23	24.68	4.08	3.92	554.01	**1.27**	--	--	--	--	246.75	40.84	39.23	5,540.13	**39.23**
	Benzo(ghi)perylene	mg/kg	12.19	2.64	1.12	767.23	12.60	3.47	3.47	554.01	**1.12**	--	--	--	--	88.95	32.35	34.70	5,540.13	**32.35**
	Benzo[k]fluoranthene	mg/kg	136.25	3.25	1.27	767.23	405.73	4.56	3.92	554.01	**1.27**	--	--	--	--	4,069.49	45.63	39.23	5,540.13	**39.23**
	Chrysene	mg/kg	117.98	3.65	1.43	767.23	306.81	5.09	4.45	554.01	**1.43**	--	--	--	--	3,635.53	51.38	44.52	5,540.13	**44.52**
	Dibenz(ah)anthracene	mg/kg	43.63	3.54	1.42	767.23	54.29	4.86	4.41	554.01	**1.42**	--	--	--	--	542.86	48.58	44.13	5,540.13	**44.13**
	Fluoranthene	mg/kg	14.85	2.54	1.09	767.23	1,957.42	420.68	419.58	69,251.68	**1.09**	--	--	--	--	3,914.85	841.35	839.16	138,503.35	**839.16**
	Fluorene	mg/kg	6,830.60	44.59	17.54	38,361.66	50,892.99	156.71	133.55	69,251.68	**17.54**	68,306.01	445.91	175.36	383,616.62	101,785.97	313.43	267.10	138,503.35	**175.36**
	Indeno[1,2,3-cd]pyrene	mg/kg	48.73	2.90	1.15	767.23	62.64	4.00	3.57	554.01	**1.15**	--	--	--	--	626.38	40.03	35.67	5,540.13	**35.67**
	2-Methylnaphthalene	mg/kg	5.04	5.69	154.74	38,361.66	5.02	5.47	500.36	27,866.87	**5.02**	8.37	9.46	1,547.37	383,616.62	6.01	6.55	1,132.02	63,046.73	**6.01**
	Naphthalene	mg/kg	33.98	36.92	415.86	38,361.66	33.32	36.20	116.06	27,700.67	**33.32**	339.83	369.21	378.05	383,616.62	99.95	108.61	348.19	83,102.01	**99.95**
	Phenanthrene	mg/kg	4,329.17	235.76	94.31	38,361.66	301,134.27	6,731.36	5,919.25	554,013.42	**94.31**	56,061.03	2,405.58	943.13	383,616.62	--	--	--	--	**943.13**
	Pyrene	mg/kg	10.67	3.88	1.86	767.23	825.29	360.01	436.37	41,551.01	**1.86**	--	--	--	--	1,375.49	600.01	727.29	69,251.68	**600.01**
	Total PAHs	mg/kg	--	--	--	--	--	--	--	--	**--**	--	--	--	--	--	--	--	--	**--**
	Low MW PAHs	mg/kg	6,592.49	12,622.80	2,316.48	38,361.66	25,368.94	19,169.51	74,597.33	36,343.28	**2,316.48**	67,599.94	128,678.69	23,164.80	383,616.62	130,652.20	97,560.30	372,986.63	181,716.40	**23,164.80**
	High MW PAHs	mg/kg	39.51	72.42	46.33	767.23	29.05	39.00	699.35	340.72	**29.05**	--	--	--	--	156.91	208.68	3,491.06	1,700.82	**156.91**
Petroleum	Gasoline Range Organics	mg/kg	--	--	--	--	--	--	--	--	**--**	--	--	--	--	--	--	--	--	**--**
	TPH - Diesel	mg/kg	105,086.17	199,535.36	35,638.15	590,179.41	407,143.89	301,204.82	1,137,154.37	554,013.42	**35,638.15**	1,050,861.71	1,995,353.63	356,381.52	5,901,794.15	610,715.84	451,807.23	1,705,731.55	831,020.12	**356,381.52**
	TPH - Kerosene	mg/kg	105,086.17	199,535.36	35,638.15	590,179.41	407,143.89	301,204.82	1,137,154.37	554,013.42	**35,638.15**	1,050,861.71	1,995,353.63	356,381.52	5,901,794.15	610,715.84	451,807.23	1,705,731.55	831,020.12	**356,381.52**
Semivolatile Organics	Normal paraffin hydrocarbons	mg/kg	170,870.11	324,444.50	57,947.64	959,631.73	407,143.89	301,204.82	1,137,154.37	554,013.42	**57,947.64**	--	--	--	--	610,715.84	451,807.23	1,705,731.55	831,020.12	**451,807.23**
	Phenol	mg/kg	--	--	--	--	4,885.73	526.11	503.73	5,918.74	**503.73**	--	--	--	--	14,657.18	1,578.34	1,511.20	17,756.23	**1,511.20**

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	Meadowlark	Killdeer	Red-Tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	NOAEL Lowest	California Quail	Meadowlark	Killdeer	Red-Tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	LOAEL Lowest
	2-methylphenol (o-cresol)	mg/kg	--	--	--	--	127,436.04	10,037.62	9,293.33	134,503.46	**9,293.33**	--	--	--	--	--	--	--	--	**--**
	4-methylphenol (p-cresol)	mg/kg	--	--	--	--	127,436.04	10,101.66	9,357.99	136,360.50	**9,357.99**	--	--	--	--	--	--	--	--	**--**
	2,4-dinitrotoluene	mg/kg	0.29	0.30	0.20	7.17	13.78	13.46	35.58	285.89	**0.20**	38.14	39.15	26.35	932.00	28.79	28.13	74.35	597.39	**26.35**
	Bis[2-ethylhexyl] phthalate[a]	mg/kg	111.06	0.35	0.14	263.03	1,733.20	5.35	4.55	3,599.39	**0.14**	--	--	--	--	17,332.00	53.52	45.42	35,993.87	**45.42**
	Total PCBs[b]	mg/kg	10.01	0.65	0.33	25.09	2.92	0.30	0.27	8.47	**0.27**	100.12	3.58	1.82	250.88	29.22	1.61	1.47	84.71	**1.47**
	Aroclor 1016[b]	mg/kg	6.45	0.64	0.33	21.75	35.21	2.75	2.47	150.41	**0.33**	64.48	3.55	1.82	217.53	88.14	5.30	4.85	376.56	**1.82**
	Aroclor 1221[b]	mg/kg	2.73	0.61	0.33	24.02	0.69	0.25	0.27	8.15	**0.25**	27.30	3.44	1.82	240.18	6.88	1.48	1.47	81.52	**1.47**
	Aroclor 1232[b]	mg/kg	2.19	0.59	0.33	26.24	0.55	0.24	0.27	8.81	**0.24**	21.94	3.40	1.82	262.36	5.48	1.44	1.47	88.10	**1.44**
	Aroclor 1242[b]	mg/kg	10.36	0.65	0.33	25.55	3.09	0.30	0.27	8.74	**0.27**	103.60	3.59	1.82	255.51	30.91	1.63	1.49	87.35	**1.49**
	Aroclor 1248[b]	mg/kg	9.41	0.65	0.33	24.33	0.35	0.06	0.06	1.06	**0.06**	94.05	3.58	1.82	243.35	3.47	0.35	0.32	10.55	**0.32**
	Aroclor 1254	mg/kg	11.52	0.65	0.33	27.26	3.48	0.30	0.27	9.11	**0.27**	115.21	3.59	1.82	272.65	34.76	1.62	1.47	91.11	**1.47**
	Aroclor 1260[b]	mg/kg	20.38	0.66	0.33	51.49	7.67	0.30	0.27	15.42	**0.27**	203.80	3.62	1.82	514.89	76.65	1.64	1.47	154.21	**1.47**
	Aroclor-1262[b]	mg/kg	37.83	71.83	12.83	212.46	27.69	20.48	77.33	37.67	**12.83**	378.31	718.33	128.30	2,124.65	276.86	204.82	773.26	376.73	**128.30**
Pesticide	Dichloroprop	mg/kg	--	--	--	--	--	--	--	--	**--**	--	--	--	--	--	--	--	--	**--**
	Aldrin	mg/kg	0.45	0.08	0.03	1.06	10.22	1.99	1.96	26.80	**0.03**	2.24	0.40	0.16	5.30	51.12	9.94	9.82	133.98	**0.16**
	beta-1,2,3,4,5,6-Hexachlorocyclohexane	mg/kg	4.11	3.65	2.72	112.24	1.87	1.73	3.97	66.95	**1.73**	6.17	5.47	4.08	168.46	9.36	8.67	19.87	334.76	**4.08**
	alpha-Chlordane	mg/kg	121.50	24.28	10.08	301.53	92.53	20.47	20.66	264.12	**10.08**	607.51	121.40	50.41	1,507.65	925.29	204.66	206.56	2,641.24	**50.41**
	gamma-Chlordane	mg/kg	121.50	24.19	10.04	301.53	92.53	20.40	20.57	264.12	**10.04**	607.51	120.97	50.22	1,507.65	925.29	203.98	205.75	2,641.24	**50.22**
	Dichlorodiphenyldichloroethylene	mg/kg	30.37	0.21	0.07	0.06	20.48	0.11	0.09	0.03	**0.03**	300.36	2.30	0.80	1.70	135.88	0.71	0.59	0.40	**0.40**
	Dichlorodiphenyltrichloroethane	mg/kg	30.37	0.30	0.10	2.53	20.48	0.16	0.14	1.41	**0.10**	300.36	3.47	1.19	46.28	135.88	1.05	0.88	12.68	**0.88**
	Dieldrin	mg/kg	1.93	0.06	0.02	1.64	0.28	0.01	0.01	0.35	**0.01**	6.07	0.20	0.08	5.16	0.57	0.02	0.02	0.69	**0.02**
	Endosulfan I	mg/kg	93.44	66.32	41.40	1,671.48	0.92	0.71	1.29	21.88	**0.71**	--	--	--	--	--	--	--	--	**--**
	Endosulfan II	mg/kg	93.44	66.32	41.40	1,671.48	0.92	0.71	1.29	21.88	**0.71**	--	--	--	--	--	--	--	--	**--**
	Endosulfan sulfate	mg/kg	62.89	55.40	41.40	2,159.84	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**	--	--	--	--	5.13	1.36	1.41	140.40	**1.36**
	Methoxychlor	mg/kg	--	--	--	--	59.78	11.20	10.92	441.01	**10.92**	--	--	--	--	119.56	22.39	21.84	882.02	**21.84**

Shaded cells represent the lowest chemical specific NOAEL-based and LOAEL-based SSLs

a. Values for diethyl phthalate and di-n-butyl phthalate were used as a surrogate for bis(2)ethylhexyl phthalate.
b. Aroclor-1254 TRV was used as surrogate in the calculation of the SSL.

> Studies included contamination from the following sources: mine wastes (ores, tailings), smelter deposits, other industrial sources, vehicle and other urban emissions, wastewater effluents, composts, fertilizers, dredged materials, sewage sludges, fly ashes, flue dusts, nuclear waste, and arsenical pesticide residues. Where materials such as fertilizers were added to soil, data were excluded if mixing with soil did not occur. In addition, some measurements were taken from background locations. For example, chemical data for arsenic included the following sources: mine waste (24 observations), smelter operations (23 observations), fly ash disposal (18 observations), pesticide use (19 observations), nuclear waste (4 observations), unidentified urban sources (3 observations), background or no apparent anthropogenic source (13 observations), and unknown source (18 observations). Field studies in which a current, local atmospheric source of contaminants was present were excluded from the database."

Similarly, the development of the small mammal bioaccumulation database was described in *Development and Validation of Bioaccumulation Models for Small Mammals* (ES/ER/TM-219) as follows:

> "A literature search was performed for studies that reported chemical concentrations in co-located small mammal and soil samples. Data were restricted to only studies that reported whole body or carcass (whole body minus selected organs or other tissues) concentrations. To ensure relevancy of UFs and models to field situations, only field studies in which resident small mammals were collected were considered. All small mammal tissue burdens were therefore assumed to be at equilibrium with soil concentrations. There is some uncertainty associated with this assumption based on the heterogeneity of concentrations in surface soil. However, the potential impact of this heterogeneity on the assumption of equilibrium is expected to be minimal based on the mobility of small mammals and the evaluation of multiple individuals, which would tend to provide an average estimate of tissue concentrations over the sampled areas. To ensure comparability of data, only 'total' chemical analyses of both soil and small mammals (i.e., resulting from extractions of metals using concentrated acids) were included. Data resulting from DTPA, acetic acid, and other mild extraction methods were excluded. The mean (or composite) chemical concentration in soil and small mammal reported for each sampling location evaluated in each study was considered an observation. If data for multiple small mammal species were reported at a site, each was considered a separate observation. Soil and small mammal data in the database were reported as mg/kg dry weight. If studies reported small mammal concentrations in terms of wet weight, dry weight concentrations were estimated assuming a 68% water content (EPA, 1993). Data concerning soil characteristics [e.g., soil pH, % organic matter, cation exchange capacity, soil texture, etc.] were rarely reported and therefore do not appear in the database. Because chemical uptake was expected to vary according to small mammal diet preferences, each species was assigned to one of the three trophic groups: insectivore (diet consisting primarily of insects and other invertebrates), herbivore (diet consisting primarily of plant material), and omnivore (diet consisting of both animal and plant material). A summary of the small mammal species included in the database and the trophic groups to which they were assigned is presented in Table 1. To validate the models developed from the literature-derived data, soil and small mammal data collected as part of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedial investigations at sites in Oklahoma (PTI 1995) and Montana (LaTier et al., 1995) were acquired as a validation dataset. Small mammal species in this validation dataset, however, represented only the herbivore and omnivore trophic groups. Validation data for insectivores were unavailable."[7]

Literature Derived Bioaccumulation Data for Terrestrial Arthropods. Estimating exposures to insectivorous or omnivorous wildlife involved estimating bioaccumulation into soil invertebrates. Soil

[7] References in this passage can be found in the original source (*Development and Validation of Bioaccumulation Models for Small Mammals* [ES/ER/TM-219]); complete citation is provided in Chapter 11.

