APPENDIX D.4

100-B/D/H/F/K AREA GROUNDWATER (RC-GW-3, RIVER CORRIDOR) EVALUATION UNIT SUMMARY TEMPLATE

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PART I. EXECUTIVE SUMMARY

EU LOCATION

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PRIMARY CONTAMINANTS, CONTAMINATED MEDIA AND WASTES

The RC-GW-3 Evaluation Unit is related to four Hanford groundwater interest areas: 100-BC (including the 100-BC-5 Groundwater Operable Unit (OU)), 100-FR (including the 100-FR-3 OU), 100-HR (including the 100-HR-3 OU), and 100-KR (including the 100-KR-4 OU). In this review, the focus will be on the groundwater Interest Areas (IA) because the data tend to be collected based on these areas. The primary contaminants for the 100-BC IA are hexavalent chromium, Sr-90, and tritium (H-3) (DOE/RL-2016-09, Rev. 0, p. 2-1). The 100-BC vadose zone is comprised of Hanford formation sand and gravel where the water table is at a depth of 18-24 meters. The upper portion of the unconfined aquifer beneath most of 100-BC is in the highly permeable sediments of the Hanford formation and lower portion is within the Ringold unit E sands and gravels (DOE/RL-2016-09, Rev. 0, p. 2-3).

The primary contaminants for the 100-FR IA are nitrate, hexavalent chromium, Sr-90, and trichloroethene (TCE) (DOE/RL-2016-09, Rev. 0, p. 3-2). The 100-FR vadose zone and the unconfined aquifer (from 1-8 m thick) are composed of Hanford formation sand and gravel where the bottom of the aquifer is the Ringold upper mud unit (RUM) (DOE/RL-2016-09, Rev. 0, p. 3-1).

The primary contaminants for the 100-HR IA are hexavalent chromium, nitrate, Sr-90, and tritium (H-3) (DOE/RL-2016-09, Rev. 0, p. 4-2). In 100-HR vadose zone thickness (and depth to groundwater) ranges from 0 to 27 meters where the thickness of the unconfined aquifer (present in the Ringold Formation unit E sands and gravels in 100-D and in the Hanford formation gravels in 100-H) mimics the topography of the Ringold Formation upper mud unit (RUM) (DOE/RL-2016-09, Rev. 0, p. 4-1).

The primary contaminants for the 100-KR IA are hexavalent chromium, tritium (H-3), nitrate, Sr-90, C-14, and trichloroethene (TCE) (DOE/RL-2016-09, Rev. 0, p. 5-2). In 100-KR the unconfined aquifer ranges from 5-32 meters and is primarily present in the Ringold Formation unit E sand and gravel and is overlain by the gravels and interbedded sand and silt of the Hanford formation. Contaminant concentrations are highest within the upper part of the aquifer although mobile contaminants (including hexavalent chromium) have been detected over the entire aquifer thickness.

BRIEF NARRATIVE DESCRIPTION:

The CP-GW-1 EU is related to four Hanford interest areas: 100-BC, 100-FR, 100-HR, and 100-KR; however, which include the CERCLA Groundwater Operable Units (OUs), 100-BC-5, 100-FR-3, 100-HR-3, and 100-KR-4.

The 100-BC interest area includes the 100-BC-5 GW OU and surrounding areas contaminated mainly by wastes from the B and C Reactors and related operations. DOE has completed remediation of 100-BC waste sites covered by an interim action Record of Decision (ROD) (DOE/RL-2016-09, Rev. 0, p. 2-1). One of the last remedial actions in the area included a very large soil excavation down to the water table (~24 m), backfilling with native soil and revegetation, and after the completion of this remediation in

2013, there were no known remaining sources of significant contamination that could migrate to groundwater (DOE/RL-2014-32, Rev. 0, page BC-1; DOE/RL-2015-07, Rev 0, page 2-3). DOE monitors groundwater to meet Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Atomic Energy Act of 1954 (AEA) requirements (DOE/RL-2016-09, Rev. 0, p. 2-3).

The 100-FR interest area includes the 100-FR-3 OU and surrounding areas contaminated mainly by wastes from the F Reactor and related operations and biological experiments. Waste site remediation under an interim Record of Decision (ROD) has been completed. EPA signed a CERCLA ROD in September 2014 (EPA 2014). The selected remedy for groundwater is MNA. DOE monitors groundwater to meet Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Atomic Energy Act of 1954 (AEA) requirements (DOE/RL-2016-09, Rev. 0, p. 3-1).

The 100-HR-D/H interest area includes the 100-HR-3 OU and surrounding areas contaminated by waste releases from operation of the D, DR, and H Reactors and related support facilities. By the end of 2015, 97% of the waste sites had been addressed (closed, interim closed, final closed, no action, not accepted, or rejected). The final 3 percent will be remediated under a ROD for final action. DOE monitors groundwater to meet Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) requirements (DOE/RL-2016-09, Rev. 0, p. 4-1, 4-6).

The 100-KR groundwater interest area includes the 100-KR-4 operable unit (OU) where groundwater was contaminated by waste releases associated KE and KW Reactor operations and associated support facilities. At the end of 2015, 51 percent of the waste sites were addressed (closed, interim closed, no action, or not accepted or rejected), with 33 percent having undergone active remediation to remove secondary sources of contamination that could migrate to groundwater and reduce the risk of direct exposure at the surface. DOE monitors groundwater to meet Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Atomic Energy Act of 1954 (AEA) requirements (DOE/RL-2016-09, Rev. 0, p. 5-1, 5-6).

Summary Tables of Risks and Potential Impacts to Receptors

Table D.4-1 provides a summary of nuclear and industrial safety related risks to humans and impacts to important physical Hanford site resources.

Human Health

A Facility Worker is deemed to be an individual located anywhere within the physical boundaries of the 300 FF interest area; a Co-located Person (CP) is an individual located 100 meters from the physical boundaries of the 300 FF interest area; and Public is an individual located at the closest point on the Hanford Site boundary not subject to DOE access control. The nuclear-related risks to humans are based on unmitigated (unprotected or controlled conditions) dose exposures expressed in a range of from Not Discernible (ND) to High. The estimated mitigated exposure that takes engineered and administrative controls and protections into consideration, is shown in parentheses.

Groundwater and Columbia River

Direct impacts to groundwater resources and the Columbia River have been rated based on available information for the current status and estimates for future time periods. These impacts are also expressed in a range of from Not Discernible (ND) to Very High.

Ecological Resources

The risk ratings are based on the degree of physical disruption (and potential additional exposure to contaminants) in the current status and as a potential result of remediation options.

Cultural Resources[1]

No risk ratings are provided for Cultural Resources. Table D.4-1 identifies the three overlapping Cultural Resource landscapes that have been evaluated: Native American (approximately 10,000 years ago to the present); Pre-Hanford Era (1805 to 1943) and Manhattan/Cold War Era (1943 to 1990); and provides initial information on whether an impact (both direct and indirect) is KNOWN (presence of cultural resources established), UNKNOWN (uncertainty about presence of cultural resources), or NONE (no cultural resources present) based on written or oral documentation gathered on the entire EU and buffer area. Direct impacts include but are not limited to physical destruction (all or part) or alteration such as diminished integrity. Indirect impacts include but are not limited to the introduction of visual, atmospheric, or audible elements that diminish the cultural resource's significant historic features. Impacts to Cultural Resources as a result of proposed future cleanup activities will be evaluated in depth under Section 106 of the National Historic Preservation Act (16 USC 470, et. seq.) during the planning for remedial action.

Table D.4-1. Risk Rating Summary (for Human Health, unmitigated nuclear safety basis indicated, mitigated basis indicated in parentheses (e.g., "Very High" (Low)).

		Evaluation Time Period	
		Active Cleanup (to 2064)	
Population or Resource		**Current Condition:**	**From Cleanup Actions:**
Human Health	Facility Worker	***Low to Medium*** (Low)	***Proposed Alternatives (range of actions)*: *Low to Medium*** (Low)
	Co-located Person	***Low to Medium*** (Low)	***Proposed Alternatives (range of actions)*: *Low to Medium*** (Low)
	Public	***Not Discernible (ND) to Low*** (ND to Low)	***Proposed Alternatives (range of actions)*: *Not Discernible (ND) to Low*** (ND)
Environmental	Groundwater	100-BC IA: Medium (Cr-VI) 100-HR IA: Medium (Cr-VI)[a] 100-FR IA: Medium (NO3) 100-KR IA: Medium (Cr-VI, H-3)[a] Overall: Medium (Cr-VI, NO3, H-3)	100-BC IA: Medium (Cr-VI) 100-HR IA: Medium (Cr-VI)[a] 100-FR IA: Medium (NO3) 100-KR IA: Medium (Cr-VI, H-3)[a] Overall: Medium (Cr-VI, NO3, H-3)
	Columbia River	Benthic/Riparian: 100-BC: Medium (Cr-VI) 100-HR: Medium (Cr-VI)[a] 100-FR: Low (Cr-VI, NO3) 100-KR: Medium (Cr-VI)[a] Free-flowing: All IAs: Not Discernible **Overall**: Medium (Cr-VI)[a]	Benthic/Riparian: 100-BC: Medium (Cr-VI) 100-HR: Medium (Cr-VI)[a] 100-FR: Low (Cr-VI, NO3) 100-KR: Medium (Cr-VI)[a] Free-flowing: All IAs: Not Discernible **Overall**: Medium (Cr-VI)[a]

[1] References throughout this Evaluation Unit Summary Template supporting analyses related to Ecological Resources and/or Cultural Resources may be found in Appendices J and K, respectively. Refer to the specific EU when searching for the reference.

		Evaluation Time Period	
		Active Cleanup (to 2064)	
Population or Resource		**Current Condition:**	**From Cleanup Actions:**
	Ecological Resources[b]	Low to Very High	Very High
Social	Cultural Resources[b]	**Native American:** Direct: Known Indirect: Known **Historic Pre-Hanford:** Direct: Known Indirect: Known **Manhattan/Cold War:** Direct: Known Indirect: Known	**Native American:** Direct: Known Indirect: Known **Historic Pre-Hanford:** Direct: Known Indirect: Known **Manhattan/Cold War:** Direct: Known Indirect: Known

a. Groundwater contaminants are being treated (Cr-VI in 100-HR using *In Situ* Redox Manipulation (ISRM) and P&T and Cr-VI in 100-KR using P&T) although other contaminants are likely being extracted (e.g., Cr-VI in 100-BC).

b. For both Ecological and Cultural Resources see Appendices J and K, respectively, for a complete description of Ecological Field Assessments and literature review for Cultural Resources. Ecological ratings are described in Table 4-11 of the Final Report.

SUPPORT FOR RISK AND IMPACT RATINGS FOR EACH POPULATION OR RESOURCE

Human Health

Current

Facility workers are at risk when working in or around areas with contaminated soils. Exposure to such contaminants is limited because groundwater and contaminated soils are located below grade. However, during certain operations (e.g., drilling, sampling, removal, treatment, and disposal), there may be the potential for exposure to hazardous and radioactive contaminants; however, the potential exposure would be very small.

Unmitigated Consequences: Facility Worker – Low to Medium, CP – Low to Medium; Public – ND to Low

Mitigation: The Department of Energy and contractor site-specific safety and health planning that includes work control, fire protection, training, occupational safety and industrial hygiene, emergency preparedness and response, and management and organization—which are fully integrated with nuclear safety and radiological protection—have proven to be effective in reducing industrial accidents at the Hanford site to well below that in private industry. Further, the safety and health program must effectively ensure that ongoing task-specific hazard analyses are conducted so that the selection of appropriate PPE can be made and modified as conditions warrant. Task-specific hazard analyses must lead to the development of written work planning documents and standard operating procedures (SOPs) [DOE uses the term work planning documents in addition to procedures] that specify the controls necessary to safely perform each task, to include continuous employee exposure monitoring. Last, ICs will be used to control access to residual contaminants in soil and groundwater as long as they exceed the cleanup levels (CULs).

Mitigated Consequences: Facility Worker – Low, CP – Low; Public – ND

Risks and Potential Impacts from Selected or Potential Cleanup Approaches

Remediation alternatives have been selected for each RC-GW-3 OU as interim actions as part of an integrated strategy to achieve cleanup standards along the river corridor. The range of alternatives include (i) pump and treat; (ii) remove, treat, and dispose; (iii) monitored natural attenuation (MNA); and (iv) Institutional controls (ICs) to control access to residual contaminants in soil and groundwater as long as they exceed the cleanup levels (CULs). As such, impacts from potential remediation approaches will vary, depending on the activity. Worker risks are thus rated as *Low to Medium*.

Unmitigated Risk: Facility Worker – Low to Medium; CP – Low; Public –ND to Low.

Mitigation: Refer to Current.

Mitigated Risk: Facility Worker – Low; CP – Low; Public – ND to Low.

Environmental

Current

Groundwater: As illustrated in Table D.4-2, the saturated zone (SZ) GTM values translate to:

- 100-BC: Group A and B primary contaminants range from *Low* for Sr-90 to *Medium* for hexavalent chromium. There is no calculated tritium (Group C) plume areas and thus no rating.
- 100-HR-D/H: Group A and B primary contaminants range from *Low* for Sr-90 to *Medium* for hexavalent chromium. There is no calculated tritium or nitrate (Group C) plume areas and thus no rating for either of these primary contaminants.
- 100-FR: Group A and B primary contaminants are *Low* for hexavalent chromium, Sr-90, and TCE. The nitrate plume areas (Group C) translate to *Medium* ratings.
- 100-KR: Group A and B primary contaminants are *Low* for Sr-90, C-14, and TCE to *Medium* for hexavalent chromium. The tritium and nitrate plume areas (Group C) translate to *Medium* and *Low* ratings, respectively.

Thus the overall rating for the RC-GW-3 EU threat to groundwater would be *Medium* related to hexavalent chromium (100-BC, 100-HR-D/H, and 100-KR) and nitrate (Group C) in the 100-FR IA.

Columbia River: Based on the information in the 2015 Hanford Site Groundwater Monitoring Report (DOE/RL-2016-09, Rev. 0) summarized in Table D.4-3, four plumes from these four IAs are currently intersecting the Columbia River at concentrations exceeding the WQS. The ratings obtained from using the process shown in Chapter 6 (Figure 6-10) range from *Not Discernible* for Sr-90 (100-BC) to *Low* for Cr-VI (100-FR), Sr-90 (100-KR), and C-14 (100-KR) to *Medium* for Cr-VI (100-BC, 100-HR-D/H and 100-KR). Tritium in 100-BC and 100-HR-D/H and nitrate 100-HR-D/H were not rated because either the plume area was zero or not calculated. The ratings for the other contaminants would be *Not Discernible*. Thus *current* impacts from these IAs to the Columbia River benthic and riparian zone ecology would be rated as *Medium* related to hexavalent chromium in 100-BC, 100-HR-D/H (currently being treated using P&T and ISRM), and 100-KR (currently being treated using P&T).

Ecological Resources: There are areas where groundwater plumes intersect the riparian vegetation. Monitoring shows concentrations of chromium exceeding aquatic water criteria in groundwater near shoreline. Potential for contaminant uptake by terrestrial vegetation. Sensitive animals and bird species use region and may be at risk.

Risks and Potential Impacts from Selected or Potential Cleanup Approaches

Groundwater: As described in Part V, some constituents may be significantly impacted by cleanup operations or radioactive decay. To summarize, the modified results (from those for Current Conditions) for the River Corridor are:

- Hexavalent chromium (Group A) – For 100-HR-D/H it is assumed that the P&T and ISRM systems would continue to be effective resulting in *Medium* and *Low* ratings for Active and Near-term, Post-Cleanup periods, respectively (to account for inventory and treatment uncertainties and because the final ROD has yet to be signed). For 100-KR it is assumed that the P&T system would continue to be effective resulting in *Medium* and *Low* ratings for Active and Near-term, Post-Cleanup periods, respectively (again to account for inventory and treatment uncertainties and because the final ROD has yet to be signed).
- Sr-90 (Group B) – The maximum concentrations for IAs other than 100-KR would result in *Low* ratings in the Near-term, Post-Cleanup period.
- Tritium (Group C) – In 100-KR, the tritium plume area has decreased from ~0.3 km^2 in 2003-2005 to 0.11 km^2 in 2015, with a recent dip to less than 0.1 km^2 in 2012 and 2013. (DOE/RL-2016-09, Rev. 0, p. 5-5). A continued decrease, due to radioactive decay, would reduce the plume to less than 0.1 km^2 by the end of the Active Cleanup period leading to a *Low* rating. A *Low* rating is maintained for the Near-term, Post-Cleanup period, to account for uncertainty.

Columbia River: For those contaminants currently in contact with the River, the following changes would be made to ratings (as described in Part V):

- 100-HR-D/H: Hexavalent chromium is expected to reach the cleanup level (10 µg/L) during the Active Cleanup period (DOE/RL-2011-111, Draft A) using the P&T and ISRM systems resulting in a *Medium* rating and a corresponding *Low* rating for the Near-term, Post-Cleanup period to account for uncertainties in inventory and treatment.
- 100-KR: Hexavalent chromium is expected to reach the cleanup level (10 µg/L) over much of 100-KR during the Active Cleanup period (DOE/RL-2010-97, Draft A) resulting in a *Medium* rating and a corresponding *Low* rating for the Near-term, Post-Cleanup period again to account for uncertainties in inventory and treatment.

As described in Part V because most of the plumes are unlikely to contact the Columbia River over the next 150 years (unless hydrologic conditions change significantly), the ratings (primarily *Not Discernible* or *Low*) for most of the contaminants not currently in contact with the Columbia River will not be modified. However, for Sr-90 (100-FR) even though the plume moves very slowly, there is a chance that it could reach the River in the Active Cleanup period (*Low* rating) but decay would likely result in no plume (all things being equal) for a *Not Discernible* rating during the Near-term, Post-Cleanup period.

Ecological Resources: Remediation activities in the shoreline will need to be monitored to evaluate resources and seasonal use of shoreline

Cultural Resources

Current

Entire shoreline area is extremely culturally sensitive based on prehistoric, ethno-historic, and historic land use in the area. Upland areas where characterization and monitoring activities take place may be culturally sensitive regions as well. Traditional cultural places are known to be located in the vicinity as well as National Register eligible archaeological sites associated with all 3 landscapes.

Risks and Potential Impacts from Selected or Potential Cleanup Approaches

Entire shoreline area is extremely culturally sensitive based on prehistoric, ethno-historic, and historic land use in the area. Upland areas where characterization and monitoring activities take place may be culturally sensitive regions as well. Traditional cultural places are known to be located in the vicinity as well as National Register eligible archaeological sites associated with all 3 landscapes.

