# River Corridor Introduction

## River Corridor Overview

The Columbia River flows through the northern Hanford Site before turning south toward the city of Richland. The region of the Site along the shoreline is known as the Hanford River Corridor. The River Corridor consists of six former reactor areas (100-BC, 100-KR, 100-N, 100-D, 100-H, and 100-F, fabrication of nuclear fuel assemblies (300 Area), research involving the processing of irradiated fuel (300 Area), and maintenance service areas (1100 Area) (Map RC.1).

Between 1943 and 1963, nine plutonium production reactors were built along the Columbia River in six areas: the 100-B, 100-K, 100-N, 100-D, 100-H, and 100-F Areas. The 100-B Reactor was constructed first, followed in chronological order by 100-D, 100-F, 100-H, 100-DR (built as a replacement for 100-D), 100-C, 100-KE and 100-KW, and 100-N Reactors. Only the N Reactor was constructed with a closed loop coolant circuit, and a secondary use of steam production for power generation at the Hanford Generating Plant. Production of special nuclear materials (principally Pu-239 and tritium) was the primary function of the reactors. All reactors have been retired from service (DOE/RL-2008-46, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan*). Liquid and solid wastes discharged during the reactor operational periods were the primary contaminant sources in the reactor areas.

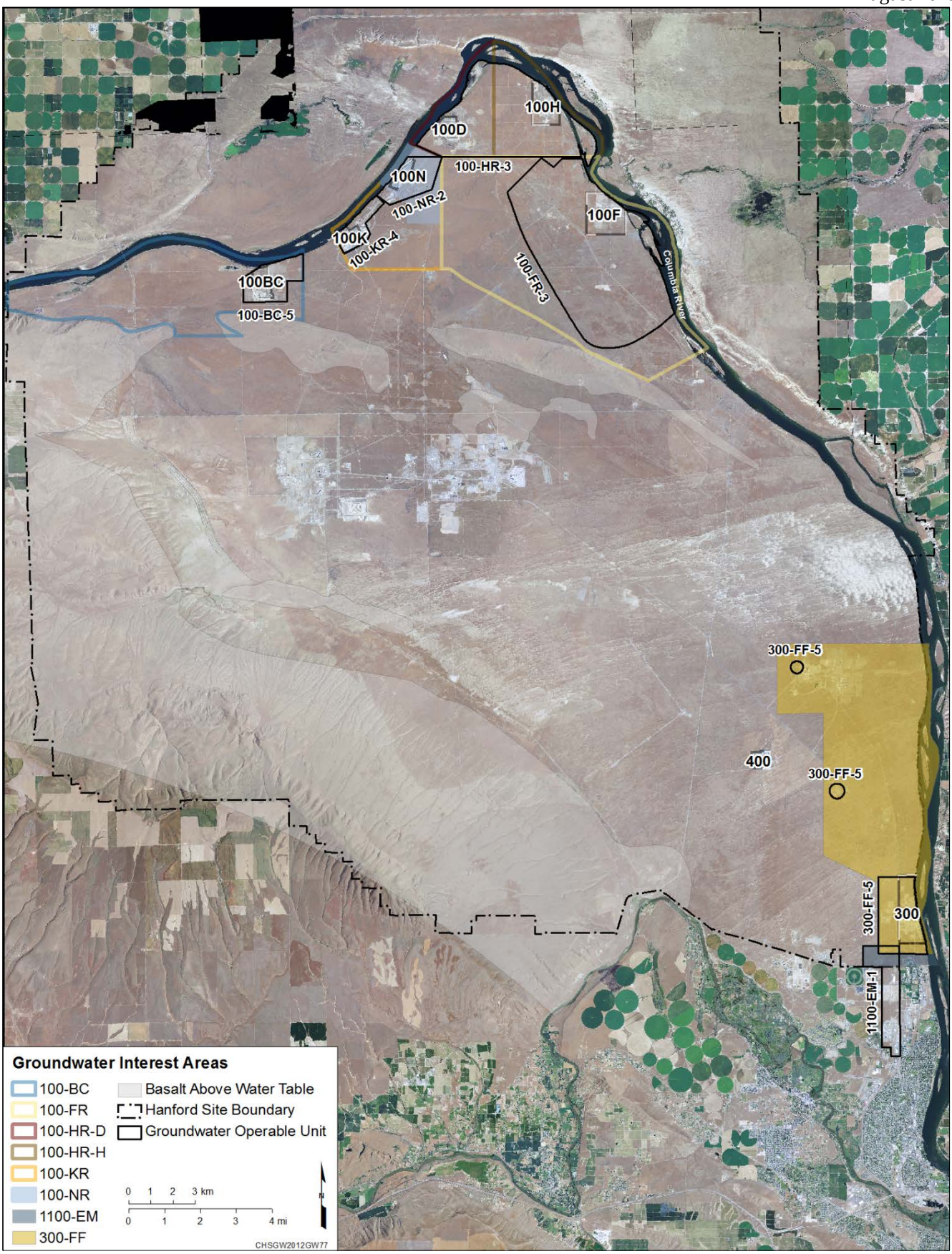
Contaminant sources in the 100 Areas included cooling water conditioning and handling facilities, underground piping, liquid and solid waste disposal sites, and unplanned releases (surface spills). Sources of groundwater contamination in the 300 Area included routine disposal of liquid effluent associated with fabrication of nuclear fuel assemblies, and research involving the processing of irradiated fuel. The liquid waste was discharged to ponds and trenches designed for infiltration to the underlying soil. Periodic spills and accidental releases from various facilities also occurred. Nearly all of the principal liquid waste disposal facilities have been remediated, with excavations at some waste sites (such as 100-C-7, 100-B-27, 100-D-100, and 100-H-46) extending to groundwater. Six groundwater operable units (OUs) and 15 source OUs are associated with the River Corridor (Table RC.1). Groundwater OUs are associated with informally defined groundwater interest areas that cover the entire Hanford Site.