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 observations (as detailed in the RCBRA [DOE/RL-2007-21] and *Central Plateau Ecological Risk Assessment Data Package Report* [DOE/RL-2007-50]) indicate that earthworms are nonexistent in upland soil and have little or no contribution to the invertebrate portion of bird and mammal diets at the Hanford Site. Rather, insects and other arthropods (for example, beetles, ants, and spiders) are the primary prey of invertebrate-feeding birds and mammals at the site. Consequently, the data collected to address 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. This database was largely developed to support bioaccumulation modeling for the U.S. Army Adaptive Risk Assessment Modeling Systems (ARAMS[8]) and was first presented in *Development of Terrestrial Exposure and Bioaccumulation Information for the Army Risk Assessment Modeling System (ARAMS)* (USACHPPM, 2004). A literature search was performed for studies that reported chemical concentrations in collocated biota and media samples[9]. Literature databases searched included those hosted by the Defense Technical Information Center (*Online Information for the Defense Community*, Public Technical Reports [DTIC, 2012]), EPA (ECOTOX database) and the U.S. National Library of Medicine (TOXLINE: Toxicology Data Network).

From the range of studies reviewed, 22 were identified as containing relevant data (i.e., reported collocated soil and biota concentrations). Terrestrial invertebrate data focused on studies of accumulation in insects or spiders and reported whole body concentrations. To ensure relevancy of the soil to biota factors and models to field situations, only field studies that collected resident terrestrial invertebrates were considered. Therefore, all terrestrial invertebrate residues were assumed to be at equilibrium with soil concentrations.

To ensure comparability of data, only "total" chemical analyses of both soil and biota (e.g., resulting from extractions of metals using concentrated acids) were included. Data resulting from acetic acid, diethylenetriaminepentaacetic acid, and other mild extraction methods were excluded. The mean (or composite) chemical concentration in media and biota reported for each sampling location evaluated in each study was considered an observation. If data for multiple species were reported at a site, each species was considered a separate observation. Soil and biota data in the terrestrial arthropod database were reported as mg/kg DW. If a study identified in the literature search reported biota concentrations in wet weight, then DW concentrations were either calculated using the water content presented in the study or estimated assuming water content percentages as presented in *Wildlife Exposure Factors Handbook* (EPA/600/R-93/187) when water content was not presented in the study.

Data concerning species, soil pH, percent organic matter (OM), cation exchange capacity (CEC), soil texture, and soil Ca concentration (mg/kg dry wt) were included in the database whenever reported. Additionally, class, order, and family taxonomic data were included for each species in the database. These data was used to develop uptake factors by taxon for terrestrial invertebrates. Because chemical uptake was expected to vary according to terrestrial invertebrate diet preferences, each species was assigned to one of three trophic

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[8] ARAMS was previously known as the Army Risk Assessment Modeling System.

[9] Data usability requirements included: only paired/collocated samples with detects in both tissue and soil at levels above detection limits; terrestrial invertebrate data focuses on whole body tissue samples; only field studies, not laboratory studies, were included except where noted; only total chemical analyses of both soil and biota – data resulting from mild acid extraction methods were excluded; the mean or composite chemical concentration in media and biota reported per location in each study was considered an observation; data on distinct species were considered separate observations; all wet weight measurements were converted to dry weight using study specific water content or estimations from *Wildlife Exposure Factors Handbook* (EPA/600/R-93/187). Additional detail on data usability is found in *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311) within Appendix H.

groups: predator (diet consisting primarily of other insects), herbivore (diet consisting primarily of plant material), and detritivore (diet consisting primarily of organic matter in the leaf litter).

To ensure the accuracy of the terrestrial arthropod database, all data were verified by at least one reviewer. The reviewer would first exam the study for data presented and analytical methods used. The reviewer would then check all calculations and conversions necessary to obtain required units (e.g., mg/kg dry weight). Finally, a minimum of 25 percent of all data was checked. If an error was found during this check, then 100 percent of the data was verified. Unit conversion and transposition errors were the most common types of errors found; however these were infrequent. All errors were corrected.

Development of Integrated Bioaccumulation Models. 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 log-linear 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 exists between the chemical concentration in soil and that in terrestrial biota, simple log-linear regressions were performed using SAS PROC REG (*SAS/STAT 9.2 User's Guide, Second Edition* [SAS, 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: $p \leq 0.05$, $r^2 > 0.2$, and a positive slope. If regression analyses did not meet 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 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 remediated 100-D/H 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 100-D/H as described in Section 7.4.1. To identify which COPEC-receptor-waste sites combinations should be brought forward to the SMDP to identify community- or population-level effects 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. Wildlife PRG were also developed using toxicity reference values based on LOAELs. Use of LOAEL-based, wildlife risk assessment is consistent with several EPA guidance documents, including: *Framework for Ecological Risk Assessment* (EPA/630/R-92/001), *Ecological Significance and Selection of Candidate Assessment Endpoints* (EPA/540/F-95/037), *Generic Ecological Assessment Endpoints (GEAEs) for Ecological Risk Assessment* (EPA/630/P-02/004F), and *Issuance of Final Guidance: Ecological Risk Assessment and Risk Management Principles for Superfund Sites* (OSWER Directive 9285.7-28 P). The use of LOAEL values is also consistent with 2007 MTCA (WAC-173-340-7493 (4)) when standard receptor species are used. The risk assessment used substitute receptor species in accordance with 2007 MTCA (WAC-173-340-7493(7)), which has a provision that Ecology may require the use of no observed adverse effect levels (NOAELs). Consistent with EPA guidance listed above, and the *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311) found in Appendix H, LOAEL-based wildlife SSLs and PRGs were used for purposes of the risk assessment. Less than ten percent of the 100-D/H waste sites have been interim closed out under the Interim Rods and evaluated in this RI/FS have residual contamination that exceeds DOE's proposed LOAEL-based wildlife PRGs. Only four additional interim closed waste sites

contain residual contaminations that exceed NOAEL-based wildlife PRGs. The use of LOAELs for wildlife PRGs was decided to be the best approach based on the above information.

7.3.2.3 Radionuclide Exposures

Exposure to radionuclides differs from chemical exposure. Terrestrial biota receives exposure to radionuclides through a combination of both internal and external pathways. Internal exposure is a function of radiation emitted from radionuclides retained in tissues. At a terrestrial site such as the 100-D/H OUs, external exposure is due to 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-D/H Source OUs waste sites (Table 7-1). The BCGs for radionuclides use conservative assumptions for internal and external exposure. While 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 developing BCGs:

- The source medium is infinite in extent and contains uniform concentrations of radionuclides (that is, 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 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.

Table 7-4. Preliminary Remediation Goals 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
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	**54**	68	91	2,714	54	**32**	39	170	2,516	32	32
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	**14**	20	181	289	14	14
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**	610	109	544	**517**	1,424	1,765	517	109
Metal	Copper	mg/kg	423	461	**213**	12,881	213	233	193	1,217	4,631	193	193
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	NTD	NTD	NTD	NTD	NTD	97	**92**	366	325	92	92
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	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	371	59	57	**22**	22	22
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)

PRG = preliminary remediation goal

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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:

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

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 in the 100-D/H 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 because the river stage is elevated from mid-April to mid-July, making the seeps inaccessible. Therefore, an AUF of 0.75 was employed for all species except bats. For bats, an AUF of 0.5 was used since 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 as they maintain water balance through excreting concentrated urine, obtaining water from food, and generating water during metabolism ("Perognathus parvus" [Verts and Kirkland, 1988]). Estimating drinking water exposure can be complicated because the presence of seeps and observed concentrations depend on river stage and, for several species of birds, migration patterns are a factor. 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. Therefore, though it represents an overestimate, the 95 percent UCL of the arithmetic mean concentration of the analyzed constituent was used as the EPC for simplicity. While filtered water data are used in evaluations of the effects on aquatic receptors because those concentrations are bioavailable, unfiltered concentrations are more appropriate for drinking water, as bioavailability may change within the digestive tract. Both were included to be comprehensive, as in rare cases, filtered measurements can be higher than unfiltered. Results were not pooled so as to not bias any one sampling event at which both measurements occurred.

7.3.4 PRGs

The PRGs presented in this chapter 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 chapter as 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 use of bioaccumulation models that

included exclusively arthropods as the invertebrate portion of receptors' diets[10] 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 invertebrates such as earthworms are rarely encountered in the arid upland soil 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 the 2007 MTCA guidance ("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 ecological risk assessment within ERAGS (EPA 540-R-97-006) and reflects *Ecological Risk Assessment and Management Principles for Superfund Sites* (OSWER Directive 9385.7-28 P), which encourages the use of site-specific ecological risk data to support cleanup decisions, whenever practicable. The process for developing PRGs is also consistent with Ecology's "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 the WAC 173-340 Table 749-3 are based on updated exposure models (*Guidance for Developing Ecological Soil Screening Levels* [OSWER Directive 9285.7-55]) and toxicological literature reviews not available at the time WAC 173-340 Table 749-3 was developed. These PRGs are intended to be applied to all upland environments across the Hanford Site. Though 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. PRGs were researched for inorganic and organic constituents, but not radionuclides. Ultimately, PRGs were only recommended for inorganics, as data were limited for organics.[11] Confidence in the PRGs as a whole is greater than for the SSLs as they were developed specifically for use at the Hanford Site using site-specific data. Relative to each other, confidence in some PRGs is greater than in others. The additional confidence is due to 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 are included in the SMDP in Section 7.6 as needed.

Inorganic chemical PRGs for 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), included in Appendix H
- RCBRA (DOE/RL-2007-21)
- *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).

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[10] Further detail on the estimation of invertebrate tissue concentrations is found in Section 7.3.2.2.

[11] Here in Chapter 7, if a second tier effect threshold (e.g., PRG) was not available or recommended, chemical-waste site combinations were retained for further evaluation in the SMDP (section 7.6) if the exposure point concentration exceeded the SSL).

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	28.6
Cadmium	9.84	20
Chromium	259	149
Cobalt	15.7	15.7
Copper	70	58
Lead	9,090	1,700
Manganese	1,260	1,260
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	8,980

All of the site specific toxicological thresholds presented in these documents are no observed-effect concentrations (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 the 2007 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 invertebrate. There is no WAC or EcoSSL value for invertebrates. The background value of 15.7 mg/kg is greater than the EcoSSL of 13 mg/kg. While the WAC plant value of 20 mg/kg is

greater than the background value, it is based upon 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 (DOE/RL-2007-21), but this value was the highest concentration tested and was 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 upon 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 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 ERAGS (EPA 540-R-97-006) and 2007 MTCA (WAC 173-340-7493) guidelines for selecting site-specific criteria. In selection of values that differ from 2007 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 not available at the time 2007 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 in the Central Plateau, 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 are included in the SMDP in Section 7.6 as needed.

Detailed information regarding the source areas for the samples used for the most recent bioassays are included within ECF-HANFORD-11-0158. These source areas included the old central shop area (OCSA), 120-KW-1, 600-218, 600-220, 600-228, and 600-281. Each of the waste sites where samples were collected is depicted on a map and the Waste Identification Data System (WIDS) general summary reports are included. These descriptions include site location, and process descriptions as well as summaries of the waste types, categories, physical state, and dimensions as available. The forms of the specific chemicals that may be expected can be generalized from these summaries but not specifically determined. Using lead as an example, welding flux materials and lead-based paints found in metals shops of the OCSA could yield highly bioavailable forms of lead. The representativeness of these samples to the concentration, chemical form, bioavailability, and bioaccessability of metals throughout the rest of the Hanford Site is uncertain. The concentration ranges tested in the bioassays are by design representative of the broader Hanford Site, as a specific range of concentrations was targeted for testing based on known concentration distributions for the Hanford Site (see DOE/RL-2010-118). Concentration ranges targeted for testing were largely achieved (ECF-HANFORD-11-0158). The design was intended to maximize the representativeness of the contaminant concentration distributions; it was an implicit assumption that analyte forms, and therefore bioavailability and bioaccessibility, would overlap between locations for which bioassays were conducted and locations for which they were not. However, the true representativeness of forms and bioavailability of metals in samples used for bioassays as compared to that for metals in soils from individual waste sites at which bioassays were not conducted and to which resulting PRGs are applied, is unknown and may vary by waste site.

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 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 physical barriers prevent 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 ERA practice, and what was done for this ERA, is to initially characterize risks assuming an AUF of 1 (all exposure is within the site) and then refine that assumption should the highly conservative exposure estimate and risk characterization suggest an unacceptable risk warranting further evaluation. Hence, this section describes the method that EPCs were derived within the waste sites that assumed an AUF of 1. The SMDP in Section 7.6 describes how AUFs should be used for evaluating waste sites.

In total, 95 waste sites in the 100-D Source OUs and 47 waste sites in the 100-H Source OUs were verification sampled and included in this ERA. Chapter 6 details the computation of the EPCs for the waste sites at the 100-D/H Source OUs. Briefly, the 95 percent UCL of the arithmetic mean was calculated as the EPC for each decision unit (shallow, overburden, staging pile area, and footprint staging pile and focused) 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 discussed 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 uses proxy values of one-half the detection limits for nondetect values. For small datasets (n less than 10), 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* (OSWER 9285.6-10) (the most recent EPA guidance for UCL calculation) and ProUCL 4.00.05 were used to recalculate EPCs for the human health and ecological risk assessments of the 100-D/H 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 Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (OSWER Directive 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-DR-1, 100-DR-2, 100-HR-1 and 100-HR-2 Source Operable Units* (ECF-100DR1-11-0004) (Appendix G). The purpose of *Computation of Exposure Point Concentrations for the 100-DR-1, 100-DR-2, 100-HR-1, and 100-HR-2 Source Operable Units* (ECF-100DR1-11-0004) 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-D/H OUs are provided in Tables H-7 and H-8 (Appendix H).

For the drinking water evaluation included in Section 7.4.4, limited data are available and estimating exposure can be complicated as the presence of seeps and observed concentrations depend on river stage. For several species of birds, migration patterns are also a factor. EPCs of seep concentrations was 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-D/H Source OUs 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)

The 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.

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 including metals, pesticides, PCBs, and PAHs (as aroclors). The HQs for these comparisons are provided in Appendix H, Tables H-7 and H-8. COPCs with HQs equal to or greater than 1.0 were carried forward for further evaluation. Only metals failed the screen.[12] 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, comparison of the EPCs for these chemicals with both SSLs and PRGs were reviewed to confirm they were below both the SSL and the PRG. For these 10 chemicals, if an EPC was greater than either the SSL or the PRG, the chemical was carried forward to 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 SOF method. With the SOF method, contributions were considered significant if the EPC was greater than the SSL. The SOF equation is as follows:***

[12] Metals failing the SSL screen for at least one receptor are identified by waste site in the results section in Tables 7-6 and 7-7 and include: arsenic, barium, boron, chromium, copper, lead, lithium, manganese, mercury, molybdenum, selenium, silver, uranium/total uranium isotopes, vanadium, and zinc.

$$SOF = \sum_{j=1}^{n} Exposure_j / SSL_j$$

where:

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, individual detected radionuclide isotope COPCs were carried forward to the background evaluation.