Considerations for timing of the cleanup actions

The CP-GW-1 EU CERCLA Groundwater Operable Units (OUs), 100-BC-5, 100-FR-3, 100-HR-3, and 100-KR-4, have each undergone extensive characterization, assessment, and remediation. As such, active remediation actions are ongoing in each OU as part of an integrated strategy for achieving final cleanup in the River Corridor (WCH-71 Rev. 0).

Near-Term, Post-Cleanup Risks and Potential Impacts

Groundwater: Please see Part V for a discussion of the impact of cleanup, recharge, and decay on groundwater and Columbia River ratings in the Near-term, Post-Cleanup period. For potential impacts to groundwater, the ratings for the four 100 Area IAs tend to be either *ND* to *Low* to reflect presumed treatment effectiveness. The exception is hexavalent chromium in 100-BC (with a *Medium* rating) indicating no final remedial actions selected and inventories that might translate to appreciable plumes in this evaluation period.

Columbia River: For the ratings related to threats to the Columbia River, only the hexavalent chromium in 100-BC has a rating (*Medium*) in this period indicating that monitoring and treatment are needed.

Ecological Resources: Permanent direct and indirect effects are possible due to high sensitivity of area.

PART II. ADMINISTRATIVE INFORMATION

OU AND/OR TSDF DESIGNATION(S)

100-BC-5, 100-HR-3, 100-FR-3, and 100-KR-4

COMMON NAME(S) FOR EU

RC-GW-3 in 100 Area (100-BC-5, 100-HR-3, 100-FR-3, and 100-KR-4)

KEY WORDS

100 Areas, RC-GW-3, 100-BC-5, 100-HR-3, 100-FR-3, and 100-KR-4, River Corridor

REGULATORY STATUS

Regulatory basis

100-BC: DOE has completed remediation of 100-BC waste sites covered by an interim action Record of Decision (ROD) (DOE/RL-2016-09, Rev. 0, p. 2-1). One of the last remedial actions in the area included a very large soil excavation down to the water table (~24 m), backfilling with native soil and revegetation, and after the completion of this remediation in 2013, there were no known remaining sources of significant contamination that could migrate to groundwater (DOE/RL-2014-32, Rev. 0, page BC-1; DOE/RL-2015-07, Rev 0, page 2-3). DOE monitors groundwater to meet Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Atomic Energy Act of 1954 (AEA) requirements (DOE/RL-2016-09, Rev. 0, p. 2-3).

100-FR: Waste site remediation under an interim Record of Decision (ROD) has been completed. EPA signed a CERCLA ROD in September 2014 (EPA 2014). The selected remedy for groundwater is MNA. DOE monitors groundwater to meet Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Atomic Energy Act of 1954 (AEA) requirements (DOE/RL-2016-09, Rev. 0, p. 3-1).

100-HR: By the end of 2015, 97% of the waste sites had been addressed (closed, interim closed, final closed, no action, not accepted, or rejected). The final 3 percent will be remediated under a ROD for final action. DOE monitors groundwater to meet Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) requirements (DOE/RL-2016-09, Rev. 0, p. 4-1, 4-6).

100-KR: At the end of 2015, 51 percent of the waste sites were addressed (closed, interim closed, no action, or not accepted or rejected), with 33 percent having undergone active remediation to remove secondary sources of contamination that could migrate to groundwater and reduce the risk of direct exposure at the surface. DOE monitors groundwater to meet Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Atomic Energy Act of 1954 (AEA) requirements (DOE/RL-2016-09, Rev. 0, p. 5-1, 5-6).

Applicable regulatory documentation

100-BC: interim action record of decision (ROD) (EPA/ROD/R10-95/126; EPA/ROD/R10-99/039; EPA/ROD/R10-00/121) and RI/FS (DOE/RL-2010-96)

100-HR-D/H: remedial investigation/feasibility study (RI/FS) (DOE/RL-2010-95 Draft A), RI/FS work plan addendum (DOE/RL-2008-46-ADD1) and sampling and analysis plan (SAP) (DOE/RL-2009-40). Changes to the SAP were documented in Tri-Party Agreement Change Notices (TPA-CN-460), interim remedial action ROD (EPA/ROD/R10-96/134), which was amended in 2000 (EPA/AMD/R10-00/122).

100-FR: A CERCLA Remedial Investigation (RI)/Feasibility Study (FS) report (DOE/RL-2010-98), was finalized in 2014 and public review of the proposed plan took place between June 9 and August 11, 2014. A final record of decision (ROD) was issued in 2014 (EPA 2014). Groundwater sampling and analysis plan (SAP) (DOE/RL-2003-49, as modified by TPA-CN-241).

100-KR: A remedial investigation (RI)/feasibility study (FS) for the K Reactor Area source and groundwater OUs (DOE/RL-2010-97 Draft A) and Proposed Plan (DOE/RL-2011-82 Draft A).

Applicable Consent Decree or TPA milestones

100-BC
Not Applicable

100-HR
Not Applicable

100-FR
Not Applicable

100-KR
Not Applicable

RISK REVIEW EVALUATION INFORMATION

Completed: Revised 20 February 2017

Evaluated by: K. G. Brown, E. LeBoeuf, H. Turner

EU Designation: RC-GW-3 (100 Area (100-BC-5, 100-HR-3, 100-FR-3, and 100-KR-4)

Ratings/Impacts Reviewed by: D. Kosson, M. Gochfeld, J. Salisbury, A. Bunn

PART III. SUMMARY DESCRIPTION

CURRENT LAND USE

Currently the land use in the 100 Areas is for industrial purposes and includes maintenance shops, water supply systems, and environmental cleanup (EPA/ROD/R10-00/121).

DESIGNATED FUTURE LAND USE

(WCH-8, Rev. 0)

Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS) (DOE 1999) and associated NEPA land-use ROD issued (64 Federal Register 61615) with multi-use theme of industrial-exclusive, industrial, research and development, high-intensity recreation, low-intensity recreation, conservation (mining), and preservation land uses.

Interim action ROD for 100 Area burial grounds issued (EPA 2000) acknowledging the HCP EIS and concluding that "unrestricted use" assumption was not inconsistent with identified land uses.

Three land uses were developed by the Hanford Future Site Uses Working Group (FSUWG) for the 100 Areas in the river corridor, consisting of the following:

- "Unrestricted" Use. This included removal and disposal of contaminated soil and structures (including reactors) and remediation of groundwater to "unrestricted" status.
- Limited Recreation, Commercial, and Wildlife Use. This included cleanup of groundwater and areas designated for commercial and recreational activities to "unrestricted" use (reactors to remain in place), but allowing areas to be managed for wildlife habitat to be remediated to "restricted" status.
- "Unrestricted" Use/B Reactor Remains in Place. This is similar to the unrestricted use except that B Reactor would remain in place and be remediated to "restricted" status.

The DOE selected land uses for the 100 Area include recreation, conservation, and preservation (EPA/ROD/R10-00/121).

PRIMARY EU SOURCE COMPONENTS

Legacy Source Sites

Not Applicable

High-Level Waste Tanks and Ancillary Equipment

Not Applicable

Groundwater Plumes

There are current plumes exceeding water quality standards (WQS)[2] in the 100-BC, 100-HR-D/H, 100-FR, and 100-KR Interest Areas (IA).

In 100-BC IA, contaminants of concern associated with waste produced by the reactors and related processes are hexavalent chromium, Sr-90, and tritium (H-3) (DOE/RL-2010-96); however, previous assessments have not resulted in interim remedial measures. Approximately 94% of waste sites have been addressed (with status of closed, interim closed, no action, not accepted, or rejected). The final Record of Decision is expected in 2017. To summarize:

- Hexavalent chromium sources included cribs near reactor buildings, trenches and retention basins near the River, and pipelines from the reactor buildings to the near-river facilities; other sources included 100-C-7 and 100-C-7:1 and the 100-B-27 sodium dichromate spill site. The hexavalent chromium plume area has varied in size over the years (Figure D.4-1).
    - Maximum concentration: 57.9 µg/L (199-B3-47) versus a "Model Toxics Control Act—Cleanup" (WAC 173-340) Method B groundwater cleanup level for hexavalent chromium of 48 µg/L and a surface water standard of 10 µg/L[3]
    - Areal extent of the plume: 0.09 km^2 (48 µg/L) and 1.5 km^2 (10 µg/L)
    - Shoreline impact: 0 m (48 µg/L) and 1,735 m (10 µg/L)
    - Riparian zone intersected: 0 ha (48 µg/L) and 3.49 ha (10 µg/L)
- Sr-90 sources were liquid effluent discharges to cribs near the reactors and to cribs, trenches and retention basins. The Sr-90 plume area has increased slightly over the past several years (Figure D.4-1).
    - Maximum concentration: 35.2 pCi/L (199-B3-52) versus a WQS of 8 pCi/L
    - Areal extent of the plume: 0.55 km^2
    - Shoreline impact: 450 m
    - Riparian zone intersected: 0.95 ha
- Tritium was in effluent discharged to former cribs near the B Reactor and the Columbia River as well as the former 118-B-1 Burial Ground. These waste sites have been remediated resulting in a zero plume area in 2013 (Figure D.4-1).
    - Maximum concentration: 13,800 pCi/L (199-B8-9) versus a WQS of 20,000 pCi/L
    - Areal extent of the plume: 0 km^2
    - Shoreline impact: 0 m
    - Riparian zone intersected: 0 ha

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[2] In some interest areas, thresholds are the drinking water standards (DWS) and for others they are denoted cleanup levels, which are typically DWS or risk-based standards for cleanup. These are collectively denoted water quality standards (WQS) for the purpose of this Review.

[3] The "Model Toxics Control Act—Cleanup" (WAC 173-340) Method B groundwater cleanup level for hexavalent chromium of 48 µg/L was also listed for the 100-BC interest area (and is used for the Central Plateau EUs); however, the surface water standard was selected for River Corridor EUs for this Review.

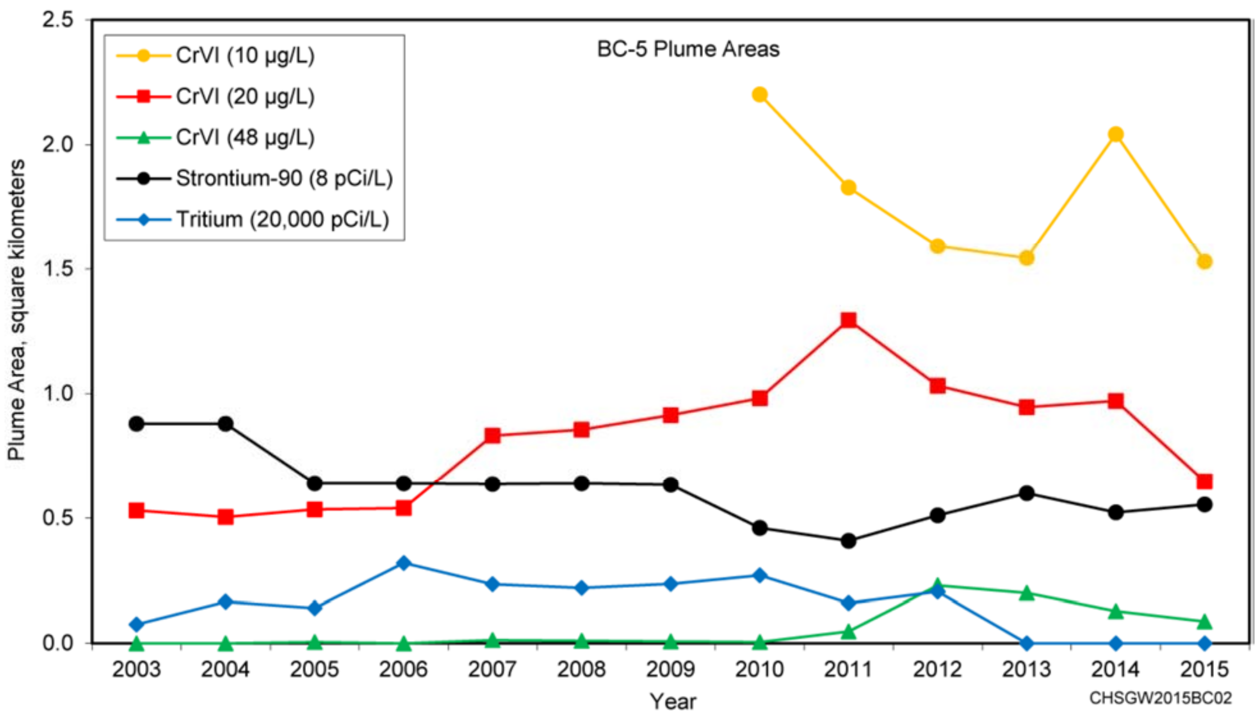

Figure D.4-1. 100-BC Plume Areas (DOE/RL-2016-09, Rev. 0, p. 2-3)

In 100-HR contaminants of concern are from waste releases associated with past operation of the D, DR, and H Reactors and associated support facilities are hexavalent chromium, nitrate, Sr-90, and tritium (H-3). By the end of 2015, 97% of the waste sites had been addressed (closed, interim closed, final closed, no action, not accepted, or rejected). The final 3 percent will be remediated under a ROD for final action, which was expected in 2016. To summarize:

- Hexavalent chromium contamination resulted from discharges to the 116-DR-1&2 trenches in 1967 creating a plume that extends across the Horn from 100-D to 100-H. Ongoing remedial activities are reducing contaminant levels and have separated the Horn plume. The hexavalent chromium plume area (20 µg/L) has been steadily decreasing since 2010 (Figure D.4-2).
    - Maximum concentration: 614 µg/L (199-D5-34) versus a 20 µg/L groundwater cleanup target identified in ROD for interim remedial action although the surface water standard of 10 µg/L is used in this Review.
    - Areal extent of the plume: .66 km^2 (48 µg/L) and 4.8 km^2 (10 µg/L)
    - Shoreline impact: 990 m (20 µg/L) and ≥990 m (10 µg/L); the shoreline impact area was not estimated at the surface water standard but must be greater than or equal to that at the cleanup level
    - Riparian zone intersected: 13.4 ha (10 µg/L)
- Nitrate plume sources in 100-HR included gas condensate from the reactors, septic systems and sewer lines, former agricultural practices, and waste sites that received nitric acid. In 2015, nitrate exceeded the DWS in one sample from well 199-D2-6, at 45.2 mg/L. The plume area has decreased to zero (Figure D.4-2).
    - Maximum concentration: 45.2 mg/L (199-D4-6) versus a WQS (equivalent) of 45 mg/L.
    - Areal extent of the plume: 0 km^2
    - Shoreline impact: 0 m

    - Riparian zone intersected: 0 ha
- Sr-90 was present in wastes disposed of at both 100-D and 100-H where 2013 concentrations in groundwater exceeded the DWS (8 pCi/L) in both 100-D and 100-H monitoring locations and is elevated in isolated source areas in both 100-H and 100-D. Sr-90 is not present in the Horn. The concentrations and distribution of strontium-90 have shown consistent, gradual declines in both areas (Figure D.4-2).
    - Maximum concentration: 32.7 pCi/L (199-B3-46) versus a WQS of 8 pCi/L
    - Areal extent of the plume: 0.02 km^2
    - Shoreline impact: 0 m
    - Riparian zone intersected: 0 ha
- Tritium has occasionally exceeded the 20,000 pCi/L DWS near the ISRM barrier in the southern portion of 100-D Area and near the DR Reactor. During 2015, the highest concentration of tritium in 100-HR was 14,400 pCi/L in well 199-D4-20, which is below the standard. No plume area was calculated resulting in a zero plume area in 2015 (Figure D.4-2).
    - Maximum concentration: 14,400 pCi/L (199-D4-20) versus a WQS of 20,000 pCi/L
    - Areal extent of the plume: 0 km^2
    - Shoreline impact: 0 m
    - Riparian zone intersected: 0 ha

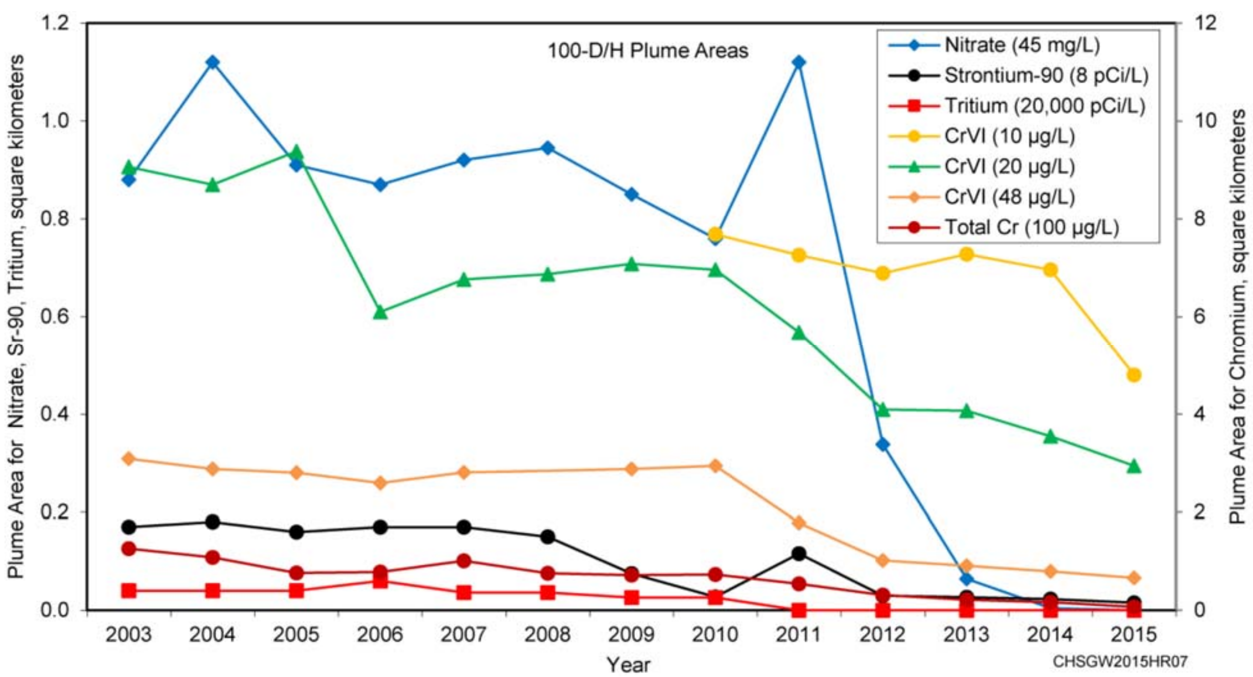

Figure D.4-2. 100-HR Plume Areas (DOE/RL-2016-09, Rev. 0, p. 4-9)

In 100-FR, contaminants of concern originated from waste sources related to reactor operations and biological experiments and include nitrate, hexavalent chromium, Sr-90, and trichloroethene (TCE). Remedial actions under an interim action record of decision are complete, and previous assessments have not resulted in any interim remedial measures for groundwater. EPA signed a CERCLA ROD in September 2014 (EPA 2014). The selected remedy for groundwater is MNA. To summarize:

- Nitrate plume sources in 100-FR included the experimental animal farm various septic tanks and leach fields, which have been remediated, as well as potentially pre-Hanford Site agriculture. Overall, the nitrate plume areas has decreased since 2009 with a small increase in 2015 (Figure D.4-3).
    - Maximum concentration: 120 mg/L (199-F8-7) versus a WQS (equivalent) of 45 mg/L
    - Areal extent of the plume: 9.7 km^2
    - Shoreline impact: 0 m
    - Riparian zone intersected: 0 ha
- Hexavalent chromium contamination resulted from facilities near the reactor building, trenches and retention basins near the Columbia River, and pipelines from the reactor building to near-river facilities. These waste sites have been remediated, and concentrations in groundwater are expected to continue to decline with time although the plume area (in this case, 10 µg/L) has increased (Figure D.4-3).
    - Maximum concentration: 51.2 µg/L (199-F7-55) versus a "Model Toxics Control Act—Cleanup" (WAC 173-340) Method B groundwater cleanup level for hexavalent chromium of 48 µg/L and a surface water standard of 10 µg/L[4]
    - Areal extent of the plume: 0.1 km^2 (48 µg/L) and 0.21 km^2 (10 µg/L)
    - Shoreline impact: 0 m (48 µg/L) and 0 m (10 µg/L)
    - Riparian zone intersected: 0 ha (48 µg/L) and 0 ha (10 µg/L)
- Sr-90 sources included the 116-F-14 Retention Basins and 116-F-2 Trench as well as areas near the reactor building and burial grounds. The combined Sr-90 plume area has remained steady over the past decade (Figure D.4-3).
    - Maximum concentration: 176 pCi/L (199-F5-55) versus a WQS of 8 pCi/L
    - Areal extent of the plume: 0.13 km^2
    - Shoreline impact: 0 m
    - Riparian zone intersected: 0 ha
- TCE plume sources in 100-FR included the former 600-127 waste site, which was remediated. The plume area has remained relatively steady from 2008 to 2012 and has increased somewhat since (Figure D.4-3).
    - Maximum concentration: 18.3 µg/L (299-F7-1) versus a WQS (equivalent) of 5 µg/L
    - Areal extent of the plume: 1.4 km
    - Shoreline impact: 0 m
    - Riparian zone intersected: 0 ha

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[4] The "Model Toxics Control Act—Cleanup" (WAC 173-340) Method B groundwater cleanup level for hexavalent chromium of 48 µg/L was also listed for the 100-BC interest area (and is used for the Central Plateau EUs); however, the surface water standard was selected for River Corridor EUs for this Review.