For those COPCs that exceeded one or more SSLs, the EPC was compared to the background value and summarized in the subsequent tables (Appendix H, Tables H-9 and H-10) in Section 7.4.2.

Similarly, for Aroclors, HIs were calculated to evaluate additive effects. If the HI for Aroclors was greater than 1, the detected Aroclors were identified for further evaluation. This approach is conservative because the measurement of Aroclors as mixtures of PCB congeners does produce some overlap of congeners in multiple Aroclor mixtures. However, a total Aroclor HI is not an uncommon practice. While potential duplication could occur depending on which mixtures are detected, at most sites only one or two Aroclor mixtures are detected and tend to dominate. Also, by carrying the HI >1 forward, when a conclusion of no risk or no unacceptable risk is reached there is less uncertainty with the conclusion because of the additional conservatism in the approach.

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 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 the 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 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 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-DR-1, 100-DR-2, 100-HR-1, and 100-HR-2 Source Operable Units* [ECF-100DR1-11-0006]). For any chemical-waste site EPC that exceeded both the SSL and background, if no PRG is presented in Table 7-4 or 7-5, then the chemical-waste site combination was automatically retained for additional evaluation in the SMDP presented in Section 7.6.

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 used were the same as those used to develop the wildlife PRGs 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). The equation is as follows:

$$HQ = Dose/TRV$$

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 to the BCGs for wildlife. The lowest water BCG of terrestrial or riparian animal receptors was taken from Graded Approach for Radiation Doses to Biota (DOE-STD-1153-2002) or was calculated using *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. The equation is as follows:

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

where:

HQ = ecological hazard quotient (unitless)

EPC = radionuclide concentration in seep (pCi/L)

AUF = area use factor

BCG = biota concentration guide (pCi/L)

7.4.5 Screening Evaluation Results

The comparisons to plant/invertebrate and wildlife SSLs are provided in Appendix H (Tables H-7 and H-8 for the 100-D and 100-H OUs, respectively). The results of the screening evaluation (that is, comparison of EPCs with SSLs) in soil is described below, and exceedances for 100-D and 100-H OUs are listed in Tables 7-6 and 7-7, respectively.

Table 7-6. Summary of Chemicals in 100-D OU Surface Soils (0 to 15 ft [0 to 4.6 m]) Exceeding SSLs and Background

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
100-D-13_Shallow_Focused	Boron (9.8) Selenium (1.7) Zinc (2.4)	Zinc (1.8)
100-D-15_Shallow_2	Zinc (1.9)	Zinc (1.4)
100-D-28:1_Shallow	Mercury (5.7) Selenium (3.3)	--
100-D-29_Shallow	Boron (10.7)	--
100-D-31:3, 100-D-31:4_Overburden	Selenium (2.3)	--
100-D-31:5_Overburden	Boron (40.2) Mercury (1.4) Selenium (3.3)	--
100-D-31:5_Shallow	Boron (21.0) Mercury (2.4) Selenium (2.9) Zinc (1.8)	Zinc (1.3)
100-D-31:6_Overburden	Boron (12.0) Mercury (8.7)	--
100-D-31:6_Shallow	Boron (11.7) Mercury (5.8)	--
100-D-31:8_Shallow_Focused_1	Vanadium (47.5)	Vanadium (3.0)
100-D-31:8_Shallow_Focused_2	Barium (4.8) Boron (338.0) Mercury (1.2) Molybdenum (1.2) Zinc (1.7)	Barium (1.2) Boron (1.3) Zinc (1.2)
100-D-42, 100-D-43, 100-D-45_Shallow	Copper (1.8)	--
100-D-47_Shallow_Focused	Vanadium (42.9)	Vanadium (2.8)
100-D-56:1_Overburden	Boron (11.3) Selenium (4.0)	Selenium (1.1)
100-D-56:1_Shallow	Selenium (3.3)	--
100-D-56:2_Shallow_Focused	Chromium (73.3)	--
100-D-61_Shallow	Boron (22.3) Selenium (2.0)	--
100-D-7_Shallow_1	Selenium (1.6)	--
100-D-7_Staging pile area footprint	Mercury (3.0)	--
100-D-70_Shallow_Focused	Copper (1.5)	Zinc (1.2)

Table 7-6. Summary of Chemicals in 100-D OU Surface Soils (0 to 15 ft [0 to 4.6 m]) Exceeding SSLs and Background

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
	Zinc (1.6)	
100-D-82_Shallow_Focused	Lead (2.7)	Lead (3.8)
100-D-83:4_Shallow_Focused	Mercury (9.5)	--
100-D-84:1_Shallow_Focused	Mercury (1.2) Vanadium (47.2)	Vanadium (3.0)
100-D-87_Shallow_Focused	Zinc (1.7)	Zinc (1.2)
100-D-88_Shallow_Focused	Vanadium (52.0)	Vanadium (3.3)
100-D-94_Shallow_Focused	Mercury (5.8)	--
116-D-8_Shallow	--	Lead (1.2)
116-D-8_Shallow_Focused_2	Selenium (2.3)	--
116-DR-5_Overburden	Zinc (1.5)	Zinc (1.1)
116-DR-5_Shallow	Chromium (63.6)	--
116-DR-8_Overburden_3	Lithium (13.9) Silver (1.1) Zinc (1.5)	Zinc (1.1)
116-DR-8_Shallow	Lithium (35.2)	--
118-D-1_Shallow_Focused	Total_U_Isotopes (1.0)	--
118-D-4_Shallow_Focused	Cadmium (1.2) Chromium (120.3) Vanadium (46.2)	Cadmium (2.9) Chromium (1.3) Vanadium (3.0)
118-D-6:4_Shallow_2	Mercury (12.0)	--
118-DR-2:2_Shallow	Mercury (1.6)	--
120-D-2_Shallow	Mercury (1.1)	--
126-D-2_Shallow_Focused	Boron (15.8) Lead (1.4)	Lead (2.0)
128-D-2_Shallow_1	Selenium (2.1)	--
132-D-1_Shallow	Mercury (10.0) Selenium (1.7)	--
132-D-1_Staging Pile Area Footprint	Mercury (6.8)	--
1607-D2-2_Shallow	Chromium (49.4) Mercury (4.8) Silver (5.9) Zinc (1.8)	Zinc (1.4)
1607-D5_Shallow	Barium (2.3)	Lead (3.0)

Table 7-6. Summary of Chemicals in 100-D OU Surface Soils (0 to 15 ft [0 to 4.6 m]) Exceeding SSLs and Background

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
	Boron (139.0) Lead (2.1)	
628-3_Shallow	Mercury (1.6)	--
628-3_Staging Pile Area_2	Mercury (1.1)	--
628-3_Staging Pile Area_3	Chromium (102.9)	Chromium (1.1)

* Analytes with exposure point concentrations consistent with background are excluded in these results.

HQ = hazard quotient

HQ = hazard quotient

NB = no background

SSL = soil screening level

Table 7-7. Summary of Chemicals in 100-H OU Surface Soils (0 to 15 ft [0 to 4.6 m]) Exceeding SSLs and Background

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
100-H-21_Overburden	Arsenic (1.1)	Lead (1.0)
100-H-21_Shallow	Arsenic (1.3)	Lead (1.1)
100-H-28:1_Shallow_Focused	Barium (1.6) Boron (132.8)	--
100-H-3_Shallow	Arsenic (1.5) Boron (9.4) Mercury (2.6)	Lead (1.3)
100-H-35_Shallow_Focused_1	Chromium (51.8)	--
100-H-35_Shallow_Focused_2	Chromium (52.3) Mercury (1.0)	--
100-H-35_Shallow_Focused_3	Arsenic (1.9) Zinc (1.9)	Zinc (1.4)
100-H-37_Shallow_Focused	Arsenic (1.3) Lead (1.1)	Lead (1.5)
100-H-4_Shallow	Mercury (4.1)	--
100-H-4_Shallow_Focused	Boron (38.8) Uranium (2.0)	--
100-H-40_Shallow_Focused	Zinc (1.7)	Zinc (1.2)
100-H-49:2_Shallow_Focused	Boron (11.3) Chromium (47.0) Zinc (1.9)	Lead (1.3) Zinc (1.4)
100-H-51:4_Shallow_Focused	Zinc (1.6)	Zinc (1.2)

Table 7-7. Summary of Chemicals in 100-H OU Surface Soils (0 to 15 ft [0 to 4.6 m]) Exceeding SSLs and Background

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
100-H-51:5_Shallow_Focused	Boron (52.6)	--
100-H-53_Shallow_Focused	Molybdenum (1.9) Zinc (1.6)	Lead (1.0) Zinc (1.2)
100-H-8_Shallow_Focused	Mercury (3.1)	Lead (1.3)
116-H-5_Staging Pile Area Footprint	Arsenic (1.0)	Lead (1.3)
116-H-7_Shallow	Chromium (49.1)	--
118-H-1:1_Overburden	Boron (21.1)	--
118-H-1:1_Shallow_1	Selenium (1.9)	--
118-H-1:1_Shallow_Focused	Boron (8.3) Chromium (55.0) Mercury (2.0)	--
118-H-3_Shallow_1	Arsenic (1.6) Lead (1.2) Zinc (2.7)	Lead (1.6) Zinc (2.0)
118-H-4_Staging Pile Area	Zinc (1.5)	Zinc (1.1)
118-H-5_Shallow	Boron (12.5)	--
118-H-6:5_Shallow_1	Arsenic (4.0) Lead (3.4)	Lead (4.8)
118-H-6:5_Shallow_2	Boron (24.4) Mercury (1.7)	--
118-H-6:5_Shallow_Focused	Arsenic (2.7) Lead (2.3)	Lead (3.2)
128-H-1_Overburden	Arsenic (4.1) Lead (5.1)	Lead (7.1)
128-H-1_Shallow_3	Arsenic (1.1) Boron (9.8) Lead (1.3)	Lead (1.8)
128-H-1_Shallow_4	Boron (8.9) Mercury (10.2)	Lead (1.3)
128-H-1_Staging pile area footprint_2	Arsenic (5.4) Lead (2.5)	Lead (3.5)
128-H-2_Shallow_Focused	Selenium (2.3)	--
128-H-3_Shallow_Focused	Arsenic (1.1) Lead (1.9)	Lead (2.6)
1607-H1_Overburden	Arsenic (1.4) Lead (1.2) Selenium (1.9)	Lead (1.7)
1607-H2_Overburden	Arsenic (1.6) Lead (1.1)	Lead (1.5)

Table 7-7. Summary of Chemicals in 100-H OU Surface Soils (0 to 15 ft [0 to 4.6 m]) Exceeding SSLs and Background

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
1607-H2_Shallow	Chromium (510.0) Mercury (25.9)	Chromium (5.3) Lead (1.1) Mercury (1.4)
1607-H3_Overburden	Boron (9.5) Chromium (124.5)	Chromium (1.3)
1607-H4_Shallow	--	Lead (1.2)
600-151_Shallow_1	Arsenic (3.2) Boron (9.7) Lead (2.5) Selenium (1.8)	Lead (3.6)
600-151_Shallow_2	Arsenic (6.0) Lead (5.3)	Lead (7.5)
600-151_Shallow_3	Arsenic (5.4) Lead (5.5)	Lead (7.8)

* Analytes with exposure point concentrations consistent with background are excluded in these results.
HQ = hazard quotient
NB = no background
SSL = soil screening level

7.4.5.1 100-D OU

The 100-D OU has 95 waste sites with CVP/RSVP data. Samples collected greater than 4.6 m (15 ft) bgs (deep and deep focused) were not included in the ERA; therefore, three (100-D-18, 100-D-19, and 116-D-6) of the 95 sites were not included in the ERA. No detections were observed at two waste sites (100-D-12 and 100-D-90). Therefore, plant/invertebrate and wildlife SSL HQs for 92 waste sites are provided in Appendix H, Table H-7. The SSL-based HQs were less than 1.0 for all COPCs in all of the decision units evaluated at 21 of the 92 waste sites. The following waste sites did not require further evaluation of ecological risk:

- 100-D Sites: 100-D-20, 100-D-21, 100-D-22, 100-D-3, 100-D-4, 100-D-48:1, 100-D-48:2, 100-D-48:3, 100-D-48:4, 100-D-49:2, 100-D-49:3, 100-D-49:4, and 100-D-80:1
- 116-D Sites: 116-D-1A, 116-D-2, 116-D-4, and 116-D-9
- 116-DR Sites: 116-DR-1,2, 116-DR-4, 116-DR-6, and 116-DR-7

The SSLs, background, and PRGs were not available for 22 COPCs. These COPCs were retained as an uncertainty and are discussed in Section 7.4.9. The EPCs for inorganic analytes barium, boron, cadmium, chromium, copper, lead, lithium, manganese, mercury, molybdenum, selenium, silver, total uranium isotopes, vanadium, and zinc exceeded 1 or both of the SSLs at the remaining waste sites, as presented in Appendix H, Table H-7. Within these waste sites, EPCs of analytes exceeded the plant/invertebrate SSLs, while fewer analytes exceeded the wildlife SSLs. These waste site decision units were carried forward to the background evaluation.

7.4.5.2 100-H OU

The 100-H Source OU has 47 waste sites with CVP/RSVP data. Samples collected greater than 4.6 m (15 ft) bgs (deep and deep focused) were not included in the ERA. Five of the 47 waste sites (118-H-6:2, :3, and :6; 100-H-9, -10, -11, -12, -13, -14, and -31, which represents 5 remediated waste sites and 5 consolidated waste sites) were not included in the ERA. Therefore, plant/invertebrate and wildlife SSL HQs for 42 waste sites are provided in Table H-8 (Appendix H). The SSL-based HQs were less than 1.0 for all COPCs in all of the decision units evaluated at the following two waste sites: 100-H-24 and 116-H-3. These waste sites were eliminated from further evaluation of ecological risk.