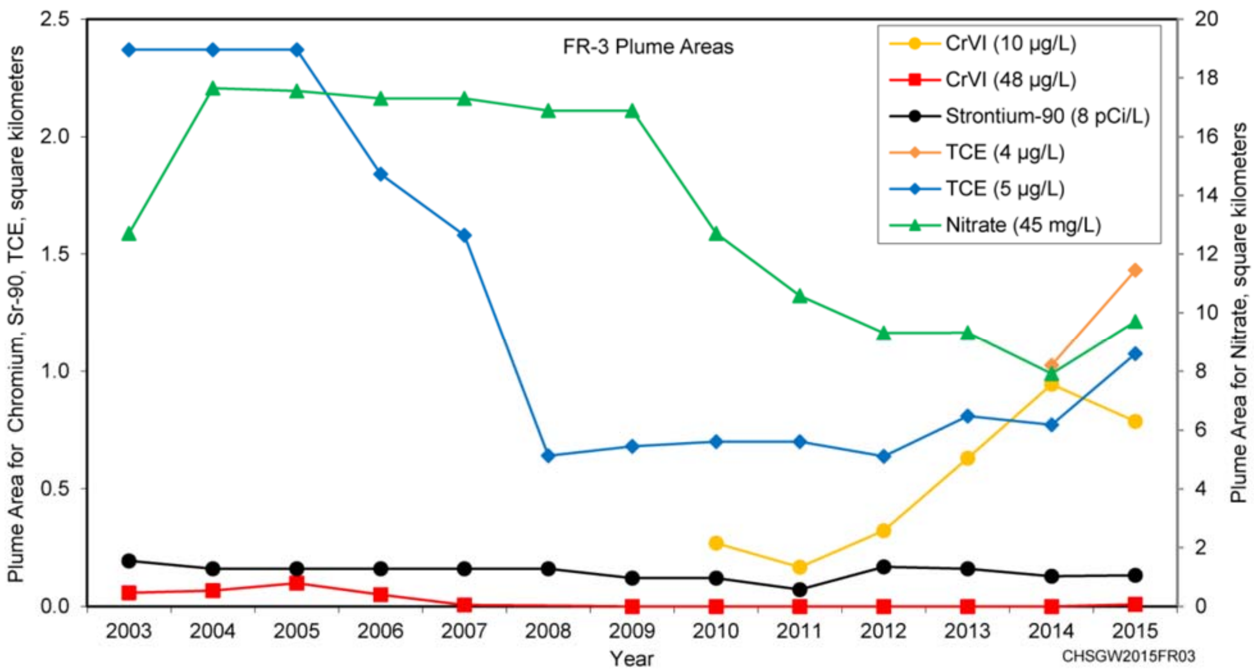


Figure D.4-3. 100-FR Plume Areas (DOE/RL-2016-09, Rev. 0, p. 3-5)

In 100-KR, contaminants of concern originated from waste releases associated with past operations of the KE and KW Reactors and associated support facilities and include hexavalent chromium, tritium (H-3), nitrate, Sr-90, C-14, and trichloroethene (TCE). Remedial actions under an interim action record of decision are 51% complete. To summarize:

- Hexavalent chromium is a mobile contaminant, and its presence resulted from spills, leaks, and limited intentional discharge of concentrated sodium dichromate dihydrate solutions and spent reactor cooling water from retention basin leaks and intentional discharges to the 116-K-1 Crib and 116-K-2 Trench. Plume areas have generally decreased since 2005 (Figure D.4-4).
    - Maximum concentration: 348 µg/L (199-K-111A) versus a 10 µg/L surface water standard (used for this Review)
    - Areal extent of the plume: 0.07 km^2 (48 µg/L) and 1.5 km^2 (10 µg/L)
    - Shoreline impact: 271 m (10 µg/L)
    - Riparian zone intersected: 0.64 ha (10 µg/L)
- Tritium is also a highly mobile contaminant with sources including releases of reactor gas dryer condensate to the 116-KE-1 and 116-KW-1 Cribs, releases of fuel storage basin water to the 116-KE-3 and 116-KW-2 Cribs, and solid waste disposed at the 118-K-1 Burial Ground. The tritium plume areas has been generally decreasing over the past decade (Figure D.4-4).
    - Maximum concentration: 935,000 pCi/L (199-K-202) versus a WQS of 20,000 pCi/L
    - Areal extent of the plume: 0.11 km^2
    - Shoreline impact: 0 m
    - Riparian zone intersected: 0 ha
- Nitrate originated primarily from ammonia in reactor gas dryer condensate discharged to the 116-KE-1 and 116-KW-1 Crib with additional contributions possible from sanitary waste drain fields within the 100-K Area. In K East, only well 199-K-23 had a nitrate concentration above 45 mg/L in 2015, with a maximum of 57.1 mg/L. At K West, three wells had nitrate concentrations

above 45 mg/L. Overall, the nitrate plume areas have been generally decreasing over the past decade (Figure D.4-4).
    - Maximum concentration: 75 mg/L (199-K-132) versus a WQS (equivalent) of 45 mg/L
    - Areal extent of the plume: <0.01 km^2 (assumed to be 0.01 for this Review)
    - Shoreline impact: 0 m
    - Riparian zone intersected: 0 ha
- Sr-90 was released during fuel failure events resulting in contaminated reactor cooling water that was released to the 116-K-2 Trench under off-normal conditions as well as to the reactor fuel storage basins during discharge of irradiated fuel. The Sr-90 plume area has generally decreased over the past decade (Figure D.4-4).
    - Maximum concentration: 4,000 pCi/L (199-K-132 sampled during drilling) versus a WQS of 8 pCi/L
    - Areal extent of the plume: 0.03 km^2
    - Shoreline impact: 0 m
    - Riparian zone intersected: 0 ha
- C-14 in the groundwater primarily originated from historical discharges of reactor gas dryer regeneration condensate to the 116-KE-1 and 116-KW-1 gas condensate cribs. The C-14 plume area has slowly decreased since 2007 (Figure D.4-4).
    - Maximum concentration: 39,500 pCi/L (estimated) versus a WQS of 2,000 pCi/L
    - Areal extent of the plume: 0.03 km^2
    - Shoreline impact: 0 m
    - Riparian zone intersected: 0 ha
- TCE plume sources are not currently known but are likely related to the use of solvents during equipment maintenance activities. The plume area has remained relatively steady over the past decade (Figure D.4-3).
    - Maximum concentration: 8.7 µg/L (199-K-185) versus a WQS (equivalent) of 5 µg/L
    - Areal extent of the plume: 0.01 km^2
    - Shoreline impact: 0 m
    - Riparian zone intersected: 0 ha

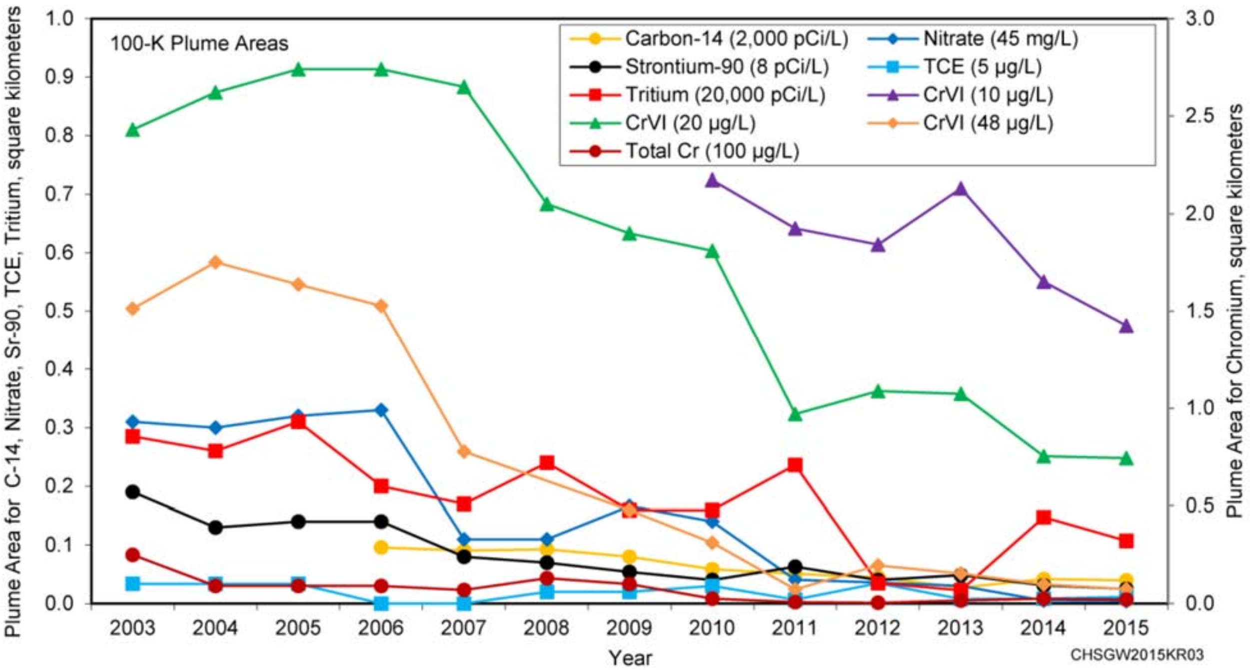


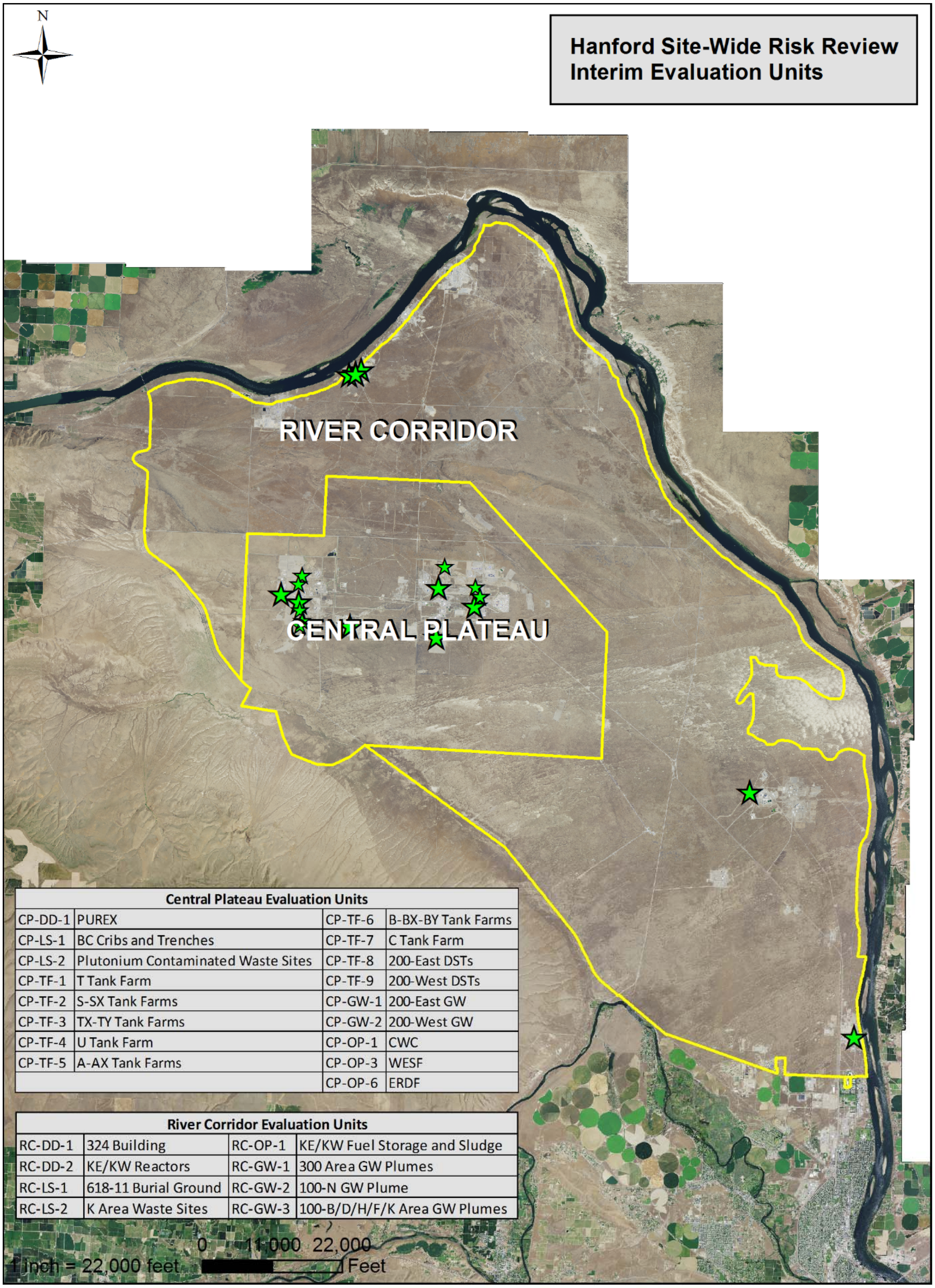
Figure D.4-4. 100-KR Plume Areas (DOE/RL-2016-09, Rev. 0, p. 5-5)

Operating Facilities

Not Applicable

LOCATION AND LAYOUT MAPS

A series of maps are used to illustrate the location of the components within the RC-GW-3 EU relative to the Hanford Site. Figure D.4-5 shows the relationship among the various Evaluation Units studied in the Interim Report and the Hanford Site. Figure D.4-6 through Figure D.4-9 illustrate the extent of groundwater contamination in the 100-BC, 100-HR-D/H, 100-FR, and 100-KR IAs.



Central Plateau Evaluation Units			
CP-DD-1	PUREX	CP-TF-6	B-BX-BY Tank Farms
CP-LS-1	BC Cribs and Trenches	CP-TF-7	C Tank Farm
CP-LS-2	Plutonium Contaminated Waste Sites	CP-TF-8	200-East DSTs
CP-TF-1	T Tank Farm	CP-TF-9	200-West DSTs
CP-TF-2	S-SX Tank Farms	CP-GW-1	200-East GW
CP-TF-3	TX-TY Tank Farms	CP-GW-2	200-West GW
CP-TF-4	U Tank Farm	CP-OP-1	CWC
CP-TF-5	A-AX Tank Farms	CP-OP-3	WESF
		CP-OP-6	ERDF

River Corridor Evaluation Units			
RC-DD-1	324 Building	RC-OP-1	KE/KW Fuel Storage and Sludge
RC-DD-2	KE/KW Reactors	RC-GW-1	300 Area GW Plumes
RC-LS-1	618-11 Burial Ground	RC-GW-2	100-N GW Plume
RC-LS-2	K Area Waste Sites	RC-GW-3	100-B/D/H/F/K Area GW Plumes

Figure D.4-5. Location of the Evaluation Units in Relation to the Hanford Site.

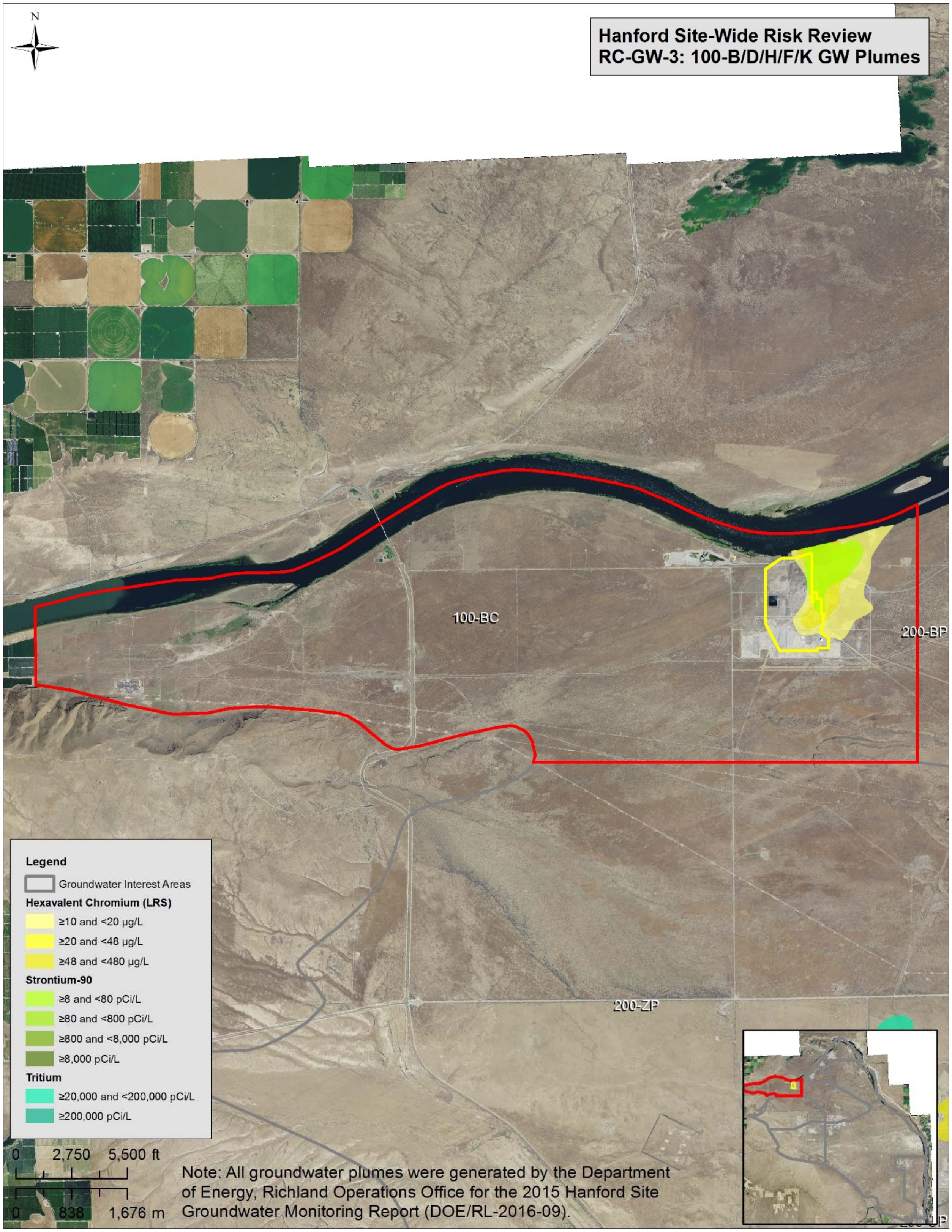


Figure D.4-6. Groundwater Contamination in the 100-BC Interest Area

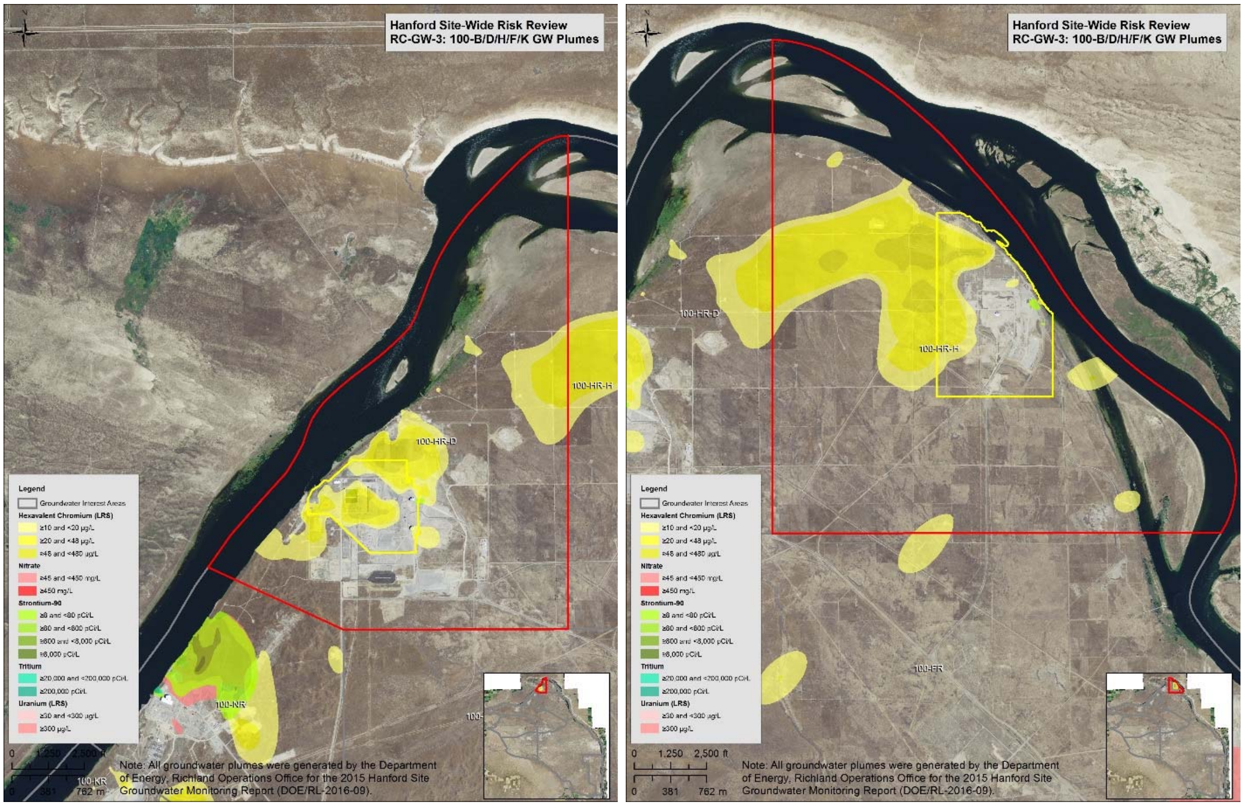


Figure D.4-7. Groundwater Contamination in the 100-HR-D (right) and 100-HR-H (left) Interest Areas

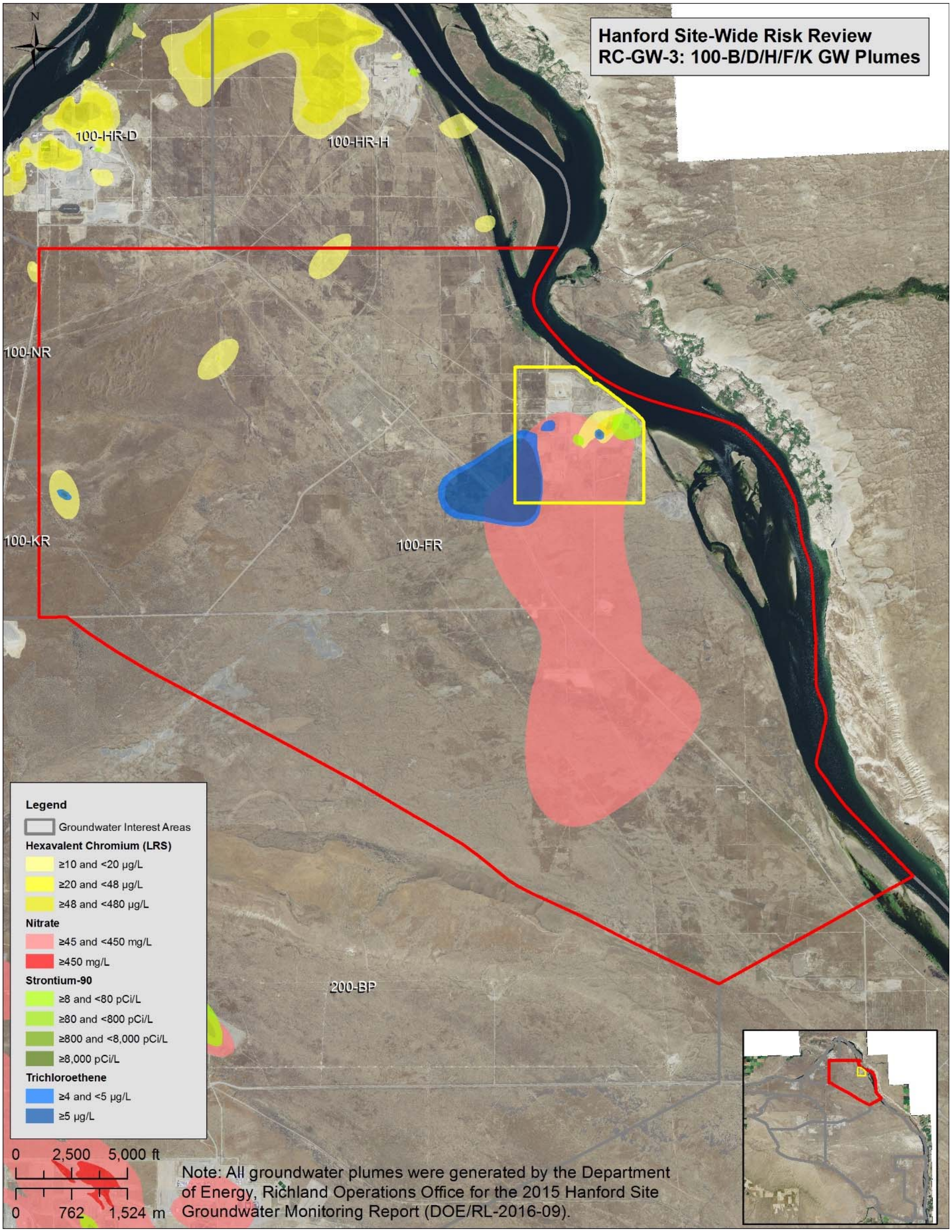


Figure D.4-8. Groundwater Contamination in the 100-FR Interest Area

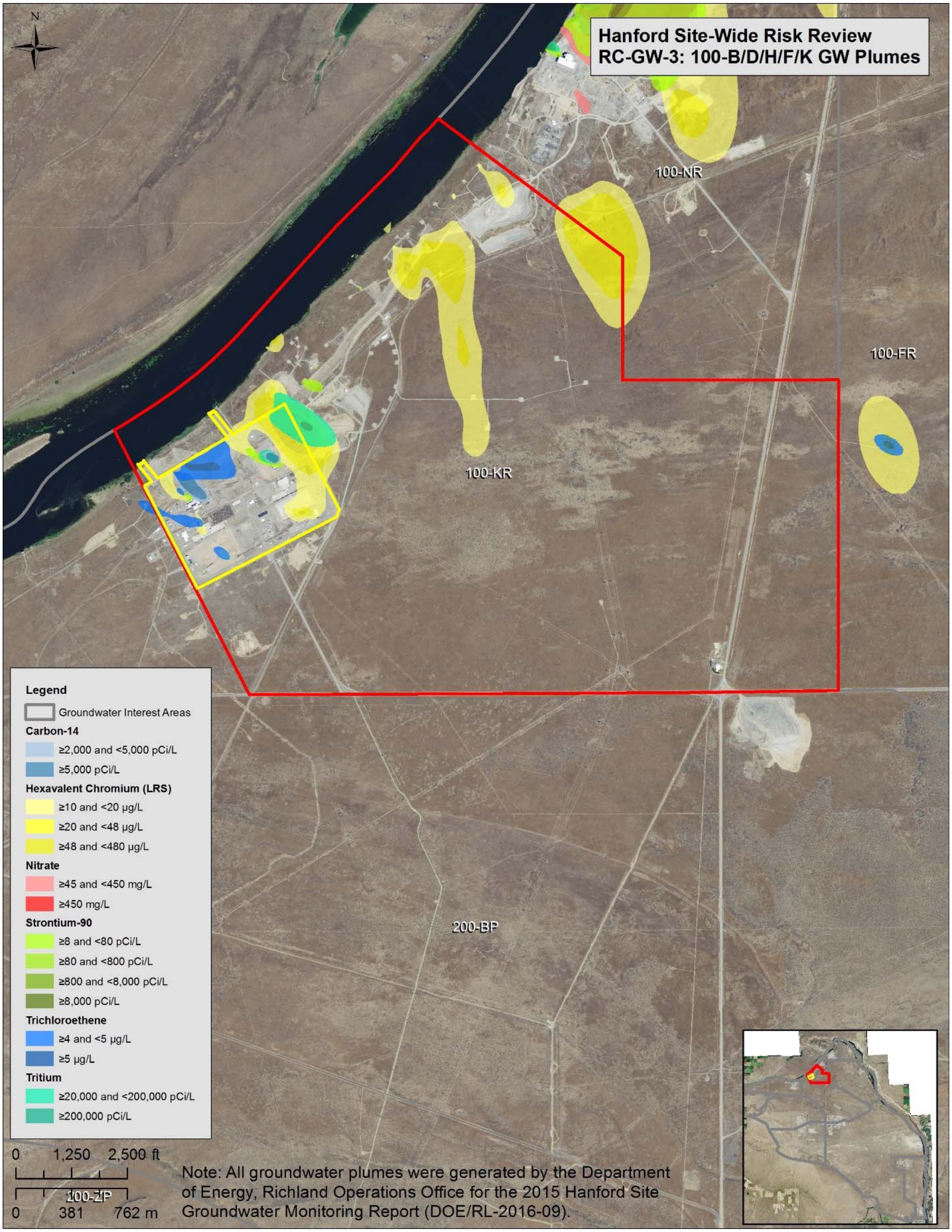


Figure D.4-9. Groundwater Contamination in the 100-KR Interest Area

PART IV. UNIT DESCRIPTION AND HISTORY

EU FORMER/CURRENT USE(S)

The RC-GW-3 Evaluation Unit is comprised of four Groundwater Interest Areas: 100-BC, 100-HR-D/H, 100-FR, and 100-KR. Brief descriptions of individual area backgrounds and current uses are provided below.

100-BC Area (after DOE/RL-2016-09, Rev. 0). The 100-BC groundwater interest area includes the 100-BC-5 operable unit (OU) and surrounding region. Two nuclear reactors formerly operated in 100-BC. The B Reactor was the first of its kind, and it operated from 1944 to 1968. Its primary mission was plutonium production for the development of an atomic bomb during World War II. The C Reactor operated from 1952 to 1969. Groundwater contamination in 100-BC is mainly associated with waste produced by the reactors and related processes. The U.S. Department of Energy (DOE) monitors 100-BC groundwater to meet Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Atomic Energy Act of 1954 (AEA) requirements. Groundwater contaminants of concern are hexavalent chromium, strontium-90, and tritium (DOE/RL-2010-96). Previous assessments have not resulted in any interim remedial measures for groundwater. DOE has completed remediation of 100-BC waste sites covered by an interim action Record of Decision (ROD. One of the last remedial actions in the area included a very large soil excavation down to the water table (~24 m), backfilling with native soil and revegetation, and after the completion of this remediation in 2013, there were no known remaining sources of significant contamination that could migrate to groundwater

100-HR (after EPA/ROD/R10-99/039 and DOE/RL-2016-09, Rev. 0). The 105-H Reactor complex was constructed after World War II to produce plutonium for use in military weapons. The H Reactor operated from 1949 to 1965, when it was retired from service. Currently, there are no active facilities, operations, or liquid discharges within the 100-HR-1 source OU. The 100-HR-1 and 100-HR-2 source OUs, located in the 100-H Area, include contaminant sources, and the 100-HR-3 groundwater OU includes contamination present in the underlying groundwater. Groundwater in 100-HR was contaminated by waste releases associated with past operation of the deactivated D, DR, and H Reactors and from associated support facilities. By the end of 2015, 97% of the waste sites had been addressed (closed, interim closed, final closed, no action, not accepted, or rejected). The final 3 percent will be remediated under a ROD for final action. Removing contaminants from the vadose zone eliminates secondary sources of contamination that could migrate to groundwater and reduce the risk of direct exposure at the surface.

100-F Area (after DOE/RL-2016-09, Rev. 0). The 100-FR groundwater interest area includes the 100-FR-3 operable unit (OU) and surrounding region. One nuclear reactor operated at 100-FR between 1945 and 1965. Groundwater contamination originated from waste sources related to reactor operations and biological experiments that continued until 1976. The U.S. Department of Energy (DOE) monitors 100-FR groundwater to meet the CERCLA and AEA requirements. Groundwater contaminants of concern are nitrate, trichloroethene, hexavalent chromium, and strontium-90 (DOE/RL-2010-98). Waste site remediation under an interim Record of Decision (ROD) has been completed. EPA signed a CERCLA ROD in September 2014 (EPA 2014). The selected remedy for groundwater is MNA.

100-K Area (after EPA/ROD/R10-99/039 and DOE/RL-2016-09, Rev. 0). The 100-K Area is situated in the north-central part of the Hanford Site along the southern shoreline of the Columbia River, approximately 40 km northwest of the city of Richland, Washington. The 100-KR groundwater interest area includes the 100-KR-4 OU. Groundwater in 100-KR was contaminated by waste releases associated with past operations of the KE and KW Reactors and from associated support facilities. At the end of

2015, 51 percent of the waste sites were addressed (closed, interim closed, no action, or not accepted or rejected), with 33 percent having undergone active remediation to remove secondary sources of contamination that could migrate to groundwater and reduce the risk of direct exposure at the surface. Former waste sites known or suspected to have contributed to observed groundwater contamination at 100-KR include 183-KE and 183-KW Head House tank farms, 116-KE-1 and 116-KW-1 Gas Condensate Cribs, 116-KE-3 and 116-KW-2 Fuel Storage Basin Cribs/Reverse Wells, 116-K-1 Crib, 116-K-2 Trench, and 118-K-1 Burial Ground.

Legacy Source Sites

Not Applicable

High-Level Waste Tanks

Not Applicable

Groundwater Plumes

Please see groundwater plume description in Part III above.

D&D of Inactive Facilities

Not Applicable

Operating Facilities

Not Applicable

Ecological Resources Setting

The potential for terrestrial ecological receptors to interact directly with any of the groundwater plumes is expected to be limited to those areas where the depth to groundwater is very shallow (<15 ft from the soil surface). On the Hanford Site, this condition is unlikely except where groundwater approaches the surface near the Columbia River. Where groundwater plumes intercept and enter the river, there may be mixing of river and groundwater at shallower depths (river bank storage), and plant roots and burrowing animals in the riparian zone could potentially access portions of the groundwater plume.

For purposes of this assessment, areas were delineated where the mapped riparian zone along the river shoreline intersects the estimated contours for the groundwater plumes. Riparian areas along the river shoreline are considered priority habitats that are classified as level 4 biological resources. The delineated area and acreage for the intersection of the riparian zone for separate contaminant plumes within each groundwater evaluation unit are provided in Table 1 and indicate the extent of biological resources that could potentially be affected by the groundwater plumes. For the groundwater evaluation units, there are approximately 70.64 acres of riparian habitat along the river shoreline that where contaminated groundwater could affect the ecological resources.