The SSLs, background, and PRGs were not available for 13 COPCs. These COPCs were retained as an uncertainty and are discussed in Section 7.4.9. The EPCs for the inorganic analytes arsenic, barium, boron, chromium, lead, manganese, mercury, molybdenum, selenium, uranium, vanadium, and zinc exceeded one or both of the SSLs at the remaining waste sites. Within these waste sites, EPCs of analytes exceeded the plant/invertebrate SSLs, while fewer analytes exceeded the wildlife SSLs. These waste site decision units were carried forward to the background evaluation.

7.4.6 Background Evaluation

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-9 and Table H-10 for 100-D OU and 100-H OU, respectively.

7.4.6.1 100-D OU

COPCs did not exceed the 90th percentile background concentrations in all of the decision units evaluated at 31 of the remaining waste sites. The background evaluation for the remaining waste sites is provided in Appendix H, Table H-9. The following 31 waste sites did not require further evaluation of ecological risks:

- 100-D Sites: 100-D-1, 100-D-2, 100-D-24, [100-D-31:1, 100-D-31:2], 100-D-31:10, 100-D-31:3, 100-D-31:4, 100-D-31:7, 100-D-31:9, 100-D-32, 100-D-50:5, 100-D-52, 100-D-74, 100-D75:3, 100-D-85:1, and 100-D-9
- 116-D Sites: 116-D-10 and 116-D-7
- 116-DR Sites: 116-DR-10 and 116-DR-9
- 118-D Site: 118-D-5
- 118-DR Site: 118-DR-1
- 120-D Site: 120-D-2
- 122-DR Site: 122-DR-1:2
- 130-D Site: 130-D-1
- 1607-D Sites: 1607-D2-1, 1607-D2-3, 1607-D2-4, and 1607-D4
- 600 Site: 600-30
- UPR-100 Site: UPR-100-D-5

Within the remaining waste sites, 46 decision units had COPC EPCs in exceedance of both an SSL and background. Barium, boron, cadmium, chromium, copper, lead, lithium, mercury, molybdenum, selenium, silver, vanadium, zinc, and total uranium isotopes were detected outside the range of background. The COPC EPCs detected in exceedance of background were carried forward to the risk assessment. Exceedances from the SSLs and background evaluations in soil are summarized in Table 7-6.

7.4.6.2 100-H OU

The COPCs did not exceed the 90th percentile background concentrations in all of the decision units evaluated at 13 of the remaining waste sites. The background evaluation for the remaining waste sites is provided in Appendix H, Table H-10. The following 13 waste sites did not require further evaluation of ecological risks:

- 100-H Sites: 100-H-17, 100-H-28:6, 100-H-41, 100-H-45, 100-H-5, 100-H-50, and 100-H-7
- 116-H Sites: 116-H-1 and 116-H-9
- 118-H Sites: 118-H-1:2, 118-H-2, and 118-H-6:4
- 600 Site: 600-152

Within the remaining waste sites, 41 waste site decision units had COPC EPCs in exceedance of both an SSL and background. Arsenic, barium, boron, chromium, lead, mercury, molybdenum, selenium, uranium, and zinc were detected outside the range of background. The COPC EPCs detected in exceedance of background were carried forward to the risk assessment. Exceedances from the SSLs and background evaluations in soil are summarized in Table 7-7.

7.4.7 PRG Evaluation Results

Further evaluation was conducted on those waste sites that were not eliminated in the SSL and background evaluations. Risks were evaluated based on the resulting HQs and are provided in Tables H-11 and H-12 (Appendix H) and summarized in Table 7-8 and Table 7-9 for the 100-D and 100-H OUs, respectively.

Table 7-8. Summary of 100-D OU Waste Sites Ecological Evaluation Based on PRGs for Surface Soils (0 to 15 ft [0 to 4.6 m])

Waste Site/Decision Unit	Exceedances Based on Comparisons to PRGs	
	Plant/Invertebrate HQ	Wildlife HQ
100-D-28:1_Shallow	Mercury (1.9)	Selenium (1.2)
100-D-31:5_Overburden	--	Selenium (1.2)
100-D-31:5_Shallow	--	Selenium (1.0)
100-D-31:6_Overburden	Mercury (2.9)	--
100-D-31:6_Shallow	Mercury (1.9)	--
100-D-31:8_Shallow_Focused_1	Vanadium (1.1)	Vanadium (2.2)
100-D-31:8_Shallow_Focused_2	Barium (4.4) Boron (5.9) Molybdenum (1.2)	Boron (5.3)
100-D-42, 100-D-43, 100-D-45_Shallow	Copper (1.6)	--
100-D-47_Shallow_Focused	--	Vanadium (2.0)
100-D-56:1_Overburden	Selenium (1.0)	Selenium (1.5)
100-D-56:1_Shallow	--	Selenium (1.2)

Table 7-8. Summary of 100-D OU Waste Sites Ecological Evaluation Based on PRGs for Surface Soils (0 to 15 ft [0 to 4.6 m])

Waste Site/Decision Unit	Exceedances Based on Comparisons to PRGs	
	Plant/Invertebrate HQ	Wildlife HQ
100-D-7_Staging pile area footprint	Mercury (1.0)	--
100-D-70_Shallow_Focused	Copper (1.3)	--
100-D-83:4_Shallow_Focused	Mercury (3.2)	--
100-D-84:1_Shallow_Focused	Vanadium (1.1)	Vanadium (2.2)
100-D-88_Shallow_Focused	Vanadium (1.2)	Vanadium (2.4)
100-D-94_Shallow_Focused	Mercury (1.9)	--
116-DR-8_Shallow	Lithium (2.0)	--
118-D-4_Shallow_Focused	Vanadium (1.0)	Vanadium (2.1)
118-D-6:4_Shallow_2	Mercury (4.0)	--
132-D-1_Shallow	Mercury (3.3)	--
132-D-1_Staging Pile Area Footprint	Mercury (2.3)	--
1607-D2-2_Shallow	Mercury (1.6) Silver (3.9)	--
1607-D5_Shallow	Barium (2.2) Boron (2.4)	Boron (2.2)

HQ = hazard quotient
PRG = preliminary remediation goal

Table 7-9. Summary of 100-H OU Waste Sites Ecological Evaluation Based on PRGs for Surface Soils (0 to 15 ft [0 to 4.6 m])

Waste Site/Decision Unit	Exceedances Based on Comparisons to PRGs	
	Plant/Invertebrate HQ	Wildlife HQ
100-H-28:1_Shallow_Focused	Barium (1.5) Boron (2.3)	Boron (2.1)
100-H-4_Shallow	Mercury (1.4)	--
100-H-53_Shallow_Focused	Molybdenum (1.9)	--
100-H-8_Shallow_Focused	Mercury (1.0)	--
118-H-6:5_Shallow_1	--	Lead (1.1)
128-H-1_Overburden	--	Lead (1.6)
128-H-1_Shallow_4	Mercury (3.4)	--
1607-H2_Shallow	Chromium (1.4) Mercury (8.6)	Chromium (1.9) Mercury (1.7)
600-151_Shallow_2	--	Lead (1.7)
600-151_Shallow_3	--	Lead (1.8)

HQ = hazard quotient
PRG = preliminary remediation goal

7.4.7.1 100-D OU

The following 15 waste sites did not exceed the plant/invertebrate or the wildlife PRGs (HQs were less than 1.0) and were eliminated from further evaluation (Appendix H, Table H-11):

- 100-D Sites: 100-D-13, 100-D-15, 100-D-29, [100-D-31:3, 100-D-31:4], 100-D-56:2, 100-D-61, 100-D-82, and 100-D-87
- 116-D Site: 116-D-8
- 116-DR Site: 116-DR-5
- 118-D Site: 118-D-1
- 118-DR Site: 118-DR-2:2
- 120-D Site: 120-D-2
- 126-D Site: 126-D-2
- 628-D Site: 628-D-3

The EPCs for the inorganic analytes barium, boron, copper, lithium, mercury, molybdenum, selenium, silver, and vanadium exceeded one or both groups of PRGs (plants/invertebrates, wildlife). These COPCs will be retained as COPECs in one or more of the remaining 24 waste site decision units (Appendix H, Table H-11) and will be further addressed in the SMDP.

The risk assessment identified COPECs for the following waste site decision units because of potential ecological risks to plants, invertebrates, or wildlife that may be from Hanford Site releases (Table 7-8):

- 100-D-28:1_Shallow: Mercury, Selenium
- 100-D-31:5_Overburden: Selenium
- 100-D-31:5_ Shallow: Selenium
- 100-D-31:6_Overburden: Mercury
- 100-D-31:6_Shallow: Mercury
- 100-D-31:8_Shallow_Focused_1: Vanadium
- 100-D-31:8_Shallow_Focused_2: Barium, Boron, Molybdenum
- 100-D-42, 100-D-43, 100-D-45_Shallow: Copper
- 100-D-47_Shallow_Focused: Vanadium
- 100-D-56:1_Overburden: Selenium
- 100-D-56:1_Shallow: Selenium
- 100-D-7_Staging pile area footprint: Mercury
- 100-D-70_Shallow_Focused: Copper
- 100-D-83:4_Shallow_Focused: Mercury
- 100-D-84:1_Shallow_Focused: Vanadium
- 100-D-88_Shallow_Focused: Vanadium
- 100-D-94_Shallow_Focused: Mercury
- 116-DR-8_Shallow: Lithium
- 118-D-4_Shallow_Focused: Vanadium

- 118-D-6:4_Shallow_2: Mercury
- 132-D-1_Shallow: Mercury
- 1607-D2-2_Shallow: Mercury, Silver
- 1607-D5_Shallow: Barium, Boron

7.4.7.2 100-H OU

The following 19 waste sites did not exceed the plant/invertebrate PRGs or the wildlife PRGs (HQs were less than 1.0 and were eliminated from further evaluation) (Appendix H, Table H-12):

- 100-H Sites: 100-H-21, 100-H-3, 100-H-35, 100-H-37, 100-H-40, 100-H-49:2, 100-H-51:4, 100-H-51:5
- 116 Sites: 116-H-5, 116-H-7
- 118-H Sites: 118-H-3, 118-H-4, 118-H-5, 118-H-1:1
- 128-H Sites: 128-H-2, 128-H-3
- 1607 Sites: 1607-H1, 1607-H3, 1607-H4

The EPCs for the inorganic analytes barium, boron, chromium, lead, mercury, molybdenum exceeded one or both groups of PRGs (plants/invertebrates, birds/mammals). These COPCs will be retained as COPECs in one or more of the remaining four waste site decision units (Appendix H, Table H-12) and will be further addressed in the SMDP.

The risk assessment identified COPECs for the following waste site decision units because of potential ecological risks to plants, invertebrates, or wildlife that may be attributable to past site practices (Table 7-9):

- 100-H-28:1_Shallow_Focused: Barium, Boron
- 100-H-4_Shallow: Mercury
- 100-H-53_Shallow_Focused: Molybdenum
- 100-H-8_Shallow_Focused: Mercury
- 118-H-6:5_Shallow_1: Lead
- 128-H-1_Overburden: Lead
- 128-H-1_Shallow_4: Mercury
- 1607-H2_Shallow: Chromium, Mercury
- 600-151_Shallow_2: Lead
- 600-151_Shallow_3: Lead

7.4.8 Characterization of Drinking Water Ingestion

The EPCs from seep water along the 100-D and 100-H 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 Columbia River Corridor. The results of these comparisons for inorganics are provided in Appendix H (Table H-13 and Table H-14 for 100-D for 100-H, respectively). Under this scenario, doses of nitrate at 100-H and aluminum and nitrate at 100-D were greater than 1 percent (that is, HQ greater than 0.01) for one or more of the evaluated receptors, while exposure from all other chemicals to all other receptors produced HQs less than 0.01. Thus, other than for the chemical-source OU combinations listed above, exposure from chemicals to all receptors produced HQs less than 1, indicating

no additional risk for wildlife exposure to nonradionuclides from drinking seeps at the 100-D/H Area. Further, the results of the evaluation presented in Appendix H should be considered acceptable for all of the chemical-source OU combinations (except the three listed), as 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. Inclusion of drinking ingestion in the development of SSLs and PRGs is not warranted. For those chemical-Source OU-receptor combinations listed, further discussion is provided below:

- **Aluminum**—For aluminum, the dose from ingestion of prey and soil is not significant in terrestrial environments with soil pH greater than 5.5 as the aluminum is bound and unavailable for biological uptake (OSWER Directive 9285.7-60). Hence, for wildlife residing in the circum-neutral soil of the 100-D and 100-H Source OUs, drinking ingestion by wildlife represents the primary contribution to the total dose of aluminum and, even for mammals, yielded an HQ less than 0.1 (Appendix H, Tables H-13 and H-14) under the worst-case scenario, even for the more susceptible bats.

- **Nitrate**—While the drinking ingestion dose at 100-D yielded an HQ of 0.013 for bats, dietary ingestion shown in Table H-7 for 100-D is below 0.001 for all waste sites. Thus, dietary ingestion of nitrate would be insignificant relative to drinking ingestion from seeps, and total exposure from the combined prey ingestion and drinking water ingestion would not be at a level of concern. Similarly, the drinking ingestion dose at 100-H yielded an HQ of 0.26 for elk, 0.36 for badgers, and 0.47 for bats, and the dietary ingestion shown in Table H-8 for 100-H is below 0.0001 for all waste sites. Dietary ingestion of nitrate would be insignificant relative to drinking ingestion from seeps, and total exposure from the combined prey ingestion and drinking water ingestion would not be at a level of concern. Thus, with the HQs being less than 1 under a worst-case scenario and with more available and uncontaminated sources of drinking water available (for example, the Columbia River), there is no unacceptable risk. Exposure to nitrate through drinking seep water does not warrant further evaluation, and inclusion in SSL or PRG development is not required.

Evaluation of radionuclide doses from wildlife drinking seep water is included in Appendix H, Table H-15. EPCs for seeps were compared to the lower of BCGs for terrestrial and riparian animals. The total SOF for wildlife drinking seep water from 100-D was 0.037. With the maximum SOF from terrestrial soil pathways from any waste site within the 100-D Source OUs being 0.04 (Appendix H, Table H-7), there is no additional risk for wildlife exposure to radionuclides from drinking seeps at 100-D. Similarly, the total drinking ingestion SOF for 100-H seep water was 0.12. Combined with a worst-case SOF from terrestrial soil pathways of 0.23 within 100-H waste sites (Appendix H, Table H-8), there is no risk for wildlife exposure to radionuclides from drinking seep water at 100-H.