Cultural Resources Setting

The potential for cultural resources in the area of the groundwater plumes is high and likely to affect the Native American, Historic Pre-Hanford, and Manhattan Project/Cold War landscapes. As discussed in RC-LS-2, K Area Waste Sites EU, there are documented cultural resources along the shoreline for all the landscapes. A literature review of the setting for the groundwater EUs has not been completed.

Current remedial actions for groundwater plumes have included evaluation of Section 106 of the National Historic Preservation Act. Future activities will also include Section 106 evaluations.

Consultation with Hanford Tribes (Confederated Bands of the Yakama Nation, Wanapum, Confederated Tribes of the Umatilla Indian Reservation, and the Nez Perce) and other groups who may have an interest in the areas (e.g. East Benton Historical Society, Prosser Cemetery Association, Franklin County Historical Society, the Reach, and the B-Reactor Museum Association) will be completed. Consultation with Hanford Tribes will be necessary to provide input on indirect effects to both recorded and potential unrecorded TCPs in the area and other cultural resource issues of concern.

PART V. WASTE AND CONTAMINATION INVENTORY

The method described in Chapter 6 of the Methodology Report was used to approximate saturated zone inventories for the primary contaminants in the 100-BC, 100-HR-D/H, 100-FR, and 100-KR Interest Areas.

CONTAMINATION WITHIN PRIMARY EU SOURCE COMPONENTS

Legacy Source Sites

Not Applicable

High Level Waste Tanks and Ancillary Equipment

Not Applicable

Vadose Zone Contamination

The potential impacts of remaining vadose zone inventory on groundwater is evaluated in the corresponding legacy source EUs.

Groundwater Plumes

The estimated inventory for the saturated zone contamination is provided in Table D.4-2 where the process outlined in Chapter 6 of the Methodology Report (CRESP 2015). For the 100-BC, 100-HR-D/H, 100-FR, and 100-KR groundwater plumes (DOE/RL-2016-09, Rev. 0), the following information is provided:

- Maximum measured concentration in 2015 (DOE/RL-2016-09, Rev. 0);
- Upper 95% confidence limit (UCL) on the log-transformed groundwater and aquifer tube (AT) data from HEIS (http://ehs.hanford.gov/eda/) exceeding the given threshold (e.g., DWS), where the AT can also be used to estimate if the plume is in contact with the Columbia River;
- Plume area in 2015 (exceeding the water quality standard (WQS), often the DWS or risk-based cleanup level) (DOE/RL-2016-09, Rev. 0);
- Assumed plume thickness, which as described in Chapter 6 of the Methodology Report (CRESP 2015) is the minimum of the thickness from Table 3 from the Hanford 200-UP-1 Operable Unit Interim Record of Decision or the unconfined aquifer thickness is used for the contaminant depth interval[5];

[5] Plume depths are not known for the 100 Areas primary contaminants. As indicated in the Methodology Report (CRESP 2015), the minimum of the value from the Hanford 200-UP-1 OU Interim ROD (EPA 2012) or the unconfined

- Estimated plume pore volume and mass or activity in water (M^{SZ}) using the process described in Chapter 6 of the Methodology Report (CRESP 2015);
- The Groundwater Threat Metric (GTM) for the plume and corresponding rating.

As illustrated in Table D.4-2, the saturated zone (SZ) GTM values translate to:

- 100-BC: Group A and B primary contaminants range from *Low* for Sr-90 to *Medium* for hexavalent chromium (Cr-VI). There is no calculated tritium (Group C) plume areas and thus no rating.
- 100-HR-D/H: Group A and B primary contaminants range from *Low* for Sr-90 to *Medium* for hexavalent chromium. There is no calculated nitrate of tritium (Group C) plume areas and thus no rating.
- 100-FR: Group A and B primary contaminants are *Low* for hexavalent chromium, Sr-90, and TCE. The nitrate plume areas (Group C) translates to *Medium*.
- 100-KR: Group A and B primary contaminants are *Low* for Sr-90, C-14, and TCE to *Medium* for hexavalent chromium. The tritium and nitrate plume areas (Group C) translate to *Medium* and *Low* ratings, respectively.

Thus, the overall rating for the RC-GW-3 EU threat to groundwater would be *Medium* related to hexavalent chromium (Group A) in the 100-BC, 100-HR-D/H, and 100-KR IAs; and tritium (Group C) in the 100-KR IA; and nitrate (Group C) in the 100-FR IA.

Impact of Cleanup, Recharge Rate, and Radioactive Decay on Groundwater Ratings

For some constituents there may be significant impacts from cleanup operations or radioactive decay. However, because of the shallow vadose zone in the River Corridor and proximity to the River, potential impacts of different recharge rates are assumed insignificant. To summarize, the results for the River Corridor impacts include:

- Hexavalent chromium (Group A) – There are current plumes in 100-BC, 100-HR, and 100-KR that translate to current *Medium* ratings. For 100-BC, there is no current treatment (where the final ROD is expected 2017) so the rating is assumed to remain *Medium* for the Active and Near-term, Post-Cleanup periods (since there is no assumed biological "decay"). For 100-HR-D/H it is assumed that the P&T and ISRM systems would continue to be effective resulting in *Medium* and *Low* ratings for Active and Near-term, Post-Cleanup periods, respectively (to account for inventory and treatment uncertainties and because the final ROD has yet to be signed). For 100-FR-3, the rating (*Low*) will not be modified because there is not treatment and the final ROD has not been signed. For 100-KR it is assumed that the P&T system would continue to be effective resulting in *Medium* and *Low* ratings for Active and Near-term, Post-Cleanup periods, respectively (again to account for inventory and treatment uncertainties and because the final ROD has yet to be signed).
- Sr-90 (Group B) – There are current plumes in all four IAs that currently translate to *Low* ratings. Maximum measured concentrations range from 32.7 to 4000 pCi/L. All other things being equal, these concentrations adjusted for decay after 50 years would still result in non-zero Sr-90

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aquifer thickness is used. The unconfined aquifer thicknesses are: 100-BC: ~30 m, 100-HR: ~10 m, 100-FR: ~10 m and 100-KR: ~30 m (Last 2006). Use of the depths from the Hanford 200-UP-1 OU Interim ROD (EPA 2012) or the unconfined aquifer thickness likely results in very large uncertainties in the pore volume and related estimates.

plumes in all areas and thus the ratings for the Active Cleanup period remain *Low* for these OUs. For the 100-KR maximum concentration, the value adjusted for decay over 150 years (Near-term, Post-Cleanup period) would still result in a concentration above the 8 pCi/L limit (all other things being equal) resulting in again a *Low* rating; however, the maximum concentrations for the other areas would result in *Not Discernible* ratings.

- Carbon-14 (Group A), Trichloroethene (TCE) (Group B), Tritium/Nitrate (Group C) – There are current plumes for these contaminants in one or more IAs. However, since there are neither remedial activities selected for these constituents nor will there likely be radioactive or biological decay or other significant impacts, the ratings are assumed to not change for the Active and Near-term, Post-Cleanup periods. The proposed groundwater remedial alternative, MNA including the installation of additional monitoring wells, would be used to monitor remedial performance and reduce uncertainties in the extent of nitrate contamination (DOE/RL-2016-09, Rev. 0, p. 3-8).

Columbia River

The process illustrated in Chapter 6 of the Methodology Report (CRESP 2015) is used to evaluate potential impacts to the Columbia River. Note that the evaluation of potential benthic and riparian impacts has a common thread up to the point when the shoreline impact (benthic) or riparian zone impact area is used to define ratings. Thus a common evaluation for the benthic and riparian zone is performed here.

<u>Benthic and Riparian Zone – Current Impacts</u>

Based on the information in the 2015 Hanford Site Groundwater Monitoring Report (DOE/RL-2016-09, Rev. 0) summarized in Table D.4-3, four plumes from these four IAs are currently intersecting the Columbia River at concentrations exceeding the WQS. The ratings obtained from using the process shown in Chapter 6 (Figure 6-10) range from *Not Discernible* for Sr-90 (100-BC) to *Low* for Cr-VI (100-FR), Sr-90 (100-KR), and C-14 (100-KR) to *Medium* for Cr-VI (100-BC, 100-HR-D/H and 100-KR). Tritium in 100-BC and 100-HR-D/H and nitrate 100-HR-D/H were not rated because either the plume area was zero or not calculated. The ratings for the other contaminants would be *Not Discernible*. Thus *current* impacts from these IAs to the Columbia River benthic and riparian zone ecology would be rated as *Medium* related to hexavalent chromium in 100-BC, 100-HR-D/H (currently being treated using P&T and ISRM), and 100-KR (currently being treated using P&T).

<u>Benthic and Riparian Zone – Active Cleanup and Near-term, Post Cleanup for Current Plumes</u>

For those contaminants currently in contact with the River:

- 100-BC-5: Hexavalent chromium rating (*Medium*) is not modified since there is no selected treatment and the final ROD has not been signed. The Sr-90 rating remains *Not Discernible* since the plume is assumed to continue to decrease due to radioactive decay.
- 100-HR-3: Hexavalent chromium is expected to reach the cleanup level (10 µg/L) during the Active Cleanup period (DOE/RL-2011-111, Draft A) using the P&T and ISRM systems resulting in a *Medium* rating and a corresponding *Low* rating for the Near-term, Post-Cleanup period to account for uncertainties in inventory and treatment. The Sr-90 (100-HR) rating will remain *Not Discernible* since the plume is assumed to decrease due to radioactive decay.
- 100-FR-3: No plumes currently in contact with the Columbia River (i.e., no shoreline impact estimates) (DOE/RL-2016-09, Rev. 0).
- 100-KR-4: Hexavalent chromium is expected to reach the cleanup level (10 µg/L) over much of 100-KR during the Active Cleanup period (DOE/RL-2010-97, Draft A) resulting in a *Medium* rating

and a corresponding *Low* rating for the Near-term, Post-Cleanup period to account for uncertainties in inventory and treatment. Because of the localized hot spot for Sr-90, the rating is not modified since radioactive decay over the 150-year period appears to not be sufficient (all other things being equal) to lower the concentration below the 8 pCi/L standard. For TCE, the *Not Discernible* rating is not modified for the Current or Near-term, Post-Cleanup periods.

For those contaminants not currently in contact with the Columbia River, the next step is to estimate if a plume could likely contact the River within the next 50 or 150 years. From inspection of the plumes areas over time (Figure D.4-1 through Figure D.4-4) for the various IA, it appears as though most of the plumes (i.e., those which are 150+ m from the River) are unlikely to contact the Columbia River over the Active Cleanup period (50 years) or Near-term, Post-Cleanup period (150 years) unless hydrologic conditions change significantly (from those over the past decade). Thus ratings (primarily *ND* or *Low*) will not change for many of these contaminants. For hexavalent chromium (100-FR), the current *Low* rating will not be modified for the Active Cleanup and Near-term, Post-Cleanup periods because no final remedial selection has been made. For Sr-90 (100-FR) even though the plume moves very slowly, there is a chance that it could reach the River in the Active Cleanup period (thus assigned a *Low* rating to account for uncertainties); however, radioactive decay would result in no plume (all things being equal) for a *Not Discernible* rating during the Near-term, Post-Cleanup period.

Benthic and Riparian Zone – Long-term

From the above analysis, only the hexavalent chromium in 100-BC (no remedial action selected) and C-14 in 100-KR (hot spot) are predicted to have *Medium* ratings. These results indicate the need for both monitoring and remedial action selection for these IAs. The final RODs for the 100-BC and 100-KR IAs are expected in 2017 and 2016, respectively.

Threats to the Columbia River Free-flowing Ecology

As described in Appendix E.2, the large dilution effect of the Columbia River on the contamination from the seeps and groundwater upwellings results in *Not Discernible* ratings for the Active Cleanup and Near-term, Post Cleanup periods and insignificant long-term impacts to the free-flowing ecology for all contaminants[6].

Facilities for D&D

Not Applicable

Operating Facilities

Not Applicable

[6] "Groundwater is a potential pathway for contaminants to enter the Columbia River. Groundwater flows into the river from springs located above the water line and through areas of upwelling in the river bed. Hydrologists estimate that groundwater currently flows from the Hanford unconfined aquifer to the Columbia River at a rate of ~ 0.000012 cubic meters per second (Section 4.1 of PNNL-13674). For comparison, the average flow of the Columbia River is ~3,400 cubic meters per second (DOE/RL-2016-09, Rev. 0)." This represents a dilution effect of more than eight orders of magnitude (a dilution factor of greater than 100 million). Thus the differences from EU to EU were not found distinguishing and the potential for groundwater contaminant discharges from Hanford to achieve concentrations above relevant thresholds is very remote.

Table D.4-2. Summary of the Evaluation of Threats to Groundwater as a Protected Resource from Saturated Zone (SZ) Contamination associated with the RC-GW-3 Evaluation Unit (100-BC, 100-HR-D/H, 100-FR, and 100-KR Interest Areas)

IA	PC	Grp	WQS[a]	Area (km^2)[b]	Thick-ness (m)[c]	Pore Vol. (Mm^3)	Max GW Conc	95th % GW UCL	Porosity[d]	K_d (mL/g)[d]	ρ (kg/L)[d]	R	SZ Total M^{SZ} (kg or Ci)	SZ GTM (Mm^3)	SZ Rating[e]
100-BC	Cr-VI	A	10 µg/L	1.5	24	6.48	50.6 µg/L	20.4 µg/L	0.18	0	1.84	1	1.32E+02	1.32E+01	Medium
	Sr-90	B	8 pCi/L	0.55	15	1.48	35.2 pCi/L	23.3 pCi/L	0.18	22	1.84	226	3.46E-02	4.32E+00	Low
	H-3	C	20000 pCi/L	---	---	---	---	---	0.18	0	1.84	1	---	---	---
100-HR-D/H	Cr-VI	A	10 µg/L	4.8	10	8.64	614 µg/L	43.1 µg/L	0.18	0	1.84	1	3.72E+02	3.72E+01	Medium*
	NO3	C	45 mg/L	---	10	---	45.2 mg/L	---	0.18	0	1.84	1	---	---	---
	Sr-90	B	8 pCi/L	0.02	10	0.036	32.7 pCi/L	21.3 pCi/L	0.18	22	1.84	226	7.65E-04	9.57E-02	Low
	H-3	C	20000 pCi/L	---	---	---	---	---	0.18	0	1.84	1	---	---	---
100-FR	NO3	C	45 mg/L	9.7	10	17.5	120 mg/L	97.1 mg/L	0.18	0	1.84	1	1.70E+06	---	Medium
	Cr-VI	A	10 µg/L	0.21	10	0.378	51.2 µg/L	30.1 µg/L	0.18	0	1.84	1	1.14E+01	1.14E+00	Low
	Sr-90	B	8 pCi/L	0.13	10	0.234	176 pCi/L	111 pCi/L	0.18	22	1.84	226	2.60E-02	3.25E+00	Low
	TCE	B	5 µg/L	1	10	1.8	18.3 µg/L	9.66 µg/L	0.18	0	1.84	1	1.74E+01	3.48E+00	Low
100-KR	Cr-VI	A	10 µg/L	1.5	24	6.48	348 µg/L	23.6 µg/L	0.18	0	1.84	1	1.53E+02	1.53E+01	Medium*
	H-3	C	20000 pCi/L	0.11	30	0.594	935000 pCi/L	100000 pCi/L	0.18	0	1.84	1	5.94E+01	---	Medium
	NO3	C	45 mg/L	0.01	24	0.0432	75.3 mg/L	70.2 mg/L	0.18	0	1.84	1	3.03E+03	---	Low
	Sr-90	B	8 pCi/L	0.03	15	0.081	4000 pCi/L	54.6 pCi/L	0.18	22	1.84	226	4.42E-03	5.53E-01	Low
	C-14	A	2000 pCi/L	0.04	24	0.173	14200 pCi/L	6180 pCi/L	0.18	0	1.84	1	1.07E+00	5.34E-01	Low
	TCE	B	5 µg/L	0.01	30	0.054	8.70 µg/L	8.02 µg/L	0.18	0	1.84	1	4.33E-01	8.66E-02	Low

a. The Water Quality Standard (WQS) is typically the drinking water standard (DWS). The exception is hexavalent chromium (Cr-VI) where the surface water standard (10 µg/L) is used for this Review.

b. Plume area (DOE/RL-2016-09, Rev. 0).

c. As indicated in the Methodology Report (CRESP 2015), the minimum of the value from the Hanford 200-UP-1 OU Interim ROD (EPA 2012) or the unconfined aquifer thickness is used. Plume depths are not known for the 100 Areas primary contaminants. The unconfined aquifer thicknesses are 100-BC: ~30 m, 100-HR: ~10 m, 100-FR: ~10 m and 100-KR: ~30 m (Last 2006). Use of depths from the Hanford 200-UP-1 OU Interim ROD (EPA 2012) or the unconfined aquifer thickness likely results in very large uncertainties in the pore volume and related estimates.

d. Parameters obtained from the analysis provided in Attachment 6-1 to Methodology Report (CRESP 2015).

e. For Group C contaminants, rating is based on plume area. Groundwater Threat Metric rating based on Table 6-3, Methodology Report (CRESP 2015) for the Group A and B primary contaminants. Groundwater contaminants that are being treated (Cr-VI in 100-HR using *In Situ* Redox Manipulation (ISRM) and P&T and Cr-VI in 100-KR using P&T) are indicated in the table with an asterisk (*) although other contaminants are likely being extracted (e.g., Cr-VI in 100-BC).

Table D.4-3. Summary of the Evaluation of Groundwater as Pathway to the Columbia River associated with the RC-GW-3 Evaluation Unit (100-BC, 100-HR-D/H, 100-FR, and 100-KR Interest Areas)

IA	PC	Group	WQS	BCG or AWQC[a]	Max GW Conc	95th % GW UCL	$R1, \frac{\text{Max GW Conc}}{\text{BCG or WQS}}$	$R2, \frac{\text{95th \% GW UCL}}{\text{BCG or WQS}}$	Shoreline Impact (m)[b]	Riparian Area (ha)[c]	Benthic rating	Riparian rating	Overall rating[d]
100-BC	Cr-VI	A	10 µg/L	10 µg/L	57.9 µg/L	20.4 µg/L	5.06E+00	2.04E+00	1740	3.49E+00	Medium	Medium	Medium
	Sr-90	B	8 pCi/L	279 pCi/L	35.2 pCi/L	23.3 pCi/L	1.26E-01	8.35E-02	450	9.47E-01	---	---	ND
	H-3	C	20000 pCi/L	2.65E+08 pCi/L	13800 pCi/L	---	---	---	---	---	---	---	---
100-HR-D\H	Cr-VI	A	10 µg/L	10 µg/L	614 µg/L	43.1 µg/L	6.14E+01	4.31E+00	990	1.34E+01	Medium	Medium	Medium*
	NO3	C	45 mg/L	7.1 mg/L	45.2 mg/L	---	1.44E+00	---	---	---	---	---	Low
	Sr-90	B	8 pCi/L	279 pCi/L	32.7 pCi/L	21.3 pCi/L	1.19E-01	7.62E-02	0	---	---	---	ND
	H-3	C	20000 pCi/L	2.65E+08 pCi/L	14400 pCi/L	---	---	---	---	---	---	---	---
100-FR	NO3	C	45 mg/L	7.1 mg/L	120 mg/L	97.1 mg/L	3.82E+00	3.09E+00	0	---	---	---	Low
	Cr-VI	A	10 µg/L	10 µg/L	51.2 µg/L	30.1 µg/L	5.10E+00	3.01E+00	0	---	---	---	Low
	Sr-90	B	8 pCi/L	279 pCi/L	176 pCi/L	111 pCi/L	6.31E-01	3.98E-01	0	---	---	---	ND
	TCE	B	5 µg/L	47 µg/L	18.3 µg/L	20.0 µg/L	3.89E-01	4.26E-01	0	---	---	---	ND
100-KR	Cr-VI	A	10 µg/L	10 µg/L	348 µg/L	23.6 µg/L	3.48E+01	2.36E+00	271	6.35E-01	Medium	Medium	Medium*
	H-3	C	20000 pCi/L	2.65E+08 pCi/L	935000 pCi/L	100000 pCi/L	3.53E-03	3.78E-04	0	---	---	---	ND
	NO3	C	45 mg/L	7.1 mg/L	75.3 mg/L	70.2 mg/L	2.39E+00	2.23E+00	0	---	---	---	Low
	Sr-90	B	8 pCi/L	279 pCi/L	4000 pCi/L	54.6 pCi/L	1.43E+01	1.96E-01	0	---	---	---	Low
	C-14	A	2000 pCi/L	609 pCi/L	14200 pCi/L	6180 pCi/L	2.33E+01	1.02E+01	0	---	---	---	Low
	TCE	B	5 µg/L	47 µg/L	8.70 µg/L	8.02 µg/L	1.85E-01	1.71E-01	0	---	---	---	ND

a. Biota Concentration Guide (BCG) from RESRAD-BIOTA v1.8 (consistent with DOE Technical Standard DOE-STD-1153-2002) for radionuclides. For chemicals, the Ambient Water Quality Criterion (AWQC) (Table 6-1 in DOE/RL-2010-117, Rev. 0) or Tier II Screening Concentration Value (SVC) (http://rais.ornl.gov/documents/tm96r2.pdf) used when AQWC not provided.

b. Shoreline impact (m) (DOE/RL-2016-09, Rev. 0)

c. The intersection area between the groundwater plume and the riparian zone was provided by PNNL based on the 2013 Hanford Site Groundwater Monitoring Report (DOE/RL-2016-09, Rev. 0).

d. The groundwater contaminants that are being treated (Cr-VI in 100-HR using In Situ Redox Manipulation (ISRM) and P&T and Cr-VI in 100-KR using P&T) are indicated in the table with an asterisk (*) although other contaminants are likely being extracted (e.g., Cr-VI in 100-BC).

PART VI. POTENTIAL RISK/IMPACT PATHWAYS AND EVENTS

CURRENT CONCEPTUAL MODEL

100-BC (from DOE/RL-2013-22, Rev. 0)

The vadose zone in 100-BC is comprised of Hanford formation sand and gravel (Figure D.4-10). The water table is at a depth of approximately 18 to 24 meters. The upper portion of the unconfined aquifer beneath most of 100-BC is in the highly permeable sediments of the Hanford formation. The lower portion of the aquifer, and the entire aquifer near the Columbia River, is within the Ringold unit E sands and gravels. The unconfined aquifer is 32 to 48 meters thick, and the base of the aquifer is a silt/clay-rich unit commonly called the Ringold upper mud unit (RUM) (DOE/RL-2010-96).

The hydraulic gradient is steepest in the north near the Columbia River, where the water table is in Ringold unit E. The gradient is very low in southern 100-BC where the water table is in the highly permeable Hanford formation. In northern 100-BC, flow is primarily to the north during periods of low and moderate river stage. When river stage is very high, river water flows into the aquifer. A reversed gradient was not observed in 2013, similar to observations in the other river corridor areas. In July when the river stage was high, trend surface analysis showed the potential for flow toward the northwest.

The water table is very flat in southern 100-BC. Trend surface analysis of available data in 2013 indicated flow in southern 100-BC was toward the north-northeast in January and July, and northeast in late February. The water table dipped toward the northwest in October 2013 at a very low gradient. The results of the analyses in February and October have greater uncertainty than the others because the difference in water-table elevations was only about 2 cm across a distance of more than 1 km. Tracer tests conducted in the 100-C-7:1 excavation in spring and summer 2012 indicated flow toward the northeast (PNNL-21845). Recent movement of groundwater contaminants in the shallow aquifer also indicates that flow primarily is toward the northeast.

The Columbia River did not rise to its normal seasonal high in June 2015 due to meager snowpack in the Cascade Mountains. As a result, there was no reversed gradient from the river into the aquifer in summer 2015 (DOE/RL-2016-09, Rev. 0).

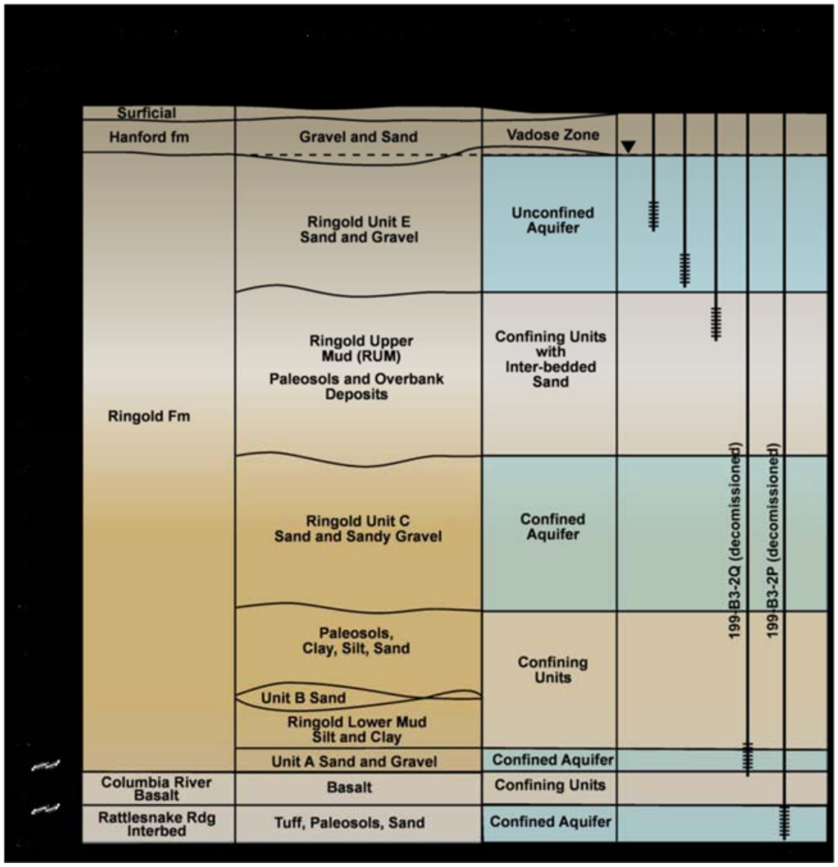

Figure D.4-10. 100-BC Geology (after DOE/RL-2016-09, Rev. 0)

100-FR (from DOE/RL-2016-09, Rev. 0)

The vadose zone and the unconfined aquifer comprise Hanford formation sand and gravel (Figure D.4-11). Ringold unit E is largely absent in this region, but a remnant of Ringold unit E is interpreted to exist in the southwestern 100-F Area and smaller remnants in central and eastern 100-F Area. In two locations, Ringold unit E extends above the water table, comprising the entire aquifer thickness. The bottom of the aquifer is the Ringold upper mud unit (RUM). The aquifer ranges from 1 to 8 meters thick. Most of the monitoring wells are screened across all, or nearly all, of the aquifer.

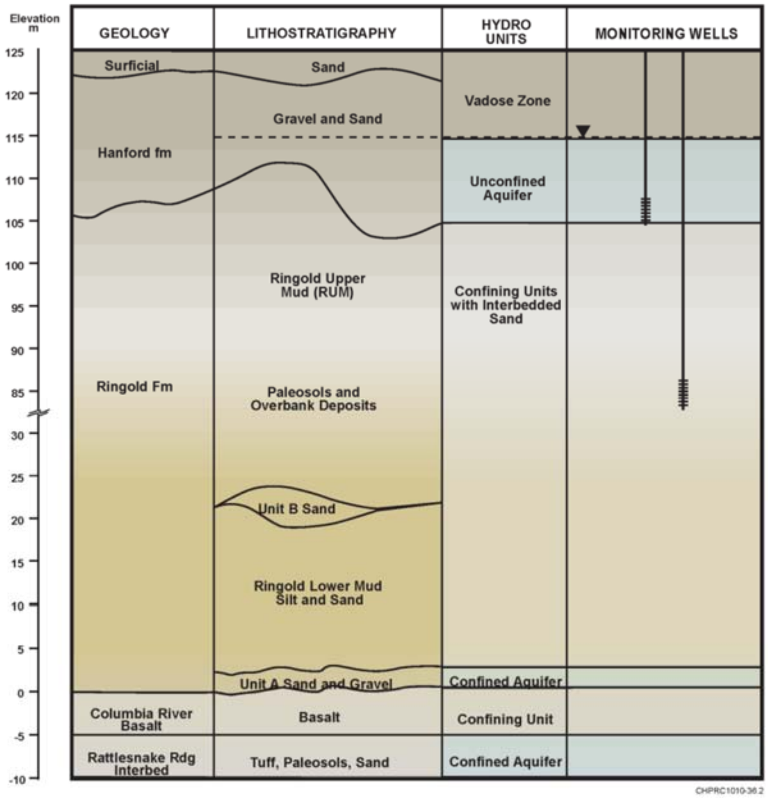

Figure D.4-11. 100-FR Geology (after DOE/RL-2016-09, Rev. 0)

100-HR (from DOE/RL-2013-22, Rev. 0)

Vadose zone thickness, which also represents the depth to groundwater, ranges from 0 to 27 meters, with an average thickness of 20 meters in 100-D and an average thickness of 11.3 meters in 100-H. Thickness of the unconfined aquifer ranges from nearly 0 to 12 meters across the area. Aquifer thickness varies from about 6 to 9 meters beneath 100-D, and from 2 to 5 meters beneath 100-H. The thickness of the unconfined aquifer mimics the topography of the RUM (Hydrogeological Summary Report for 600 Area Between 100-D and 100-H for the 100-HR-3 Groundwater Operable Unit [DOE/RL-2008-42]). The uneven surface of the silt- and clay rich Ringold Formation upper mud unit (RUM) forms the base of the unconfined aquifer.

The unconfined aquifer is primarily present in the Ringold Formation unit E sand and gravels in 100-D and in the Hanford formation gravels in 100-H (Figure D.4.12). Across the Horn, the geology is transitional, changing from predominantly Ringold unit E closer to 100-D to Hanford formation farther east. Pockets of Ringold unit E are found as remnants in various locations. Areas where Ringold unit E is absent form channels across the Horn, resulting in preferential groundwater flow pathways.

Groundwater in 100-HR-3 flows generally to the east-northeast direction, from 100-D across the Horn to 100-H. Flow in 100-H is easterly, generally towards the river. In the southern and central portions of 100-D, groundwater flows to the northwest, towards the Columbia River. The hydraulic gradients are flatter during high river stage when compared to low river conditions. Operation of pump and treat systems at 100-HR-3 has created localized changes in groundwater flow direction and velocity throughout 100-HR-3. These changes are expressed as local depressions and mounds in the water table, affecting the local flow direction and gradient.

Daily and seasonal fluctuations in the river stage also affect groundwater flow in 100-HR-3. As would be expected, longer term changes in the river stage produce more extensive and longer lived changes in the water levels, hydraulic gradient, and flow directions in the unconfined aquifer. The effect of river water migrating into the aquifer can cause lower contaminant concentrations in aquifer tubes and in some near-river wells. Seasonal changes in hexavalent chromium concentrations caused by mixing with river water are most evident at locations within a few meters of the shoreline. Longer-term changes in the river stage produce more extensive and longer-lived changes in the water levels, hydraulic gradient, and flow directions in the unconfined aquifer relative to daily fluctuations.

Contaminants of concern in the 100-HR-3 unconfined aquifer were identified in the RI/FS and include hexavalent chromium, nitrate, strontium-90, and uranium. In the first water bearing unit within the RUM in the 100-H and Horn areas, the contaminant of concern is hexavalent chromium. Other contaminants of interest within 100-HR-3 include technetium-99, sulfate, and tritium. Technetium-99 and uranium have historically been detected in 100-HR-3 groundwater downgradient from their source. Sulfate previously exceeded the 250 mg/L secondary drinking water standard in wells within and downgradient of the *In Situ* Redox Manipulation (ISRM) barrier in 100-D because of injections of sodium dithionite solution.

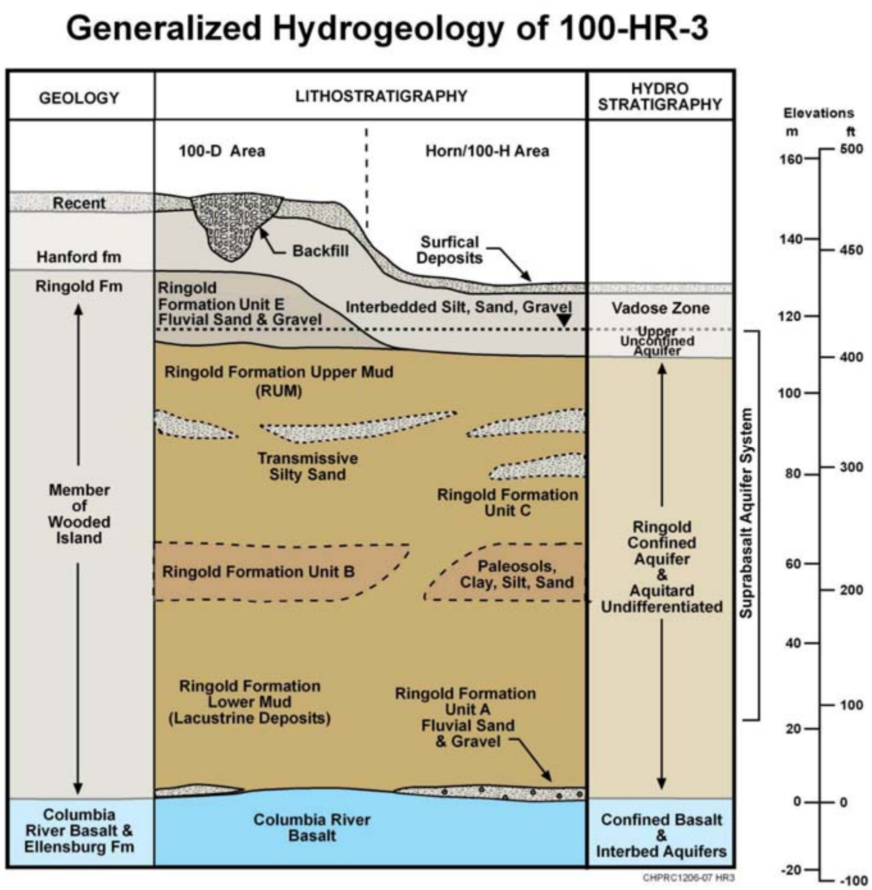

Figure D.4.12. 100-HR Geology (after DOE/RL-2016-09, Rev. 0).

100-KR (from DOE/RL-2016-09, Rev. 0)

The unconfined aquifer in 100-KR ranges from 5.2 to more than 32 meters thick. This aquifer is primarily present in the Ringold Formation unit E sand and gravel (Figure D.4-13). This unit is overlain by the gravels and interbedded sand and silt of the Hanford formation, which comprise the bulk of the vadose zone. The vadose zone ranges from less than 1-meter thick near the Columbia River to 32 meters thick inland. The uneven surface of the silt- and clay-rich Ringold Formation upper mud unit (RUM) forms the bottom of the unconfined aquifer. Contaminant concentrations are generally highest within the uppermost portion of the aquifer near the water table, however, mobile contaminants (e.g., hexavalent chromium) have been detected over the entire aquifer thickness, particularly near source areas.

Groundwater in 100-KR flows generally to the northwest toward the Columbia River, which forms a discharge boundary for the unconfined aquifer. Operation of pump and treat (P&T) systems at 100-KR creates changes in groundwater flow direction and velocity. Larger mounds, such as that produced by the combined discharges from KR4 and KX systems near the middle of the 116-K-2 Trench, create conditions of radial flow away from the mound. This creates local diversion of groundwater flow direction away from the natural patterns. Groundwater further inland of 100-K Area generally flows to the north and northeast toward 100-N and 100-D Areas. The actual flow direction and apparent velocity in this inland area is somewhat uncertain due to sparse groundwater elevation measurements in the area.

Daily and seasonal fluctuations in the river stage also affect groundwater flow in 100-KR. As would be expected, longer term changes in the river stage produce more extensive and longer lived changes in the water levels, hydraulic gradient, and flow directions in the unconfined aquifer. Intrusion of river water into the aquifer during high river stage can lower contaminant concentrations in aquifer tubes and in some near-river wells. The highest river stage in 2015 was during two brief periods in mid-February (maximum river-stage elevation at 100-K was 120.55m [395.51 ft] on February 24, 2015). The seasonal high river stage that typically occurs in June through July was substantially reduced in 2015 due to regional drought conditions. The low river-stage period for 2015 was observed from late August through December.

Contaminants of concern (COCs) in the 100-KR unconfined aquifer were identified in the RI/FS and include chromium (total and hexavalent), tritium, nitrate, strontium-90, carbon-14, and trichloroethene (TCE). All elevated anthropogenic chromium at 100-KR is understood to be present as hexavalent chromium and so total chromium and hexavalent chromium are discussed as hexavalent chromium for purposes of this report.