Given the results provided in Appendix H, Tables H-13 through H-15, there is no significant risk to wildlife in the 100-D/H Source OUs from drinking freshwater seeps along the Columbia River in the 100-D/H 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 (for example, uptake and food web exposures) carries 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 overestimate rather than

underestimate the likelihood and magnitude of risks to ecological receptors. The following uncertainties and limitations are associated with the proposed methodology and available data for the ERA:

- **Data Use**—The quantitative evaluation of chemical concentrations in soil included surface soil from the 0 to 4.6 m (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 (2007 MTCA, "Terrestrial Ecological Evaluation Procedures" [WAC 173-340-7490(4)(b)]). This depth range may overestimate the depth to which many terrestrial receptors would be exposed. MTCA (WAC 173-340) identifies the biologically active zone as 1.8 to 4.6 m (6 to 15 ft) (2007 MTCA [WAC 173-340]). Evaluation of data that extends beyond the biologically active zone could either overestimate or underestimate 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 values were available for some COPCs (2,4,5-trichlorophenol, 2,4-DB(4-(2,4-dichlorophenoxy)butanoic acid), 2,4-dichlorophenol, 2,4-dinitrophenol, 2-chloronaphthalene, 4,4'-DDD (dichlorodiphenyldichloroethane), acetone, alpha-BHC, butylbenzylphthalate, carbazole, dibenzofuran, di-n-butylphthalate, dinoseb(2-sec butyl-4,6-dinitrophenol), gamma-BHC (Lindane), heptachlor epoxide, isophorone, nickel-63, neptunium-237, nitrogen in nitrate, nitrogen in nitrite, nitrogen in nitrite and nitrate, total petroleum hydrocarbons - diesel range extended to C36, total petroleum hydrocarbons - motor oil (high boiling), and total petroleum hydrocarbons – gasoline range) 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 remedial alternatives that protect receptors with SSLs may also protect receptors lacking sufficient toxicity data. In addition, the absence of SSLs for plants and soil invertebrates can be addressed through site-specific bioassays, which are a component of Tier 2.

  Bioavailability and toxicity of metals are functions of many factors including soil pH, with metals (e.g., aluminum, iron, lead, mercury) generally being more bioavailable and toxic at low pH (*Guidance for Developing Ecological Soil Screening Levels* [OSWER Directive 9285.7-55]). The pH levels for soil used to develop plant toxicity values range 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 levels for soil used to develop invertebrate toxicity values were between 3.8 and 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. Because the range of pH values in soil associated with plant and soil invertebrate toxicity values within the published literature include values substantially lower than those present throughout most of the Hanford Site, the resulting SSLs for plants and soil invertebrates may not accurately represent toxicity. Because metals are more bioavailable at lower pH, the SSLs may overestimate concentrations in Hanford Site soil that would be toxic to plants and soil invertebrates; therefore, risk estimates may be overly conservative. Evaluating this potential overestimation of bioavailability was one of the goals of a 2011 Hanford Site field effort to collect soil with a pH range more reflective of Hanford Site soils (*Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site* [ECF-HANFORD-11-0158]). With the exception of four samples collected from within the River Corridor, 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. Further, oxidized environments (upland or well-aerated soils like those at the Hanford Site) promote the precipitation of ferric-oxide compounds, which are not

available to plants for uptake. Thus, the PRGs more accurately reflect the actual bioavailability of potential contaminants within the Hanford Site soil than they do the SSLs developed using published data from laboratory studies and other sites.

For Tier 2 values, uncertainty inherent to the Tier 1 bioaccumulation estimates was reduced (where possible) by replacing the Tier 1 bioaccumulation models with models that include Hanford Site-specific bioaccumulation data (small mammal, arthropod, and plant tissue data, each paired with collocated soil data). Principle 3 of OSWER Directive 9285.7-28P maintains site-specific data, including tissue residue data, is preferable to literature-based data to develop protective quantitative cleanup levels. Hanford Site-specific and literature-based bioaccumulation data overlap and display comparable distributions for many analytes (e.g., cadmium, copper, lead, and zinc). However in some cases (e.g., aluminum and thallium in soil invertebrates and small mammals, and silver in plants and small mammals), Hanford Site-specific and literature-based bioaccumulation data do not overlap and are discontinuous. In these cases, bioaccumulation models using the combined data may either over or under estimate the actual accumulation of chemicals into tissue biota, with the resulting Tier 2 values being either over-conservative or under-conservative.

The decision to pool Hanford and literature data when it is not continuous may introduce uncertainty at the expense of site-specificity. Exclusive use of Hanford soil-tissue data is reasonable if the conditions at Hanford are unique and indicative of a bioaccumulation relationship than differs from that observed in the broader literature. A different relationship could be due to unique bioavailability characteristics due to soil properties, source of the chemicals being evaluated, or the specific species accumulating the chemicals. Bioaccumulation scatterplots for Hanford and literature data presented in Appendix D of *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311 in Appendix H), however, do not support the likelihood of unique conditions. Given the heterogeneous distribution of soil concentrations, relatively small waste sites, and soil covers over waste sites, there is uncertainty in the Hanford data irrespective of soil types and study methods. As a consequence, use of the Hanford data alone could either overestimate or underestimate actual exposure and bioaccumulation. Considering the uncertainties of both approaches (i.e., using Hanford only data or pooled data), the benefit of pooling was determined to outweigh the uncertainties of pooling. Significant more detailed discussion is provided in Appendix D of *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311).

With respect to TPH (both high boiling point motor oil and diesel extended to the C36 range), though no SSL or PRG was previously developed for soil at the Hanford Site, published literature is available to provide prospective. 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 petroleum hydrocarbons than plants. Using lube oil to represent TPH-motor oil, no-effect thresholds ranged from 15 to 1,490 mg/kg in soil and EC20 was 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 (2007) lists ecological indicator soil concentrations (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]). The highest concentration of TPH-diesel was at 160 mg/kg measured 126-D-2_Shallow_Focused, and the highest concentration of TPH-motor oil was at 188 mg/kg measured at 100-H-4_Shallow_Focused. Given these maximum concentrations are below the 2007 MTCA diesel range ecological indicator soil

concentration and on the low end of the range of NOAECs, no further evaluation of TPH is warranted.

PCB congener data can be more beneficial than aroclor data. Congener analysis is more precise with less interference in the analysis from other chemicals, the quantitation is more accurate, and composition of weathered, degrade, or metabolized mixtures is easier. Congener analysis may be more appropriate when PCB hot spots have been identified, lower detection limits are needed, fingerprinting is necessary, adverse effect have been observed, or cleanup will be based on congener-specific TEFs. However, disadvantages of using congeners include more limited availability of toxicological data, more costly analysis, significant variation between laboratories, and a greater amount of effort in data management. Given that PCBs are not the primary constituent of concern at this site, collection and analysis of aroclor data was used for risk screening purposes with the understanding that congener analysis could be performed as an additional analytical step if it was determined from the conservative evaluation of the aroclor data that further evaluation of risk associated with PCBs is necessary. Screening assessment of aroclor data in soils at the 100-D/H OUs did not produce results suggesting further analysis using congeners was warranted.

PCB congeners were analyzed for in all media evaluated in the CRC Risk Assessment (DOE/RL-2010-117, Volume II, Rev. 0). This study analyzed sediment, island soil, surface water, and fish tissue for the 209 PCB congeners. Table 3-1 summarizes the analytical parameters by medium. Summary statistics for each medium analyzed are provided in Chapter 3 Table 3-3 through Table 3-12. Risk-based screening levels and their basis for each media type are provided in Table 3-15 through Table 3-17. Selection of COPCs are presented in Table 3-18 through Table 3-36. Risk characterization results are presented in Sections 6.5.1 and 6.5.2.In summary, the dioxin-like and nondioxin PCBs were not retained as COPCs, or if they were retained and carried forward into the risk characterization they were not identified as risk drivers. In all cases, PCB-like and nondioxin PCBs were identified as reference COPCs (not correlated with a Hanford-Site release).

Similarly, six wells in the 100-HR-3 groundwater OU were analyzed for PCB congeners for this RI/FS. Dioxin like PCB congeners were analyzed (using EPA Method 1668A) at low and high river stage for the following 6 wells: 199-D5-15, 199-D8-55, 199-D8-71, 199-H4-10, 199-H4-13, and 199-H4-48 (summary statistics for these analyses are in Tables O-4 through O-19 in the RI/FS report). The approach was to conduct one round of samples for groundwater. If the results did not show concentrations greater than action levels, then further sampling was not required. Of the six wells that were analyzed, only well 199-H4-13 was sampled more than once because the first sampling round detected one PCB congener greater than the action level. However two subsequent rounds reported the same congener as nondetected or at a concentration less than the action level.

- **Wildlife 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 non-wildlife species. This is a typical limitation and extrapolation for ERAs 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 salts) that have high water solubility and high bioavailability to receptors. Because the analytical samples on which site-specific exposure estimates were based measured total metal, regardless of form, and these highly bioavailable forms are expected to compose only a fraction of the total metal concentration, this is

likely to overestimate potential risks for these chemicals. A recent study was conducted comparing the toxicity of laboratory-spiked soil versus aged field-collected soil 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 soil 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 used 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 evaluations of ecological risk) that the chemicals be evaluated on a compound-by-compound basis during the comparison to SSLs. This could underestimate risks (if there are additive or synergistic effects among chemicals) or overestimate risks (if there are antagonistic effects among chemicals). Assessment of data in this report resulted in a description of potential exposure risks because of 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 the Hanford Site, 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 indicate 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 overestimate or underestimate risks.

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

- **Food Web Exposure Modeling**—While life history data are available for many of the wildlife species 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 allometric relationships or on data from the same species in other portions of its range. Because diet composition as well as food and soil ingestion rates can differ among individuals and locations, published parameter values may not accurately reflect individuals at the Hanford Site. Consequently, SSLs may be either over-conservative or under-conservative. For example, the wildlife EcoSSLs were derived with a model that incorporates prey tissue items that compose 100 percent of the receptor's diet coming from the site, not accounting for food obtained in adjacent uncontaminated areas, whereas 2007 MTCA (WAC 173-340) values account for offsite prey consumption. Therefore, the assumed contributions of ingestion of analytes in prey tissues for the wildlife EcoSSLs are greater than those used to develop the 2007 MTCA (WAC 173-340) values and likely overestimate risk.

  Ultimately, there is uncertainty with both the 2007 MTCA (WAC 173-340) and EPA values used as SSLs with respect to site-specificity. The wildlife PRGs employed in this ERA are more site-specific than the SSLs because prey concentrations were estimated with Hanford Site data. However, there is also 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 sessile 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 sessile or have limited home ranges) are those based upon an estimate of 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* (EPA/600/R-93/187). 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. However, assuming an AUF of 1 will likely result in a conservative estimate of exposure because offsite foraging would likely be conducted in uncontaminated areas. 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 levels that are more realistic when the number of samples collected in a site was adequate in sample size to develop a UCL on the mean. A detailed description of the uncertainties associated with using max concentrations when a 95% UCL was greater than max is provided in Chapter 6, Section 6.2.6.2.

- **Comparisons to Background Concentrations**—Background concentrations were used to judge whether measured concentrations within waste sites reflect 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 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 effect of this possibility is minimal because metals and radioisotopes at concentrations consistent with background conditions should exhibit no different ecological effects than those common 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), the following two sources of data were considered for use in the ERA. These sources of data include the following:

  - 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

  - Limited field investigation data collected in 1992 from the 100-D/H OUs

These data were collected for purposes other than fulfilling needs of the risk assessment; as such, they were not used to evaluate risks quantitatively. However, these data were evaluated qualitatively by comparing concentrations of analytes to risk-based screening levels to determine whether the results could be useful for risk management decisions.

- RI and LFI data are described in Chapter 6, Section 6.2.6.6. All RI and LFI soil data from the soil borings and wells described in Chapter 6 were compared to the PRGs and SSLs used in the ERA. Detailed datasets and vertical profiles are provided in Section 4.2.2, and the soil borings/wells and associated depth intervals for data in the ERA are summarized in Appendix H (Tables H-16 and H-17).

- 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 or the SSL when no PRG was available. 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 defined by 2007 MTCA ("Terrestrial Ecological Evaluation Procedures" [WAC 173-340-7490(4)(b)]).

- A comparison of the range of detected concentrations to ecological PRGs or SSLs from each of these sample locations is provided in Appendix H, Tables H-18 and H-19. The wells and test pits that report detected concentrations greater than the ecological PRGs and SSLs for the 100-D and 100-H Source OUs are summarized in Table 7-10 and Table 7-11, respectively.

- For the 100-D Source OU (shown in Table 7-10), four LFI sample locations (100-D-12 Sodium Dichromate site, 116-D-4 Crib, 116-DR-9 Retention Basin, and 130-D-1 Underground Tank) report soil concentrations greater than ecological SSLs. Three waste sites (100-D-12 Sodium Dichromate site, 116-D-4 Crib, and 116-DR-9 Retention Basin) have been remediated under the interim action ROD. At the 130-D-1 Underground Tank (199-D5-27), bis(2-ethylhexyl)phthalate was detected at a concentration of 6.3 mg/kg in the 3 to 3.6 m (10 to 12 ft) bgs depth interval. The bis(2-ethylhexyl)phthalate concentration of 6.3 mg/kg is greater than the ecological SSL of 0.14 mg/kg. The 130-D-1 Underground Tank is an accepted waste site that will be remediated.

- For the 100-H Source OU (shown in Table 7-11), three LFI sample locations (116-H-1 Trench, 116-H-7 Retention Basin, and the 116-H-9 Crib) report soil concentrations greater than ecological SSLs. These three waste sites have been remediated under the interim action ROD.

- Two RI sample locations (116-H-2 Trench/Crib and 1607-H4 septic system) report soil concentrations greater than ecological SSLs. At the 116-H-2 Trench/Crib Test Pit, bis(2-ethylhexyl)phthalate was detected at a concentration of 0.76 mg/kg in the 3.4 to 4 m (11 to 13 ft) bgs depth interval at a concentration greater than the ecological SSL of 0.14 mg/kg. All bis(2-ethylhexyl)phthalate results were flagged with a "B" laboratory qualifier, indicating that the analyte was detected in both the sample and the associated QC blank, and the sample concentration is less than or equal to five times the blank concentration. At the 1607-H4 septic system test pit, bis(2-ethylhexyl)phthalate and eight polynuclear aromatic hydrocarbons were detected at concentrations greater than ecological SSLs in the 4 to 4.5 m (13 to 15 ft) bgs depth interval. Concentrations of PAHs and bis(2-ethylhexyl)phthalate ranged between slightly greater than the SSL to four times greater than the SSL. PAH and bis(2-ethylhexyl)phthalate concentrations were less than ecological SSLs in the 3.4 to 4 m (11 to 13 ft) bgs interval.