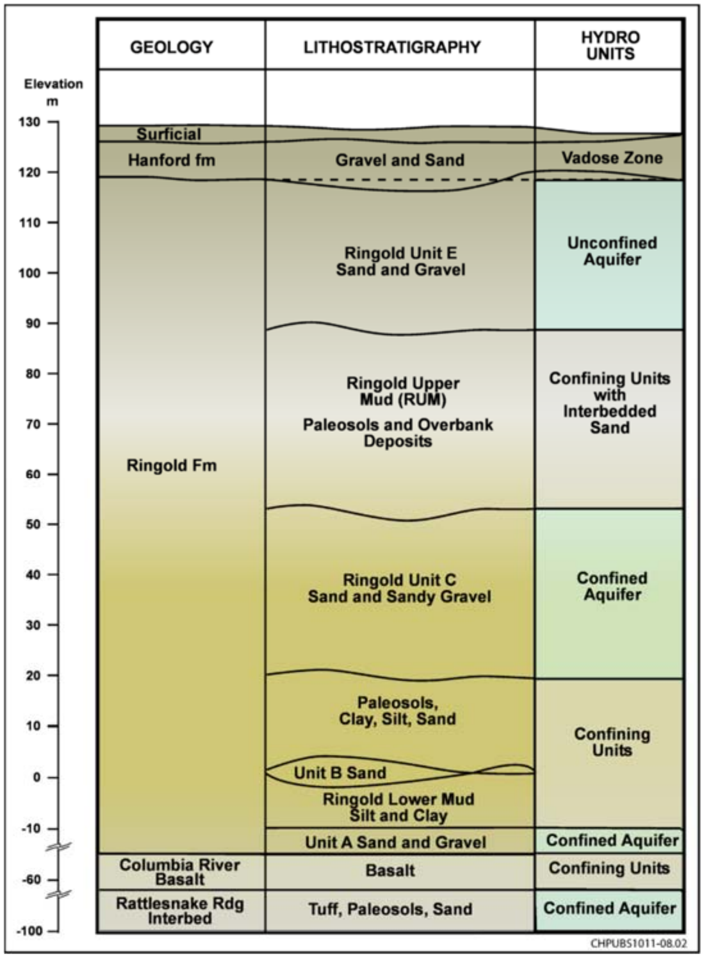

Figure D.4-13. 100-KR Geology (after DOE/RL-2016-09, Rev. 0)

POPULATIONS AND RESOURCES CURRENTLY AT RISK OR POTENTIALLY IMPACTED

Facility workers are at risk when working in or around areas with contaminated soils. Exposure to such contaminants is limited because groundwater and contaminated soils are located below grade. However, during certain operations (e.g., drilling, sampling, removal, treatment, and disposal), there may be the potential for exposure to hazardous and radioactive contaminants; however, the potential exposure would be very small. Similarly, co-located persons would be expected to have similar to reduced exposure to facility workers, while the public would be expected to have significantly reduced exposure. As noted above, The Department of Energy and contractor site-specific safety and health planning that includes work control, fire protection, training, occupational safety and industrial hygiene, emergency preparedness and response, and management and organization—which are fully integrated with nuclear safety and radiological protection—have proven to be effective in reducing industrial accidents at the Hanford site to well below that in private industry. Further, the safety and health program must effectively ensure that ongoing task-specific hazard analyses are conducted so that the selection of appropriate PPE can be made and modified as conditions warrant. Task-specific hazard analyses must lead to the development of written work planning documents and standard operating procedures (SOPs) [DOE uses the term work planning documents in addition to procedures] that specify the controls necessary to safely perform each task, to include continuous employee exposure monitoring. Last, ICs will be used to control access to residual contaminants in soil and groundwater as long as they exceed the cleanup levels (CULs). As such, mitigation actions will generally lead to reduced risks.

Facility Worker

Risks are thus rated as *Low to Medium*, with mitigated risk reduced to *Low*.

Co-Located Person

Risks are rated as *Low*; mitigated risk is also rated as *Low*.

Public

Risks are located as *Not Discernible* to *Low*; mitigated risk is rated as *Not Discernible*.

Groundwater

As illustrated in Table D.4-2, the current saturated zone (SZ) GTM values translate to:

- 100-BC: Group A and B primary contaminants range from *Low* for Sr-90 to *Medium* for hexavalent chromium (which is not being treated). There is no calculated tritium (Group C) plume areas and thus no rating.
- 100-HR: Group A and B primary contaminants range from *Low* for Sr-90 to *Medium* for hexavalent chromium (which is being treated). There is no calculated tritium or nitrate (Group C) plume areas and thus no rating for either of these primary contaminants.
- 100-FR: Group A and B primary contaminants are *Low* for hexavalent chromium, Sr-90, and TCE. The nitrate plume areas (Group C) translates to *Medium* (which is not being treated).
- 100-KR: Group A and B primary contaminants are *Low* for Sr-90, C-14, and TCE to *Medium* for hexavalent chromium (which is being treated). The tritium and nitrate plume areas (Group C) translates to *Medium* and *Low* ratings, respectively.

Thus the overall rating for the RC-GW-3 EU threat to groundwater would be *Medium* related to hexavalent chromium (100-BC, 100-HR-D/H, and 100-KR) and nitrate (Group C) in the 100-FR IA.

Columbia River

As described in Part V (Table D.4-3), four plumes from these four IAs are currently intersecting the Columbia River at concentrations exceeding the WQS. The corresponding ratings are *Not Discernible* for Sr-90 (100-BC) to *Low* for Cr-VI (100-FR), Sr-90 (100-KR), and C-14 (100-KR) to *Medium* for Cr-VI (100-BC, 100-HR-D/H and 100-KR). Tritium in 100-BC and 100-HR-D/H and nitrate 100-HR-D/H were not rated because either the plume area was zero or not calculated. The ratings for the other contaminants would be *Not Discernible*. Thus current impacts from these IAs to the Columbia River benthic and riparian zone ecology would be rated as *Medium* related to hexavalent chromium in 100-BC, 100-HR-D/H (currently being treated using P&T and ISRM), and 100-KR (currently being treated using P&T).

Ecological Resources

For the four groundwater evaluation units with plumes that are estimated to intersect the Columbia River, there are approximately 70.64 acres of riparian habitat and resources along the river shoreline that could potentially be affected.

Remediation actions taken to reduce the contaminated groundwater plumes may have indirect effects on terrestrial ecological resources. Subsurface remediation actions such as pump and treat activities or development of subsurface chemical barriers to contaminant transport may indirectly affect ecological resources through several mechanisms:

- Injection and pumping wells might alter the hydrology in the vadose zone, and change soil water availability for plants.
- Injection of barrier constituents might alter soil chemistry and nutrient availability depending on rate or distance of migration of those constituents and whether the constituents interact with soils within the rooting zone
- Well pad and road construction may disturb the surface, degrade available habitat, and impact ecological resources/receptors
- Pedestrian and vehicle traffic during construction, maintenance, monitoring, and decommission of subsurface barrier systems may degrade habitats, disturb wildlife and affect animal behavior, and introduce exotic plant species.

Use of plants to accomplish phytoremediation would incur both direct and indirect effects to ecological receptors within the area of the EU used for treatment. Direct effects include surface disturbance and habitat removal associated with preparation and planting of the phytoremediation species to be used. As with subsurface treatment activities, pedestrian and vehicle traffic during construction, maintenance, monitoring, and decommission may degrade habitats, disturb wildlife and affect animal behavior, and introduce exotic plant species.

Cultural Resources

The potential for cultural resources in the area of the groundwater plumes is high and likely to affect the Native American, Historic Pre-Hanford, and Manhattan Project/Cold War landscapes. A literature review of the setting for the groundwater EUs has not been completed. Current remedial actions for groundwater plumes have included evaluation of Section 106 of the National Historic Preservation Act. Future activities will also include Section 106 evaluations.

CLEANUP APPROACHES AND END-STATE CONCEPTUAL MODEL

Selected or Potential Cleanup Approaches

100-BC: (after DOE/RL-90-08 Procedural Draft and DOE/RL-2016-09 Rev. 0). Previous assessments have not resulted in any interim remedial measures for groundwater for 100-BC. In 2015, CERCLA activities in 100-BC included routine groundwater monitoring and the beginning of additional remedial investigation (RI) studies. DOE conducted additional RI studies in 100-BC between 2013 and 2015 to reduce uncertainties relating to (1) the completion of waste site remediation, (2) short-term changes in groundwater contaminants related to waste site remediation, (3) modeling results predicting that the Cr(VI) plume could persist for over 100 years, and (4) the level of risk associated with variable contaminant concentrations in Columbia River pore water. To address these uncertainties, a change was initiated in Tri-Party Agreement Milestone M-015-74, and the RI/ FS work plan and SAP were amended. In 2013, workers installed a series of shallow aquifer tubes called hyporheic sampling points (HSP) to monitor Columbia River pore water. In 2015, workers continued to sample a series of HSPs (Figure 2-1) to monitor Columbia River pore water. The HSPs were monitored for monthly for Cr(VI) for 2 years to identify seasonal changes and characterize the level of risk to aquatic receptors. Sampling was completed in October 2015.The revised RI/FS work plan also included groundwater monitoring. Eight new wells were installed in 2013 and early 2014. The new wells and older wells were monitored for 2 years to evaluate (1) the nature and extent of Cr(VI) and co-contaminants, (2) groundwater model input parameters, and (3) which natural attenuation processes are occurring. Monitoring frequency was quarterly for the new wells and older wells with rapid changes in Cr(VI) concentration, and semiannually or annually for wells with less variability. The 2-year period for monitoring the new wells ended in January 2016.

In 2015, DOE began to prepare an RI/FS report for 100-BC to present the results of soil and groundwater investigations, and to evaluate alternatives for remediation. Draft A of the document is expected to be submitted to EPA in late 2016.

100-FR: (after ECF-100FR3-11-0116 Revision 3). No final Record of Decision has been signed for 100-FR-3. Remedial alternatives are provided from the RI/FS for Remedial Investigation/Feasibility Study for the 100-FR-3 Operable Unit (ECF-100FR3-11-0116 Revision 3).

- **Alternative 1 – (No Action [as required by the NCP]).** This alternative is required by the NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(6)]). For this alternative, it is assumed that all site remedial activities and interim actions, with the possible exception of backfilling any unsafe open excavations, will be discontinued in December 2012. Operation of the existing DX and HX pump-and-treat systems and any other monitoring would cease.
- **Alternative 2 – Institutional Controls (ICs) and Monitored Natural Attenuation (MNA).** ICs will be used to prevent exposure to contaminated groundwater until natural attenuation processes reduce COC concentrations of the COC plumes as they migrate under ambient aquifer conditions.
- **Alternative 3 –** Pump and Treat (P&T) Optimized with Other Technologies. Installation and operation of a P&T with implementation of in-situ treatment (bioremediation) at selected wells to address hexavalent chromium (Cr(VI)) and nitrate contamination.
- **Alternative 4 –** Enhanced Pump and Treat. Installation and operation of an expanded Pump and Treat system considering ex-situ treatment for all COCs.

100-HR-3: (after DOE/RL-2010-95 Rev. 0). No final Record of Decision has been signed for 100-HR-3. Remedial alternatives are provided from the RI/FS for Remedial Investigation/Feasibility Study for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units (DOE/RL-2010-95 Rev 0).

- **Alternative 1 – (No Action [as required by the NCP]).** This alternative is required by the NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(6)]). For this alternative, it is assumed that all site remedial activities and interim actions, with the possible exception of backfilling any unsafe open excavations, will be discontinued in December 2012. Operation of the existing DX and HX pump-and-treat systems and any other monitoring would cease. The groundwater model simulations (*Modeling of RI/FS Design Alternatives for 100-HR-3* [ECF-100HR3-11-0114]) assume no continuing sources for groundwater contamination. Because the pump-and-treat systems are shut down after 2012, extraction wells along the river are turned off and no longer provide containment of inland contamination from migrating and reaching the river, as can be seen in the model prediction after 3 years of terminating interim actions. Some mass removal is predicted to occur through natural flushing, as can be seen in the changes in concentrations out through 75 years. However, relatively large areas with greater than 10 µg/L Cr(VI) are predicted to remain after 75 years. If waste site remediation is not complete, as assumed, then the area with greater than 10 µg/L Cr(VI) would be larger.
- **Alternative 2 – RTD and Void-Fill Grouting for Waste Sites and Pump-and-Treat with Biological Treatment for Groundwater.** This alternative uses RTD for removal of contamination to cleanup levels for waste sites. Void-fill grouting will be used for the box flume of waste site 100-H-36 where RTD would have large ecological impacts near the river. For groundwater, a pump-and-treat system and biological treatment targeting Cr(VI) will be used. Nitrate and strontium-90

contaminated groundwater are within the treatment footprint of the Cr(VI) plume. Based on operational data from the currently operating pump-and-treat facilities and groundwater simulation modeling results, the groundwater treatment system effluent has not and is not expected to exceed MCLs for co-extracted strontium-90 or nitrate, so no treatment is proposed for these groundwater COCs. However, if, through normal operation of the groundwater treatment system, concentrations of co-extracted COCs exceed MCLs in the effluent, specific treatment would be evaluated for the respective COCs before reinjection or other approved discharge.

- **Alternative 3 – RTD and Void-Fill Grouting for Waste Sites and Increased Capacity Pump-and-Treat for Groundwater.** This alternative uses RTD for removal of contamination to cleanup levels for waste sites. Void-fill grouting will be used for the box flume of waste site 100-H-36 where RTD would have large ecological impacts near the river. For groundwater, an expanded pump-and-treat system for treatment of Cr(VI) will be used. Nitrate and strontium-90 contaminated groundwater plumes are within the treatment footprint for the Cr(VI) plume. As identified in Alternative 2, the groundwater treatment system effluent at the 100-D and 100-H pump-and-treat systems has not, and is not, expected to exceed MCLs, so no treatment is proposed for strontium-90 or nitrate. However, if through normal operation of the groundwater treatment system, concentrations of co-extracted COCs exceed MCLs in the effluent, specific treatment would be evaluated for the respective COCs before reinjection or other approved discharge. The application of MNA (such as radioactive decay), the use of dispersion and diffusion, ongoing monitoring, and ICs for each of the groundwater co-contaminants and the vadose zone are discussed under Section 9.2.2 (Common Elements for Alternatives 2, 3, and 4). A detailed description for this alternative is provided in Section 9.2.4.
- **Alternative 4 – RTD for Waste Sites and Pump-and-Treat for Groundwater.** This alternative uses RTD for removal of contamination to cleanup levels for waste sites. For groundwater, pump-and-treat system for treatment of Cr(VI) will be used. Nitrate and strontium-90 contaminated groundwater plumes are within the treatment footprint for the Cr(VI) plume and will be co-extracted by the extraction well network used for the Cr(VI) plume remediation. As identified in Alternative 2, the groundwater treatment system effluent at the 100-D and 100-H pump-and-treat systems has not, and is not, expected to exceed MCLs, so no treatment is proposed for strontium-90 or nitrate. However, if, through normal operation of the groundwater treatment system, concentrations of co-extracted COCs exceed MCLs in the effluent, specific treatment would be evaluated for the respective COCs before reinjection or other approved discharge.

100-KR: (after DOE/RL-2010-97 Draft A). No final Record of Decision has been signed for 100-KR-4. Remedial alternatives are provided from the RI/FS for Remedial Investigation/Feasibility Study for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units (DOE/RL-2010-97 Draft A).

- **Alternative 1 – (No Action [as required by the NCP]).** This alternative is required by the NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(6)]). For this alternative, it is assumed that all site remedial activities and interim actions, with the possible exception of backfilling any unsafe open excavations, will be discontinued in December 2012. This includes ceasing operation of the existing KR-4, KW, and KX pump-and-treat systems and any additional monitoring. Since the pump-and-treat systems are shut down after 2012, the containment of the plume along the river that is obvious at 2012 is lost, as can be seen in the 2020 model prediction. Some mass removal is predicted to occur via natural flushing, as can be seen in the changes in concentrations out to 2087. However, relatively large areas with greater than 10 µg/L Cr(VI) are predicted to remain at 2087. For nitrate, the K-West plume migrates toward the river in 2037 and has mostly dissipated by 2087.

- **Alternative 2 – RTD and Groundwater P&T Optimized with Other Technologies.** Alternative 2 uses a strategy of optimizing the risk reduction as well as the cost by using a mixture of RTD with other technologies. The actions will vary, depending on the nature and extent of contamination at the waste site, as will be determined following the Decision Logic flowchart. The actions could include one or more of the following:
    - RTD of shallow vadose zone areas. RTD would also include demolition of structures (e.g., buildings) when necessary.
    - Soil flushing with treatment of groundwater.
    - Biological infiltration.
    - Bioventing or land farming for sites with TPH as a COC.
    - Temporary surface barriers.
    - For groundwater, optimization of the pump-and-treat system with biological infiltration and biological injection.
    - Supplemental ICs to mitigate exposure, where potentially required.

  Based on the modeling results, by 2020, hexavalent chromium plumes will have been remediated to meet DWS, with a few pockets above the 10 µg/L aquatic standard. Wells downgradient of areas above 10 µg/L will continue remediation of the plume and maintain containment while the rest of the inland systems are shut down. The pump-and-treat systems will continue operating through 2037 to remediate the Cr(VI) plume below 10 µg/L. Three new extraction wells are included in this alternative to capture the nitrate plume between K-West and K-East. Based on modeling, the nitrate plume is nearly completely below 45 mg/L in the K-West area by 2020 and is reduced to below 45 mg/L by 2037. To deal with the uncertainty in groundwater modeling simulations, RPO activities will be conducted throughout the life of the project.
- **Alternative 3 – RTD and Void-Fill Grouting for Waste Sites and Increased Capacity Pump-and-Treat for Groundwater.** Alternative 3 uses a strategy of RTD almost exclusively for waste site contamination to rapidly achieve the RAOs, with the greatest degree of certainty, as well as aggressive pump-and-treat for groundwater. The remedial action will include the following activities:
    - RTD for waste sites, with excavation until standards are achieved. RTD would also include demolition of structures (e.g., buildings) when necessary.
    - Temporary surface barriers.
    - For Cr(VI) in groundwater, aggressive pump-and-treat.
    - Supplemental ICs to mitigate exposure, where potentially required.

  The groundwater extracted from within the carbon-14 plume are likely to have carbon-14 greater than the DWS. Water from this well will be treated in an air stripper to reduce the carbon-14 to below the DWS prior to re-injection. The modeling predicts that by 2020, the majority of plumes are gone with only very small pockets of chromium remaining at low concentrations. The modeling further predicts that by 2020, only low concentrations of nitrate remain in the K-West plume in a small, localized area. When evaluating these groundwater modeling results, the uncertainty in the model needs to be appreciated. To deal with the uncertainty, RPO activities will be conducted throughout the life of the project.

CONTAMINANT INVENTORY REMAINING AT THE CONCLUSION OF PLANNED ACTIVE CLEANUP PERIOD

After the Active Cleanup period, only the hexavalent chromium in 100-BC-5 and C-14 in 100-KR-4 have ratings that include Medium indicating inventories that might translate to appreciable plumes. There are also a few others that might represent small plumes after the Active Cleanup period.