Table 7-10. Summary of Ecological Risk Comparisons at 100-D Source OU 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 Residual Contamination Beneath the Remediated Waste Site						
100-D-4 Trench	100-D-4 Trench (Test Pit)	No individual risks > thresholds	CVP-98-00004	No individual risks > thresholds	--	--
100-D-12 Sodium Dichromate Site	100-D-12 French Drain (Test Pit)	No individual risks > thresholds	CVP-2000-00016	No COPCs detected	100-D-12 TP1	Chromium (1.5 m [5 ft] bgs)
					100-D-12 TP2	No individual risks > thresholds
					100-D-12 TP3	No individual risks > thresholds
100-D-56 Sodium Dichromate Pipeline (Well 9)	C8375	No samples collected from this depth range	Accepted	--	--	--
116-D-1A Trench (Well 4)	C7622	No samples collected from this depth range	CVP-2000-00010	No individual risks > thresholds	199-D5-21	No individual risks > thresholds
116-D-1B Trench	C7855	No samples collected from this depth range	--	--	199-D5-29	No individual risks > thresholds
116-D-4 Crib	116-D-4 Crib (Test Pit)	No individual risks > thresholds	CVP-2000-00008	No COPCS reported above background	199-D5-24	Thallium (0.9 to 1.7 m [3 to 5.5 ft] bgs)
116-D-7 Retention Basin	C7851	No samples collected from this depth range	CVP-99-00007	No individual risks > thresholds	199-D8-60	No individual risks > thresholds
116-DR-1&2 Trench	C7852	No samples collected from this depth range	CVP-2000-00002	No individual risks > thresholds	199-D8-61	No samples collected from this depth range
					199-D8-62	No samples collected from this depth range

Table 7-10. Summary of Ecological Risk Comparisons at 100-D Source OU 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-DR-9 Retention Basin	C7850	No samples collected from this depth range	CVP-99-00006	No individual risks > thresholds	199-D8-64	Bis(2-ethylhexyl)phthalate (2.7 to 3.6 m [9 to 11.8 ft] bgs)
					199-D8-65	No individual risks > thresholds
					199-D8-66	No individual risks > thresholds
118-D-6 Reactor Fuel Storage Basin	C7857	No samples collected from this depth range	No (concrete)	--	--	--
Wells Installed to Characterize Contamination in the Unconfined Aquifer						
100-D Well No. 2	C7620	No samples collected from this depth range	--	--	--	--
100-D Well No. 3	C7621	No samples collected from this depth range	--	--	--	--
100-D Well No. 5	C7623	No samples collected from this depth range	--	--	--	--
Well 9 (redrilled for data gap 2)	C7866	No samples collected from this depth range	--	--	--	--
Wells Installed to Characterize Contamination Beneath the Unconfined Aquifer in the RUM						
100-D RUM Well R4	C7624	No samples collected from this depth range	--	--	--	--
100-D RUM Well R5	C7625	No samples collected from this depth range	--	--	--	--
100-D RUM Well R5 Redrill	C8668	No samples collected from this depth range				

Table 7-10. Summary of Ecological Risk Comparisons at 100-D Source OU 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 during LFI to Characterize Waste Site in 100-DR-1 and 100-DR-2 OUs						
116-D-6 French Drain	--	--	CVP-2000-00009	No individual risks > thresholds	199-D5-25	No samples collected from this depth range
116-D-2 Crib	--	--	CVP-2000-00013	No COPCS reported above background	199-D5-22	No individual risks > thresholds
116-D-9 Crib	--	--	CVP-2000-00012	No individual risks > thresholds	199-D5-26	No samples collected from this depth range
132-D-3 Pumping Station	--	--	RSVP-2005-033	Facility	199-D5-28	No samples collected from this depth range
116-D-5 Outfall Structure	--	--	Accepted Waste Site	--	199-D8-59	No samples collected from this depth range
116-DR-5 Outfall Structure	--	--	Interim Closed Out	No individual risks > thresholds	199-D8-63	No samples collected from this depth range
116-D-3 French Drain	--	--	No Action Waste Site	--	199-D5-23	No samples collected from this depth range
130-D-1 Underground Tank	--	--	Accepted Waste Site	--	199-D5-27	Bis(2-ethylhexyl) phthalate (3 to 3.7 m [10 to 12 ft] bgs)
108-D/ Sodium Dichromate Tanks	--	--	Not listed as a WIDS waste site	--	108-D-TNKS-TP-1	No individual risks > thresholds
					108-D-TP-1	No individual risks > thresholds
116-DR-3 Trench	--	--	Accepted Waste Site	--	118-D-5 TP	No individual risks > thresholds
					116-DR-3 TP	No individual risks > thresholds
116-DR-7 Crib	--	--	CVP-2000-00019	No individual risks > thresholds	199-D5-30	No individual risks > thresholds

* Complete reference citations are provided in Chapter 11.

Table 7-11. Summary of Ecological Risk Comparisons at 100-H Source OU 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 Residual Contamination Beneath the Remediated Waste Site						
116-H-1 Trench	C7864	No samples collected from this depth range	CVP-2000-00026	No individual risks > thresholds	199-H4-58	Lead (3 to 3.7 m [10 to 12 ft] bgs)
116-H-2 Trench/Crib	116-H-2 Trench/Crib (Test Pit)	Bis(2-ethylhexyl)phthalate (2.7 to 3.4 m [9 to 11 ft] bgs; 3.4 to 4 m [11 to 13 ft] bgs)	CVP-2000-00031	No individual risks > thresholds	199-H4-59	No individual risks > thresholds
116-H-4 Pluto Crib	C7862	No individual risks > thresholds	Accepted Waste Site	--	--	--
116-H-6 Solar Evaporation Basin	C7860	No individual risks > thresholds	--	--	--	--
116-H-7 Retention Basin	C7861	No samples collected from this depth range	CVP-2000-00027	No individual risks > thresholds	199-H4-61	Lead (0.3 to 0.9 m [1 to 3 ft] bgs); carbon-14 (2.4 to 3 m [8 to 10 ft] bgs); mercury (2.4 to 3 m [8 to 10 ft] bgs; 3 to 3.8 m [9.8 to 12.4 ft] bgs)
118-H-6 Reactor Fuel Storage Basin	C7863	No samples collected from this depth range	CVP-2006-00003	No individual risks > thresholds	--	--
1607-H4 Septic System	1607-H4 Septic System (Test Pit)	Benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, benzo(k)fluoranthene, benzo(ghi)perylene, bis(2-ethylhexyl)phthalate, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene (4 to 4.6 m [13 to 15 ft] bgs)	CVP-2000-00025	No individual risks > thresholds	--	--

Table 7-11. Summary of Ecological Risk Comparisons at 100-H Source OU 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?
Wells Installed to Characterize Contamination in the Unconfined Aquifer						
100-H Well No. 6	C7626	No samples collected from this depth range	--	--	--	--
100-H Well No. 7	C7627	No samples collected from this depth range	--	--	--	--
100-H Well No. 10	C7628	No samples collected from this depth range	--	--	--	--
100-H Well No. 11	C7629	No samples collected from this depth range	--	--	--	--
100-H Well No. 12	C7630	No individual risks > thresholds	--	--	--	--
Wells Installed to Characterize Contamination Beneath the Unconfined Aquifer in the RUM						
100-H RUM Well R1	C7639	No samples collected from this depth range	--	--	--	--
100-H RUM Well R2	C7640	No samples collected from this depth range	--	--	--	--
100-H RUM Well R3	C7631	No samples collected from this depth range	--	--	--	--
Soil Borings Installed during LFI to Characterize Priority Waste Site in 100-HR-1 and 100-HR-2 OUs						
116-H-3 French Drain	--	--	CVP-2000-00032	No individual risks > thresholds	199-H4-60	No samples collected from this depth range
116-H-9 Crib	--	--	RSVP-2009-047	No individual risks > thresholds	199-H4-62	Aluminum, barium, cadmium, chromium, cobalt, copper, manganese, nickel, vanadium (0.9 to 1.6 m [3.1 to 5.3 ft] bgs)

Table 7-11. Summary of Ecological Risk Comparisons at 100-H Source OU 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?
Limited Field Investigation - Monitoring Well Installation (Not associated with a Waste Site)						
--	--	--	--	--	199-H4-45	No samples collected from this depth range
--	--	--	--	--	199-H4-46	No samples collected from this depth range
--	--	--	--	--	199-H4-47	No samples collected from this depth range
--	--	--	--	--	199-H4-48	No samples collected from this depth range
--	--	--	--	--	199-H4-49	No samples collected from this depth range
--	--	--	--	--	199-H6-1	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) evaluated soil, sediment, and water in riparian and nearshore areas. The remedial action goals 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 (DOE/RL-2007-21) 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 in the Columbia River beyond the nearshore environment. Several investigations conducted on effluent pipelines that discharged to the Columbia River are also summarized in the following subsections.

7.5.1 Summary of Results and Conclusions of RCBRA

The RCBRA (DOE/RL-2007-21) 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. For the nearshore environment, 22 COPECs were identified and 16 of these (all inorganics) were further identified as COECs. The RCBRA (DOE/RL-2007-21) concluded that across the Hanford Reach of the Columbia River (that is, 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 upon the comparisons of COPEC concentrations to toxicity benchmarks, measures of exposure and effects in biota, or the results of wildlife exposure analyses (RCBRA [DOE/RL-2007-21]). The evaluation of these sediment COECs is summarized as follows:

- **Cadmium** was detected in 9 of 22 nearshore sediment samples (Appendix L, Tables L-68 through L-70). However, none of the samples exceeded the lower effects threshold (ecological screening level [ESL]); thus cadmium was not carried forward to the FS.
- **Total Chromium** was detected in 23 of 24 nearshore sediment samples. However, none of the samples exceeded the lower effects threshold (screening value from *Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho* [Ecology Publication 11-09-54]); thus chromium was not carried forward to the FS.
- **Manganese** was detected in 22 of 22 nearshore sediment samples. However, none of the samples exceeded the lower effects threshold (screening level); thus manganese was not carried forward to the FS.

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

- **Cr(VI)** was detected in five of eight 100-D pore water samples (Appendix L, Table L-41) and one of two 100-H pore water samples (Appendix L, Table L-46). Within 100-D, nearshore filtered samples exceeded the ESL in aquifer tubes (161 of 308 samples) and groundwater wells (84 of 103 samples). Filtered sample data were not available for pore water or seep samples, but unfiltered samples exceeded the ESL in both pore water (2 of 8 samples) and the seep (1 of 1 sample). Within 100-H, all pore water concentrations were below the ESL in the 100-H Area, and seep data were not collected. However, nearshore filtered samples exceeded the ESL in aquifer tubes (41 of 105 samples) and groundwater wells (76 of 111 samples). Given the clear pathway from groundwater to the aquifer tubes and ultimately pore water, there is a clear pathway of Cr(VI) originating from the 100-HR-3

Groundwater OU wells within the vicinity of 100-D and 100-H that warrants further evaluation in the FS.

- **Manganese** was detected in seven of seven 100-D pore water samples and two of two 100-H pore water samples, but concentrations were less than the ESLs for all sediment and pore water samples collected in the 100-D and 100-H Areas. Filtered concentrations were also below the ESL, except for one aquifer tube sample. Thus, manganese in the 100-D and 100-H nearshore areas was not recommended for evaluation in the FS.
- **Uranium** was not detected in the nine samples collected from pore water near 100-D and 100-H Areas. Thus, uranium in the 100-D/H nearshore areas was not recommended for evaluation in the FS.

The RCBRA (DOE/RL-2007-21) identified 9 of the identified 22 COPECs (arsenic, chromium, copper, lead, mercury, selenium, TPH-diesel, vanadium, and zinc) as possibly presenting risk for 1 or more of the assessment endpoint entities (terrestrial plants, invertebrates, and wildlife). 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 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). The evaluation of these COECs is summarized below.

As shown in Appendix L, Tables L-51 through L-61, concentrations of arsenic, chromium, lead, mercury, TPH-diesel, and zinc in the 100-D and 100-H riparian soil 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.

Final COECs identified within the RCBRA (DOE/RL-2007-21) are included in Table 7-12. These COECs were determined for the River Corridor as a whole. The potential or likelihood for the 100-D/H Source OUs to have contributed to the potential ecological risks identified for these COECs is discussed in Appendix L and summarized in the remainder of this section.

Table 7-12. Riparian, Nearshore, and Riverine COECs from the RCBRA and CRC

COEC	Receptors	Media	Are 100-DR-1, 100-DR-2, 100-HR-1 and 100-HR-2 Potential Sources?	Is 100-HR-3 a Potential Source?
Aluminum[a]	Fish Aquatic Invertebrates Aquatic Plants	Pore Water	No	No
Arsenic[b]	Terrestrial Plants	Riparian Soil	No	No
Cadmium[b]	Aquatic plants and invertebrates	Sediment	No	No
Chromium[a]	Fish Aquatic invertebrates Aquatic plants	Pore water	No	Yes
Chromium[a,b]	Aquatic plants and invertebrates and the bufflehead	Sediment	No	No
Chromium[b]	Terrestrial plants and invertebrates	Riparian soil	No	No

Table 7-12. Riparian, Nearshore, and Riverine COECs from the RCBRA and CRC

COEC	Receptors	Media	Are 100-DR-1, 100-DR-2, 100-HR-1 and 100-HR-2 Potential Sources?	Is 100-HR-3 a Potential Source?
Cr(VI)[a,b]	Aquatic plants and invertebrates	Sediment	No	No
Cr(VI)[a,b]	Fish Aquatic invertebrates Aquatic plants	Pore water	No	Yes
Lead[a]	Fish Aquatic invertebrates Aquatic plants	Pore water	No	No
Lead[b]	Terrestrial plants	Riparian soil	No	No
Manganese[b]	Aquatic plants and invertebrates	Sediment	No	No
Manganese[b]	Aquatic plants and invertebrates	Pore water	No	No
Mercury[b]	Terrestrial invertebrates	Riparian soil	No	No
Nickel[a]	Fish Aquatic invertebrates Aquatic plants	Pore water	No	No
Nitrate[a]	Fish Aquatic invertebrates Aquatic plants	Pore water	No	Yes
TPH–Diesel[b]	Terrestrial invertebrates	Riparian soil	No	No
Uranium[b]	Aquatic plants and invertebrates	Pore water	No	No
Zinc[b]	Terrestrial plants and invertebrates and kingbirds	Riparian soil	No	No

a. COECs presented in the executive summary of the CRC (*Columbia River Component Risk Assessment, Volume I: Screening-Level Ecological Risk Assessment* [DOE/RL-2010-117]).

b. COECs presented in Sections 8.4 and 8.5 of the RCBRA (*River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment* [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 COPECs. Soil concentrations were compared to plant and invertebrate benchmarks, while 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 (DOE/RL-2010-117) concluded that eight COECs were within sediment, pore water, island soil, and shoreline sediment (aluminum, chromium, Cr[VI], lead, manganese, mercury, selenium, and uranium). The evaluation included distinct conclusions for the reach adjacent to the 100 Area versus those for the reach adjacent to the 100-D/H Source OUs. Six COECs were identified for the 100-D/H Source OUs, as presented in Table 7-12. The potential or likelihood for the 100-D/H Source OUs to have contributed to the potential ecological risks identified for these COECs is discussed in Appendix L and summarized in the remainder of this section. The evaluation of these COECs is summarized as follows:

- **Aluminum** was detected in three of nine pore water samples in the 100-D/H nearshore areas. However, detections in all aqueous media were below ESLs. Therefore, aluminum is not considered a COEC and will not be carried forward to the risk characterization section or to the FS.