Risks and Potential Impacts Associated with Cleanup

Ecological Resources

Personnel, cars, trucks, heavy equipment and drill rigs, as well as heavy, wide hoses, on roads through non-target areas or remediation site carry seeds or propagules on tires, injure or kill vegetation or animals, make paths, cause greater compaction of soil, displace animals and disrupt behavior/reproductive success. Also seeds and propagules can be dispersed from soil from truck or blowing from heavy equipment. Often permanent or long-term compaction can result in the destruction of soil invertebrates. Compaction can decrease plant growth in those areas, decrease abundance and diversity of soil invertebrates, and prevent fossorial snakes or mammals from using the area. Compaction of soils may permanently destroy areas of the site with intense activity. Construction of new buildings can cause permanent destruction of plants and animals, and of the on-site ecosystem larger than the footprint of the building. Effects will radiate from the building, and post-remediation effects depend on the degree of use (e.g., personnel and truck traffic, type of truck traffic and heavy equipment activity). During remediation, radionuclides or other contaminants could be released or spilled on the surface, and depending upon the type and quantity, could have adverse effects on the plants and animals on site.

Cultural Resources

Personnel, truck, heavy equipment, and drill rigs may have direct impact on cultural resources in the riparian areas and in upland areas where there is soil/ground or alteration to the landscape. Assuming heavy equipment locations, new roads and staging areas have been cleared for cultural resources, then it is assumed adverse effects would have been resolved and/or mitigated. If heavy equipment and drilling locations and staging areas have not been cleared, this could result in artifact breakage and scattering, compaction and disturbance to the soil surface and immediate subsurface, thereby compromising stratigraphic integrity of an archaeological site. TCPs may be directly affected if personnel are on roads located on TCP and if personnel are unaware of cultural resource sensitivity, appropriate behaviors and protocols. For traffic on roads located on TCP, direct effects include visual, auditory and vibrational alterations to landscape/setting. Heavy equipment and drilling may cause direct effects to TCPs including destruction of culturally important plants, physical attributes of the TCP and introduction of noise and vibrations also altering the setting. These actions may interfere with traditional uses of TCP. The use of heavy, wide hoses could have direct effects to archaeological resources including artifact scattering or breakage as well as disturbance of surface sediments, if the areas have not been previously cleared. Construction of staging areas and other containment systems, and/or soil removal activities are assumed to have been cleared for cultural resources and any adverse effects would be resolved and/or mitigated. If staging areas and other containment system locations have not been reviewed for cultural resources this could result in compaction and disturbance to the soil surface and throughout the subsurface leading to permanent adverse effects to the surface and subsurface integrity of an archaeological site by destroying the stratigraphic relationships of the soil, archaeological artifacts and features as well as all proximal information associated with archaeological artifacts and features. Construction of staging areas and other containment systems, and/or soil removal activities can have direct effects to TCPs including destroying physical attributes of TCP, destruction of culturally important plants, alteration of the setting and introduction of noise and vibrations also altering the setting. These actions may interfere with traditional uses of TCP. In some instances, the waste site is considered an archaeological site and/or pockets of undisturbed soils and potentially intact archaeological material are present. In these instances, effects could include preservation of artifacts in-situ if any information had already been gleaned from archeological site testing prior to capping. Otherwise, containment systems could result in compaction and compression of artifacts by destroying the stratigraphic relationships of the soil, archaeological artifacts and features as well as all proximal information associated with archaeological artifacts and features. Direct effects to TCPs include permanent alteration of physical setting and design of TCP, permanent viewshed impacts and possibly permanent interference with traditional use of TCP. Revegetation activities may cause direct effects to TCPs including physical alteration to or restoration of TCP depending on how the area is recontoured and what plants are selected for revegetation. Contamination remaining in situ may have direct effects including permanent physical alteration of TCP, and lead to permanent intrusion in long-term use and access to TCP.

Indirect effects from personnel, truck, heavy equipment, and drill rigs may lead to the introduction of invasive plant species or removal of culturally important plants that alters the landscape/setting for roads located within the viewshed and noise-scape of TCP. New roads alter the viewshed or noise-scape. Presence of vehicles may result in visual, auditory and vibrational alterations to landscape/setting. Remediation actions may lead to visual alteration of landscape/setting. Introduction of noise alters landscape/setting. Introduction of equipment and buildings may interfere with traditional uses of TCP. During remediation activities, indirect effects could result in temporary auditory, visual and vibrational effects. Revegetation could lead to indirect effects from visual alterations to setting depending on how the area is recontoured and what plants are selected for revegetation. Remaining contamination could lead to indirect effects from permanent intrusion, which could limit the use and access to TCP.

POPULATIONS AND RESOURCES AT RISK OR POTENTIALLY IMPACTED DURING OR AS A CONSEQUENCE OF CLEANUP ACTIONS

The range of remediation alternatives for Groundwater IAs within RC-GW-3 include (i) pump and treat; (ii) remove, treat, and dispose; (iii) monitored natural attenuation (MNA); and (iv) Institutional controls (ICs) to control access to residual contaminants in soil and groundwater as long as they exceed the cleanup levels (CULs). As such, impacts from potential remediation approaches will vary, depending on the activity.

Facility Worker

Risks are thus rated as *Low to Medium*, with mitigated risk reduced to *Low*.

Co-Located Person

Risks are rated as *Low*; mitigated risk is also rated as *Low*.

Public

Risks are located as *Not Discernible* to *Low*; mitigated risk is rated as *Not Discernible*.

Groundwater

As described in Part V, some constituents may be significantly impacted by cleanup operations or radioactive decay. To summarize, the modified results for the River Corridor include:

- Hexavalent chromium (Group A) – For 100-HR-D/H it is assumed that the P&T and ISRM systems would continue to be effective resulting in *Medium* and *Low* ratings for Active and Near-term, Post-Cleanup periods, respectively (to account for inventory and treatment uncertainties and because the final ROD has yet to be signed). For 100-KR-4 it is assumed that the P&T system would continue to be effective resulting in *Medium* and *Low* ratings for Active and Near-term, Post-Cleanup periods, respectively (to account for inventory and treatment uncertainties and because the final ROD has yet to be signed).

- Sr-90 (Group B) – The maximum concentrations for OUs other than 100-KR-4 would result in a *Low* rating in the Near-term, Post-Cleanup period.
- Tritium (Group C) – In 100-KR, the tritium plume area has decreased from ~0.3 km^2 in 2003-2005 to 0.11 km^2 in 2015, with a recent dip to less than 0.1 km^2 in 2012 and 2013. (DOE/RL-2016-09, Rev. 0, p. 5-5). A continued decrease, due to radioactive decay, would reduce the plume to less than 0.1 km^2 by the end of the Active Cleanup period leading to a *Low* rating. A *Low* rating is maintained for the Near-term, Post-Cleanup period, to account for uncertainty.

Columbia River

For those contaminants currently in contact with the River, the following changes would be made to ratings (Part V):

- 100-HR-D/H: Hexavalent chromium is expected to reach the cleanup level (10 µg/L) during the Active Cleanup period (DOE/RL-2011-111, Draft A) using the P&T and ISRM systems resulting in a *Medium* rating and a corresponding *Low* rating for the Near-term, Post-Cleanup period to account for uncertainties in inventory and treatment.
- 100-KR: Hexavalent chromium is expected to reach the cleanup level (10 µg/L) over much of 100-KR during the Active Cleanup period (DOE/RL-2010-97, Draft A) resulting in a *Medium* rating and a corresponding *Low* rating for the Near-term, Post-Cleanup period to account for uncertainties in inventory and treatment.

As described in Part V, because most of the plumes (not already in contact with the River) are unlikely to contact the Columbia River over the next 150 years (unless hydrologic conditions change significantly), the ratings (primarily *ND* or *Low*) for most of the contaminants not currently in contact with the Columbia River will not be modified. However, for Sr-90 (100-FR) even though the plume moves very slowly, there is a chance that it could reach the River in the Active Cleanup period (*Low* rating) but decay would likely result in no plume (all things being equal) for a *Not Discernible* rating during the Near-term, Post-Cleanup period.

Ecological Resources

Personnel, car, pick-up truck, truck traffic as well as heavy equipment, drill rigs, and new facilities in the non-target and remediated areas will likely lead to permanent effects in areas of heavy equipment use, drill rigs and construction areas. Effects on the ecological resources are likely to include exotic/alien species, differences in native species structure, and soil invertebrate changes in areas of high activity (compaction). During remediation, radionuclides or other contaminants released or spilled on the surface could have long-term effects if the contamination remained, and plants did not recolonize or thrive. Such disruptions could affect the associated animal and plant communities.

Cultural Resources

Personnel, truck, heavy equipment, and drill rigs may have direct impact on cultural resources in the riparian areas and in upland areas where there is soil/ground or alteration to the landscape. Assuming heavy equipment locations, new roads and staging areas have been cleared for cultural resources, then it is assumed adverse effects would have been resolved and/or mitigated. If heavy equipment and drilling locations and staging areas have not been cleared, this could result in artifact breakage and scattering, compaction and disturbance to the soil surface and immediate subsurface, thereby compromising stratigraphic integrity of an archaeological site. TCPs may be directly affected if personnel are on roads located on TCP and if personnel are unaware of cultural resource sensitivity, appropriate behaviors and protocols. For traffic on roads located on TCP, direct effects include visual, auditory and vibrational alterations to landscape/setting. Heavy equipment and drilling may cause direct effects to TCPs including destruction of culturally important plants, physical attributes of the TCP and introduction of noise and vibrations also altering the setting. These actions may interfere with traditional uses of TCP. The use of heavy, wide hoses could have direct effects to archaeological resources including artifact scattering or breakage as well as disturbance of surface sediments, if the areas have not been previously cleared. Construction of staging areas and other containment systems, and/or soil removal activities are assumed to have been cleared for cultural resources and any adverse effects would be resolved and/or mitigated. If staging areas and other containment system locations have not been reviewed for cultural resources this could result in compaction and disturbance to the soil surface and throughout the subsurface leading to permanent adverse effects to the surface and subsurface integrity of an archaeological site by destroying the stratigraphic relationships of the soil, archaeological artifacts and features as well as all proximal information associated with archaeological artifacts and features. Construction of staging areas and other containment systems, and/or soil removal activities can have direct effects to TCPs including destroying physical attributes of TCP, destruction of culturally important plants, alteration of the setting and introduction of noise and vibrations also altering the setting. These actions may interfere with traditional uses of TCP. In some instances, the waste site is considered an archaeological site and/or pockets of undisturbed soils and potentially intact archaeological material are present. In these instances, effects could include preservation of artifacts in-situ if any information had already been gleaned from archeological site testing prior to capping. Otherwise, containment systems could result in compaction and compression of artifacts by destroying the stratigraphic relationships of the soil, archaeological artifacts and features as well as all proximal information associated with archaeological artifacts and features. Direct effects to TCPs include permanent alteration of physical setting and design of TCP, permanent viewshed impacts and possibly permanent interference with traditional use of TCP. Revegetation activities may cause direct effects to TCPs including physical alteration to or restoration of TCP depending on how the area is recontoured and what plants are selected for revegetation. Contamination remaining in situ may have direct effects including permanent physical alteration of TCP, and lead to permanent intrusion in long-term use and access to TCP.

Indirect effects from personnel, truck, heavy equipment, and drill rigs may lead to the introduction of invasive plant species or removal of culturally important plants that alters the landscape/setting for roads located within the viewshed and noise-scape of TCP. New roads alter the viewshed or noise-scape. Presence of vehicles may result in visual, auditory and vibrational alterations to landscape/setting. Remediation actions may lead to visual alteration of landscape/setting. Introduction of noise alters landscape/setting. Introduction of equipment and buildings may interfere with traditional uses of TCP. During remediation activities, indirect effects could result in temporary auditory, visual and vibrational effects. Revegetation could lead to indirect effects from visual alterations to setting depending on how the area is recontoured and what plants are selected for revegetation. Remaining contamination could lead to indirect effects from permanent intrusion, which could limit the use and access to TCP.

Additional Risks and Potential Impacts if Cleanup is Delayed

The CP-GW-1 EU CERCLA Groundwater Operable Units (OUs), 100-BC-5, 100-FR-3, 100-HR-3, and 100-KR-4, have each undergone extensive characterization, assessment, and remediation. By the end of 2015, 92 percent of the potential waste sites in the River Corridor had been remediated or were classified as not needing remediation under interim Records of Decision (RODs), as compared to 89 percent in 2014 and 74 percent in 2012. Cleanup of the remaining sites is underway. Based on remedy performance monitoring and the reduction in length of shoreline impacted by contaminant plumes, groundwater remediation systems in 100-HR, 100-KR, and 100-NR are reducing the amount of contamination entering the Columbia River. Delaying planned new actions or halting current active remedial actions could result in increased contaminant release to the Columbia River. Summarized below are brief descriptions of remedial actions completed to date (DOE/RL-2016-09 Revision 0).

- ***100-BC***. DOE has completed remediation of 100-BC waste sites covered by an interim action ROD. The last remedial action in the area included a very large soil excavation down to the water table (~24 m), backfilling with native soil and revegetation.
- ***100-FR****.* EPA signed a CERCLA ROD in September 2014 (EPA 2014). The selected remedy for groundwater is MNA. Groundwater contaminants are present at relatively low concentrations and do not appear to be impacting the river.
- ***100-HR***. Two P&T systems continued to operate under an interim action ROD8 to remove Cr(VI) from groundwater. In 2015, 2.6 billion L (688 million gal) of groundwater were pumped from 80 extraction wells. Since 1997, the P&T systems have removed 2,364 kg of Cr(VI). The overall areal extent of the plumes and the length of affected shoreline have declined between 1999 and 2015 (Figure ES-8). The changes are a result of groundwater contaminant removal, remediation of sources, hydraulic control, and natural processes. For 100-HR, at the end of 2015, 97 percent of the waste sites were classified as closed, interim closed, final closed, no action, not accepted, or rejected. The final 3 percent of the waste sites will be remediated under a ROD for final action.
- **100-KR**. Three P&T systems continued to operate in 100-KR, removing Cr(VI) from groundwater. In 2015, over 2.89 billion L (764 million gal) of groundwater were pumped from 42 extraction wells. A total of 836 kg of Cr(VI) have been removed from 100-KR groundwater to date. The Cr(VI) plume area (greater than 20 µg/L) was estimated to be 0.59 km2 (0.23 mi2) in 2015, a decrease of 29 percent from 2014. Since 2007, the plume area above 20 µg/L has decreased by 70 percent, and the length of shoreline that the plume intersects has decreased from 2,200 m (7,200 ft) to less than 100 m (330 ft). At the end of 2015, 51 percent of the waste sites were classified as closed, interim closed, no action, or not accepted or rejected, with 33 percent having undergone active remediation. Removing contaminants from the vadose zone eliminates secondary sources of contamination that could migrate to groundwater and reduces the risk of direct exposure at the surface.

Near-Term, Post-Cleanup Status, Risks and Potential Impacts

Please see Part V for a discussion of the impact of cleanup, recharge, and decay on groundwater and Columbia River ratings in the Near-term, Post-Cleanup period. For potential impacts to groundwater, the ratings for the four 100 Area OUs tend to be either *ND* to *Low* to reflect presumed treatment effectiveness. An exception is hexavalent chromium in 100-BC (with *Medium* rating) indicating no selected final remedial actions and inventories that might translate to appreciable plumes in this evaluation period.

For the ratings related to threats to the Columbia River, the hexavalent chromium in 100-BC has a rating (*Medium*) in this period above an *ND* or *Low* indicating again that monitoring and treatment are needed.

Populations and Resources at Risk or Potentially Impacted After Cleanup Actions (from residual contaminant inventory or long-term activities)

Table D.4-4. Summary of Populations and Resources at Risk or Potentially Impacted after Cleanup

Population or Resource		Risk/Impact Rating	Comments
Human	Facility Worker	Low (Low)	Only workers at risk or impacted would be working on monitoring and sampling.
	Co-located Person	Low to Not Discernible (Not Discernible)	Following completion of active cleanup activities, groundwater concentrations should be below AWQS.
	Public	Not Discernible (Not Discernible)	Following completion of active cleanup activities, groundwater concentrations should be below AWQS.
Environmental	Groundwater	100-BC IA: Medium (Cr-VI) 100-HR-D/H IA: Low (Cr-VI) 100-FR IA: Medium (NO3) 100-KR IA: Medium (H-3) Overall: Medium (Cr-VI, NO3, H-3)	As discussed in Part V, Cr-VI drives the risk in 100-BC (no final treatment selected). Treatment continuing in 100-HR and 100-KR. For 100-FR, nitrate (Group C) drives risk (no treatment).
	Columbia River	Benthic/Riparian: 100-BC: Medium (Cr-VI) 100-HR-D/H: Low (Cr-VI, NO3) 100-FR: Low (Cr-VI, NO3) 100-KR: Low (Cr-VI, Sr-90) Free-flowing: All OUs: Not Discernible **Overall**: Medium (Cr-VI)	As discussed in Part V, Cr-VI drives the risk in 100-BC (no final treatment selected). Treatment continuing in 100-HR-D/H and 100-KR. For 100-FR, Cr-VI drives some risk (no treatment).
	Ecological Resources[a]	Low	Contamination remaining in areas for monitored natural attenuation may still result in uptake in biota, but is not likely to cause an effect to the biota. Continued long-term monitoring activities may disrupt riparian and terrestrial habitats. Re-vegetation in EU will result in additional level 3 resources, and potentially creation of level 4 resources potentially at risk because of disturbance, especially from invasive species.

Population or Resource		**Risk/Impact Rating**	**Comments**
Social	Cultural Resources[a]	**Native American:** Direct: Known Indirect: Known **Historic Pre-Hanford:** Direct: Known Indirect: Known **Manhattan/Cold War**: Direct: Unknown Indirect: Unknown	Permanent direct and indirect effects are possible due to high sensitivity of area.

a. For both Ecological and Cultural Resources see Appendices J and K, respectively, for a complete description of Ecological Field Assessments and literature review for Cultural Resources. Ecological ratings are described in Table 4-11 of the Final Report.

LONG-TERM, POST-CLEANUP STATUS – INVENTORIES AND RISKS AND POTENTIAL IMPACT PATHWAYS

Because final remedial actions have not been selected for the 100-BC and 100-FR Groundwater Operable Units, the ratings (*Medium* for threats to groundwater and the Columbia River) indicate the need for monitoring and treatment of groundwater in these areas.

PART VII. SUPPLEMENTAL INFORMATION AND CONSIDERATIONS

The 100-B/D/H/F/K Area needs to remain under DOE control to maintain institutional control for all remediation activities until all soil and groundwater contaminants reach CULs, to include areas outside 100-B/D/H/F/K which have the potential to also contaminant groundwater in this area.

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