- **Cr(VI)** was detected in 5 of 10 pore water samples in the 100-D/H Area reach of the Columbia River, but was not collected from sediment. Within 100-D, nearshore filtered samples exceeded the ESL in pore water (2 of 8 samples), aquifer tubes (17 of 62 samples), seep (1 of 1 sample), and groundwater wells (84 of 103 samples). Within 100-H, all pore water concentrations were below the ESL and seep data were not collected. However, nearshore filtered samples exceeded the ESL in aquifer tubes (41 of 105 samples) and groundwater wells (76 of 111 samples). Given the clear pathway from groundwater to the aquifer tubes and ultimately pore water, there is a clear pathway of Cr(VI) originating from the 100-HR-3 Groundwater OU wells within the vicinity of 100-D and 100-H that warrants further evaluation in the FS.

- **Total Chromium** was detected in 23 of 24 nearshore sediment samples and 3 of 9 pore water samples in the 100-D/H nearshore areas. However, samples were less than the ESL for all sediment and pore water samples collected in the 100-D/H Areas and all aquifer tubes and seep samples collected in the 100-H Area. However, filtered total chromium samples were detected above the ESL in aquifer tubes (17 of 62 samples), seeps (1 of 8 samples), and groundwater wells (20 of 37 samples). While Cr(VI) concentrations are elevated in the same media, mean and maximum concentrations of Cr(VI) are well below those of total chromium. Therefore, given the clear pathway from groundwater to the aquifer tubes and ultimately pore water, there is a potential pathway of total chromium originating from the 100-HR-3 Groundwater OU wells within the vicinity of 100-D/H that warrants further evaluation in the FS.

- **Lead** was not detected in pore water samples collected from the 100-D/H nearshore areas. Filtered concentrations within the 100-H aquifer tube, seep, and groundwater samples were below the ESL. Thus, the 100-HR-3 Groundwater OU wells within the vicinity of 100-D/H do not contribute to concentrations of lead observed in pore water at locations within the reach of the Columbia River.

- **Nickel** was detected in 2 of 9 pore water samples collected from the 100-D/H nearshore areas. The ESL was exceeded within 100-D in a limited number of aquifer tubes (8 of 62 filtered samples and 10 of 64 unfiltered samples) and groundwater wells (2 of 37 filtered samples and 3 of 36 unfiltered samples). Samples from all aqueous media were below the ESLs within the 100-H Area. Thus, the 100-HR-3 Groundwater OU wells within the vicinity of 100-D/H do not contribute to concentrations of nickel observed in pore water indicative of risk to aquatic plants in the Columbia River Reach adjacent to or downstream from the 100-D/H Areas.

- **Nitrate** was not collected from pore water in the 100-D/H nearshore areas. For the purposes of the ERA, nitrate was identified as a potential risk in the CRC (DOE/RL-2010-117) because of one anomalously high detection that exceeded the LOEC screening value identified at 37.64 mg/L.

More importantly, as suggested by reference concentrations as high as 20.7 mg/L, nitrate is a common constituent in the Columbia River and its tributaries, a reflection of the agricultural land use prevalent in the area. More recent work has shown that nitrate toxicity is hardness dependent (*Evaluation of the Role of Hardness in Modifying the Toxicity of Nitrate to Freshwater Organisms* [Nautilus, 2013]). However, with a maximum detect in 100-H aquifer tubes of 602 mg/L, nitrate was retained as COPEC within the reach of the Columbia River adjacent to the 100-H.

7.5.3 100-D/H 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 reactors and facilities were shut down. Today, the three inactive 100-D/H 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) summarized 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 C, DR, and 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/hour, 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 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 discharged from the B and D/DR Reactors.

The analytical results from the 1984 and 1995 effluent pipeline characterization studies at the B, C, D/DR, and F Reactors may reasonably be applied to effluent pipelines in 100-D/H, 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, no remediation requirements under CERCLA. This is supported by the following:

- Minimal deteriorated condition of the pipelines
- Continued decrease of radionuclide concentrations because of 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 these pipelines.

7.5.4 Summary of the Evaluation of Riparian Soil

The RCBRA (DOE/RL-2007-21) evaluated ecological risks at representative riparian study sites adjacent to, or where they may be directly affected by, known contaminated media (groundwater seeps, soil, or sediment). The RCBRA (DOE/RL-2007-21) 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 risks to terrestrial plants or invertebrates from exposure to island and riparian soil.

Most concentrations detected in riparian soil within the 100-D/H OU were below ESLs (in this case specifically the SSLs) described previously. Except for aluminum, bis(2-ethylhexyl)phthalate, thallium, and vanadium, all other detections were below PRGs (Appendix L, Tables L-51 through L-61). These four chemicals are discussed below. 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 8-4, 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 soil of the 100-D/H OUs were below plant ESLs (Tables L-51, L-52, L-55, and L-56) except thallium. Thallium was identified in the RCBRA (DOE/RL-2007-21) as being below background. Likewise, the CRC (DOE/RL-2010-117) did not identify risks to terrestrial plants from exposure to island and riparian soil. Therefore, no COPECs in 100-D/H riparian soil warrant further evaluation in the FS based on risks to terrestrial plants. This finding is also supported by the results of 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. Though these lines of evidence carry less weight given their limited datasets and temporal variability (that is, they were conducted just once), the results 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

Concentrations of chromium, mercury, and zinc exceeded SSLs for terrestrial invertebrates in the 100-D riparian soil study area (2f, Rip 1, Rip 2, Rip 3, Rip 8, Rip 9, Rip 10); concentrations were higher than the terrestrial invertebrate LOEC (RCBRA [DOE/RL-2007-21], Table 5-70). However, no chemicals, including chromium, mercury, and zinc, had concentrations that exceeded the Hanford Site-specific PRGs for terrestrial invertebrates (Tables L-51, L-52, L-55, and L-56) except thallium. Thallium was identified in the RCBRA (DOE/RL-2007-21) as being below background. The CRC (DOE/RL-2010-117) did not identify risks to terrestrial invertebrates from exposure to island and riparian soil. 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 indicate 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 chemicals and the possibility of bias because 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 specific for the 100-D/H Areas. 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 (DOE/RL-2007-21) using both field measures and desktop food web modeling using models similar 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 through 7-4. Results of these three analyses are described below. The results all suggest that there is no risk to wildlife in the riparian soil of the 100-D/H OUs.

For riparian soil, 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], Table 5-48), and were less than available tissue effect levels (RCBRA, page 5-91).

Dietary exposure to terrestrial birds and mammals estimated using wildlife exposure models and riparian soil 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, selenium and vanadium concentrations within the 100-D Area, 100-H Area, and horn area were within Hanford Site-wide background, and copper and zinc concentrations were below Hanford-specific ESLs (Appendix L, Tables L-57 and L-58) for wildlife and therefore do not warrant further evaluation in the FS.

Most concentrations detected in riparian soil within the 100-D/H Areas were below SSLs and PRGs. ESL results showed the following three chemicals within riparian soil had concentrations above wildlife ESLs within the 100-D/H OUs: aluminum, bis(2-ethylhexyl)phthalate, and vanadium (Appendix L, Section L4.5 and Tables L-53, L-54, L-57, L-58, L-60, and L-61). 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-D/H riparian areas. Bis(2-ethylhexyl)phthalate concentrations exceeded SSLs in 2 of 21 samples. The SSLs were based on unbound no-effect levels in literature-based food chain models (that is, insufficient site-specific data were available to develop a PRG). Bis(2-ethylhexyl)phthalate, a common lab contaminant, 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 not warranted. The maximum detected concentrations of vanadium (60.1 and 55 mg/kg) for the 100-D/H OUs were less than the site background of 85 mg/kg. Additional discussion is provided in Appendix L, Section L4.5. 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. The single study site with which this risk was associated is not within the 100-D/H nearshore environment.

7.5.5 Summary of Evaluation of Near Shore and Columbia River

The results from the evaluation in Appendix L showed that a range of inorganic, organic, and radiological contaminants, detected in near-river groundwater samples collected from the 100-D/HR-3 OUs, are not affecting the aquatic life exposed to pore water, surface water, or sediment in the Columbia River near the 100-DH OUs[13]. Numerous lines of evidence were considered as part of the evaluation. The evidence included, but was 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 aquatic criteria comparisons.

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 L, that with the exception of total chromium and Cr(VI) in groundwater, no COECs affect aquatic life exposed to pore water or surface water in the Columbia River near 100-D/H.

In addition to the evaluation presented in Appendix L, a qualitative evaluation presented in Appendix H considered the potential for the exposure of threatened and endangered species to site-related chemicals

[13] 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 may be overestimated by using the unfiltered (or total metals) concentrations.

within the Hanford Reach. The focus was to evaluate COCs having the potential to reach the Columbia River. The evaluation considered current and future contaminant concentrations in the Columbia River water and gravels resulting from groundwater originating from the 100-D/H area of the Hanford Site. The evaluation supports a conclusion of no effect on species listed as threatened or endangered under the Endangered Species Act. Further, the evaluation shows no evidence of effect of the proposed remedial action on the habitat for those species. This conclusion is based on several lines of evidence. First, the preferred remedy does not take an action in the Columbia River, so there will not be any direct physical effects on fish or their habitat. Second, there are no effects of contaminants on listed species of fish before, during or after the remedial actions. This second line of evidence is strengthened by data showing that contaminated groundwater does not flow to the river during moderate and high river stages when listed species have sensitive life stages in the river gravels. Appendix H should be referred to for a detailed description of this evaluation.

7.5.5.1 Risk to Fish

No COECs in the RCBRA (DOE/RL-2007-21) or in the CRC (DOE/RL-2010-117) 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 criteria (aluminum, chromium, Cr[VI], lead, nickel, and nitrate) in 100-D/H pore water samples. 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 L, Section L4, with the exception of total chromium and Cr(VI), these chemicals are not found in nearshore groundwater; therefore, there is no source for these COECs from the 100-HR-3 OU. In addition, these values are not necessarily indicative of risks to fish, because these screening values are based on water quality or plant or invertebrate risk.

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 other factor (for example, habitat, nutrient availability) was not possible because it was not considered 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-D/H, total chromium, Cr(VI), and nitrate in 100-HR-3 OU groundwater, which represents a potential source for pore water concentrations that exceed the fish surface water ESL, warrant further evaluation in the FS. Total chromium and Cr(VI) concentrations in multiple wells close to the river and aquifer tubes exceed ambient water quality criteria.

Other COPECs detected in pore water above ambient water criteria do not appear to be issues in groundwater or aquifer tubes, suggesting that the 100-HR-3 Groundwater OU is not the source of observed elevated concentrations. The exceedances for additional chemicals are discussed in more detail in Appendix L. As explained in Appendix L, exceedances of ambient water quality criteria for other chemicals within aquatic media (pore water, seeps, aquifer tubes, groundwater, surface water) were either anomalous (that is, very low frequency) or because of 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], Tables 6-88 through 6-91). Based on the combined pore water and sediment concentrations, the RCBRA (DOE/RL-2007-21) 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-201-117) identified the final COECs for pore water and sediment within the 100-HR-3 OU as aluminum, chromium, Cr(VI), lead, nickel, and nitrate. For the 100-D nearshore sampling sites, antimony and silver were detected in sediment at concentrations greater than the upper threshold sediment biota ESL (Appendix L, Tables L-72). Notably, these sediment ESLs are derived for invertebrates/microbes (e.g., *Chironomous sp.* and *Hyalella azteca*), not aquatic plants. Sediment COPECs/COECs are discussed in more detail below with risks to aquatic invertebrates and in more detail in Appendix L, with a conclusion that observed sediment concentrations do not warrant further evaluation. Pore water COPECs from the 100-D/H nearshore sampling sites are discussed in more detail in Appendix L, Section L4.2, 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-D/H OUs, Cr(VI) had concentrations of ecological relevance in the nearshore environment. Total chromium was above the ESL in nearshore groundwater wells, aquifer tubes, and seeps. Only total chromium and Cr(VI) represent 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 (that is, toxicity tests) were conducted with field-collected sediments. Significant relationships were determined with observed response within aquatic plant toxicity tests in association with confounding factors and some chemicals. Additionally, there were clear measures of exposure (that is, accumulation into plants), primarily for inorganic chemicals 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.

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. Pore water concentrations at study sites across the Hanford Reach were greater than chronic water standards or criteria for five COPECs (aluminum, cadmium, chromium, Cr(VI), and lead; RCBRA [DOE/RL-2007-21], Table 6-90). 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 sampled. Exceedances should not be ignored as they can indicate exposure at levels presenting a risk. But because of the uncertainty in the representativeness of the measurements resulting from the dynamic environment, the exceedances should be considered along with other data that identify whether there is an ongoing source of the measurements. This analysis is presented in Appendix L. 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 for both plants and aquatic invertebrates: total chromium and Cr(VI) in the 100-HR-3 Groundwater OU, which represents a potential source for pore water concentrations that exceed water quality criteria, warrant 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 Report [DOE/RL-2007-21], Section 8.5.1.2). Likewise, total chromium and Cr(VI) in sediment were identified as COECs for the 100 Area in the CRC (DOE/RL-2010-117). For sediment samples collected within the 100-D and 100-H nearshore areas (Appendix L, Tables L-72 and L-74), concentrations were greater than upper threshold ESLs for antimony and phosphorus within the 100-D Area only.

Given the uncertainty with representativeness mentioned above, each of the COECs from the RCBRA (DOE/RL-2007-21), CRC (DOE/RL-2010-117), and 100-D/H nearshore sediment is discussed in detail in Appendix L. 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-D/H nearshore environment (explanations for the exceptions are described in Appendix L). This suggests that sediments upstream from the Hanford Site potentially contribute to concentrations observed in the 100-D/H nearshore sediments. Further, riparian soil for most of the COECs is lower than upstream sediment and Hanford Site reference soil concentrations, suggesting that the riparian soil in the 100-D/H Area is not a source of the observed sediment concentrations for the RCBRA (DOE/RL-2007-21) 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 represent only a snapshot in time and do not represent all seasonal conditions and river stage fluctuations, these measures support the analysis that Hanford Site operations in 100-D/H do not adversely affect aquatic receptors exposed to sediment in the 100-D/H nearshore environment. Based on these findings, only total chromium and Cr(VI) in groundwater warrant further evaluation in the FS.

Direct Toxicity Measures. Risks to aquatic macroinvertebrates based on toxicity testing showed relationships with confounding factors and some chemicals. Histopathological measures of Asiatic clams (*Corbicula fluminea*) differed in study sites compared to reference sites; these measures also showed some negative relationships with chemicals. However, sediment bioassays at site Cr7/CR8 and 2f selected to represent 100-D/H showed no difference in amphipod (*Hyalella azteca*) growth or survival relative to reference sites. Likewise, survival and reproduction tests on water fleas in pore water showed no difference at sites representing 100-D/H relative to reference sites. Correlation between abiotic media chemistry and observed differences in measured effects from both bioassays was conducted across the 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-D/H 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. It is possible that additive and/or synergistic effects from chemical mixtures may be the cause. However, a number of different variables (both chemical and non-chemical) could lead to differences in survival between site and control samples. Determining if or which multiple variables could be causing such an effect is particularly difficult. Together, these measures do not indicate substrate concentrations were toxic. However, they do not represent all seasonal conditions and river stage fluctuations.

Community Structure Measures. Key community metrics do not suggest that contaminant-related effects to benthic macroinvertebrates are evident in aquatic study sites as a group, as indicated by the comparison of Ephemeroptera, Plecotera, and Trichoptera 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), 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 histopathological measures of clams and mussels showed no significant differences between study and reference. While, there were exceptions, COPEC concentrations generally did not correlate with differences in histopathological measures.

Weight of Evidence. As stated previously, abiotic and biotic measures collected for the RCBRA (DOE/RL-2007-21) do not represent all seasonal conditions and river stage fluctuations. Abiotic measurements 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, total chromium and Cr(VI) had concentrations of ecological relevance in the nearshore environment for the 100-D Area, 100-H Area, and horn area. Total chromium and Cr(VI) in groundwater in the 100-HR-3 Groundwater OU, which represents a potential ongoing source for pore water concentrations that exceed water quality criteria, warrant 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 (DOE/RL-2007-21) 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 not within the 100-D/H nearshore environment. However, because of the limited time at the site (winter only) and the unlikeliness of a population of bufflehead ducks feeding over this single location long enough to cause chronic exposure, total chromium does not warrant additional consideration in the FS for exposures to nearshore middle-trophic level wildlife.

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

At 100-D/H, 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 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 affect 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-HR-3 OU discharges to the Columbia River via upwelling through the riverbed and, to a lesser extent, via riverbank springs that appear during low river stage. Sampling locations (for example, 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 L. As is discussed in Section 4, springs along the 100-D and 100-H Source OU shoreline have been monitored for many years as part of the Surface Environmental Surveillance Program (SESP) (2009 Sitewide Environmental Report [PNNL-19455]). Samples of spring water and associated fine-grained sediment collected during late summer/early fall have been analyzed for Cr(VI) and other waste effluent indicators. Annual sampling is conducted 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-D and 100-H 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 available information, there is a pathway for migration of Cr(VI) in 100-HR-3 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 at mid-channel depth within the Columbia River in the vicinity of 100-D and 100-H have not measured detectable levels of Cr(VI). The flux of Cr(VI) in groundwater is too small to produce significant Cr(VI) effects related to Hanford Site operation in Columbia River surface water. This is supported by a lack of detections of Cr(VI) in surface water and a conclusion that accumulation of Cr(VI) in fish tissue such as sculpin does not pose a significant risk (see Chapter 6).[14]

7.5.6 Conclusions

Table 7-12 presents the 13 COECs identified in the riparian and nearshore media from the RCBRA (DOE/RL-2007-21) and the CRC (DOE/RL-2010-117). 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 are discussed in Appendix L to determine the likelihood that the 100-D/H OUs were sources. The conclusion of Appendix L is that of the COECs in Table 7-12, only total chromium and Cr(VI) are related to the 100-D/H OUs in groundwater.

7.5.7 Risk Conclusions and Scientific Management Decision Point

COPCs were identified in ninety-five 100-D OU waste sites, which were reclassified as "interim closed," "no action," or to be determined through the TPA (Ecology et al., 1989a) process. The COPCs were identified in forty-seven 100-H OU waste sites reclassified as "interim closed" or "no action" through the TPA (Ecology et al., 1989a) process. EPCs of COPCs for each decision unit (for example, overburden, shallow-focused, shallow, staging pile footprint) at each waste site were compared to the plant/invertebrate SSL, the wildlife SSL, background, and plant/invertebrate PRG and wildlife PRG values. Within the 100-D OU, 19 waste sites were retained for additional consideration based on EPC exceedances of six COPECs (copper, lithium, mercury, selenium, silver, and vanadium). Within the 100-H OU, 8 waste sites were retained for additional consideration based on EPC exceedances of four COPECs (barium, boron, chromium, and mercury).

[14] The noncancer HI above 1.0 for the Tribal scenario was driven by nickel, not Cr(VI).

At the SMDP, the results of the ERA were considered in the context of other factors (for example, 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 managers 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 remediated 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), total chromium and Cr(VI) in the 100-HR-3 Groundwater OU are recommended for further evaluation in the FS.

7.6 SMDP Considerations

Within the process for conducting ecological risk evaluations or assessments at CERCLA sites, several decision points occur at which risk managers, risk assessors, and other stakeholders 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 (for example, 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.[15]
- Potential for risks to ecological receptors, but there is uncertainty in one or more components of the ERA that warrant 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 (for example, human health) that would address potential ecological risks.
- Potential for risk to ecological receptors warranting evaluation of remedial alternatives in the FS.

With the 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 if the site requires evaluation of remedial alternatives in the FS include 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 unaffected habitat
- Number and location of samples collected at the site

[15] 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.

- 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 (for example, 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 (that is, level of confidence, basis, relation to other PRGs such as those for human health or groundwater protection)

As shown in Appendix H (Table H-20), 19 waste sites within 100-D OU and 8 waste sites within the 100-H OU were reported with concentrations of COPECs greater than their respective PRGs. Figures showing the location and concentration of COPECs reported with an HQ greater than 1.0 are provided in Appendix H. During development of the evaluation, 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-D/H OUs were based on a subset of the factors described above, including the following:

- Depth of samples[16] exceeding thresholds relative to the 4.6 m (15 ft) bgs standard point of compliance for ecological receptors defined by 2007 MTCA (WAC 173-340)
- Number and frequency of exceedances of the risk thresholds (PRGs)
- Magnitude of exceedance relative to the risk thresholds (the HQ)
- Confidence in the ecological risk thresholds defining the exceedances
- Quality of the sample data defining the exceedances
- Location of the samples exceeding thresholds, sample frequency, and proximity of other exceedances
- Area of exceedance relative to home range of receptor exceeding and relative to area of unaffected nearby habitat

Within these 27 waste sites, eleven inorganic metals were measured at concentrations above the PRGs identified in this chapter. After considering the factors listed above, the recommendation was not to require further evaluation in the FS or any remedial action. A summary of the rationale by chemical and receptor is provided below with the details for each specific waste site-decision unit-chemical combination being found in Appendix H, Table H-20.

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

Plants: Mercury (14 waste site decision units), vanadium (5 waste site decision units), molybdenum (2 waste site decision units), and copper (2 waste site decision units) were all measured at concentrations above plant PRGs. Molybdenum is not expected to adversely affect the plant communities as it is not documented as phytotoxic in the published literature. Samples for copper above the copper PRG (58 mg/kg) were collected at 4.8 to 7 m (16 to 23 ft) which is below the standard point of compliance of 4.6 m (15 ft) and the maximum depth at which plant roots have been observed at the Hanford Site (3 m [9.8 ft]; *Rooting Depth and Distributions of Deep-Rooted Plants in the 200 Area Control Zone of the Hanford Site* [PNL-5247]). Most vanadium samples were just above background and also collected below where plant roots have been observed at the Hanford Site. Risk to plants from mercury are unlikely because of low confidence in the PRG and no exceedance of wildlife PRGs for a bioaccumulative compound. These were infrequent and in most cases spatially distinct exceedances that would not cause a community level effect. If localized adverse effects did occur, habitat fragmentation in the 100-D OU would not be likely given the level of ecological services the habitat is providing in the current condition and the available habitat refugia nearby (see Section 7.6.3)

Invertebrates: Barium and silver were measured at concentrations above terrestrial invertebrate PRGs at three and one waste site-decision units respectively. These were infrequent and in most cases spatially distinct exceedances that would not cause a community level effect. Considering these infrequent exceedances, if deep excavation were to occur, the elevated concentrations would be mixed with much lower concentration material resulting in a lower exposure concentration. At three of the waste site decision units, samples were from a depth below the maximum at which invertebrates have previously been observed at the Hanford Site (2.7 m [8.9 ft]; *Characterization of the Hanford 300 Area Burial Grounds: Task IV – Biological Transport* [PNL-2774]). Risk to the terrestrial invertebrate community are not expected at these waste site decision units and there is ample unimpacted habitat for available in adjacent areas and along the River Corridor.

Wildlife: Selenium and lead were measured at concentrations above wildlife PRGs at five and four waste site-decision units respectively. However, selenium measurements were sometimes deep (i.e., below the maximum depth at which Hanford Site wildlife have been observed to burrow [1 m {3.3 ft} pocket mouse] "Loose Rock As Biobarriers in Shallow Land Burial" [Cline et al., 1980]) and the size of the waste sites is small. When the size of the sites was considered relative to the home range of wildlife receptors (i.e., application of an AUF), HQs were below 1.0. The population density of small mammals and the number of individuals expected to reside within these small sites was also considered. The final conclusion was that there are no population level effects to avian and mammalian receptors at any of the remediated waste sites that were evaluated including those with some measured samples of selenium and lead above PRGs.

SMDP Conclusion: As indicated in Appendix H, Table H-20, consideration of factors listed above resulted in the conclusion of no unacceptable risks to terrestrial wildlife or plants and invertebrates exposed to vadose zone soil and a recommendation of no further action for the waste sites within the 100-DR-1, 100-DR-2, 100-HR-1, or 100-HR-2 Source OUs. For unremediated waste sites, remedial actions will consider the PRGs through the SMDP process. More detail in applying that process to unremediated sites is described in Sections 7.6.2 and 7.6.3.

7.6.1 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 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 represent 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-0784]; *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, for example, 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. This ratio of the area of contamination to the home range is known as an AUF. An AUF = 1 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 is 1 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; 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-6. In considering the home range data available for each species, it must be recognized that these ranges are reduced during breeding season. On the other hand, food sources in a semiarid environment such as the Hanford Site may be scarcer than what is reflected in the studies available, some of which were not conducted in similar habitats. While many biological studies have been conducted at the Hanford Site, studies specifically on home range or population density are not available for all species or guilds being evaluated.

Completion of remedial actions as part of the cleanup verification process based on ecological PRGs will incorporate a SMDP on a case-by-case basis to determine that the action protects ecological receptors. The SMDP approach and its use in remediation decision making will be presented in detail in the RDR/RAWP. Further, in cases where verification samples exceed the PRGs and these PRGs represent the limiting value (that is, the wildlife PRGs are lower than all other applicable PRGs), a risk management decision should be made similar to 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 considered in the SMDP process include the following:

- Size of the waste site relative to home range of wildlife receptors (for example, 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 (that is, reduce survival, growth, or reproduction), as observed in 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 (for example, 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 (for example, home range, population density).

7.6.2 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 useful in screening waste sites for potential adverse effects to these communities. However, the use of these PRGs in selecting final remediation goals in the FS or the proposed plan should be considered on a site-specific basis except for waste sites where listed or protected species have been identified (that is, federal or state listed and protected threatened or endangered species). This recommendation is based upon 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 because of areas with elevated contaminants in soil. The plant and invertebrate PRGs can 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), a risk management decision should be made like 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]; *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 by 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 significant adverse effects that can be clearly attributed to soil chemistry that have 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. Sensitive species may demonstrate adverse effects at concentrations exceeding these NOECs. However, the risk management goal from *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 soil (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 more than 20 years. The RCBRA (DOE/RL-2007-21) 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 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 effect 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 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 plants 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.

7.6.3 Evaluations 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 L. The evaluation of surface sediment data for future assessments will be against the freshwater sediment ESLs presented in Appendix L, Table L-5. 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 designed to be used as cleanup levels for evaluating remedial actions. The primary source of freshwater sediment PRGs are the cleanup screening levels 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 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 7-13. As with soil investigations described above, future assessments should include SMDP considerations (Section 7.6.2).

Table 7-13. Freshwater Sediment PRGs

Chemical	PRG (mg/kg)[a]
Arsenic	120
Cadmium	5.4
Chromium	88
Copper	1,200
Lead	>1,300
Mercury	0.8
Nickel	110
Selenium	>20
Silver	1.7
Zinc	>4,200
TPH-Diesel	510

a. Freshwater sediment PRGs represent CSL/SL2 (Cleanup Screening Level) values from *Draft Development of Benthic SQVs for Freshwater Sediments In Washington, Oregon, and Idaho* [2011 Ecology Pub. No. 11-09-054].

Note: > "Greater than" value indicates that the toxic level is unknown, but above the concentration shown.

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