The following major groundwater contaminants are present in the River Corridor:

- Hexavalent chromium concentrations exceed the 10 µg/L surface water quality standard in the unconfined aquifer in each of the 100 Areas, in a confined aquifer in 100-HR-3, and in one confined well in 100-NR-2.
- Nitrate concentrations exceed the 45 mg/L drinking water standard in monitoring wells in all of the 100 Areas except 100-BC-5. A nitrate plume from agricultural sources south of the Hanford Site affects groundwater in 1100-EM-1. Nitrate concentrations in this document are expressed as the $NO_3^-$ ion. The federal and state drinking water standard for nitrate is 10 mg/L expressed as $NO_3$-N; this relates to the actual nitrogen in nitrate. Converting $NO_3$-N values to nitrate as the $NO_3^-$ ion requires the $NO_3$-N value to be multiplied by 4.43. Nitrate data provided in this report reflect the converted values and, as such, the drinking water standard appears as 45 mg/L in figures and tables. Similarly, nitrite is expressed as the $NO_2^-$ ion.
- Strontium-90 concentrations exceed the 8 pCi/L drinking water standard in all of the 100 Areas.
- Tritium concentrations exceed the 20,000 pCi/L drinking water standard in 100-BC-5, 100-KR-4, 100-NR-2, and an outlying region of 300-FF-5.
- Trichloroethene concentrations exceed the 5 µg/L drinking water standard in 100-FR-3 and 100-KR-4 and within a deeper, finer-grained sedimentary unit at 300-FF-5.
- Other contaminants include uranium in 100-HR-3 and 300-FF-5, carbon-14 in 100-KR-4, and petroleum hydrocarbons in 100-NR-2.

Liquid and solid wastes discharged during the reactor operational periods were the primary contaminant sources in the reactor areas. Contaminant sources in the 100 Areas included cooling water conditioning and handling facilities, underground piping, liquid and solid waste disposal sites, and unplanned releases.

Low mobility contaminants, including many metals and radionuclides, sorbed to sediment grains in the vadose zone. These contaminants were found at the greatest concentrations within and near the areas of discharge. When little or no liquid effluent was discharged to a waste site, soil contamination remained in the shallow sediment. Disposal of high volumes of contaminated liquid waste resulted in dispersion of low mobility contaminants deeper in the vadose zone in comparison to low-volume discharge sites.




**Map RC.1 River Corridor Overview**

**Table RC.1 River Corridor at a Glance**

| A total of 82 kilometers of Columbia River shoreline<br>River stage controlled by Priest Rapids Dam<br>Hanford Reach National Monument established in 2000 | | |
|---|---|---|
| **100 Area** | **300 Area and Outlying Regions** | **Former 1100 Area** |
| Five groundwater operable units: 100-BC-5, 100-KR-4, 100-NR-2, 100-HR-3[a], 100-FR-3 | One groundwater operable unit: 300-FF-5 (includes 300 Area Industrial Complex, 618-10/316-4 and 618-11 facilities) | One former groundwater operable unit: 1100-EM-1 |
| Nine nuclear reactors and associated facilities | Historically used for nuclear fuel fabrication | Historically used for vehicle maintenance and solid waste disposal |
| Inactive liquid waste cribs, ditches, trenches, retention basins, pipelines, and spills; four RCRA sites | Inactive liquid waste cribs, trenches, ponds, pipelines, and spills; one RCRA site | Former waste sites remediated |
| Interim site remediation 75% complete overall[b] | Interim site remediation > 85% complete overall[b] | Final waste site remediation 100% complete |
| Interim groundwater remediation active for hexavalent chromium in 100-KR-4 and 100-HR-3, and strontium-90 and petroleum hydrocarbons in 100-NR-2 | Monitored natural attenuation of uranium, organics, and tritium | Final groundwater remediation complete |
| RI/FS underway | RI/FS underway | Final ROD in place |

a. The 100-HR-3 Operable Unit includes the 100-D and 100-H Areas.
b. Percent of sites that have been remediated or classified as not requiring remediation.

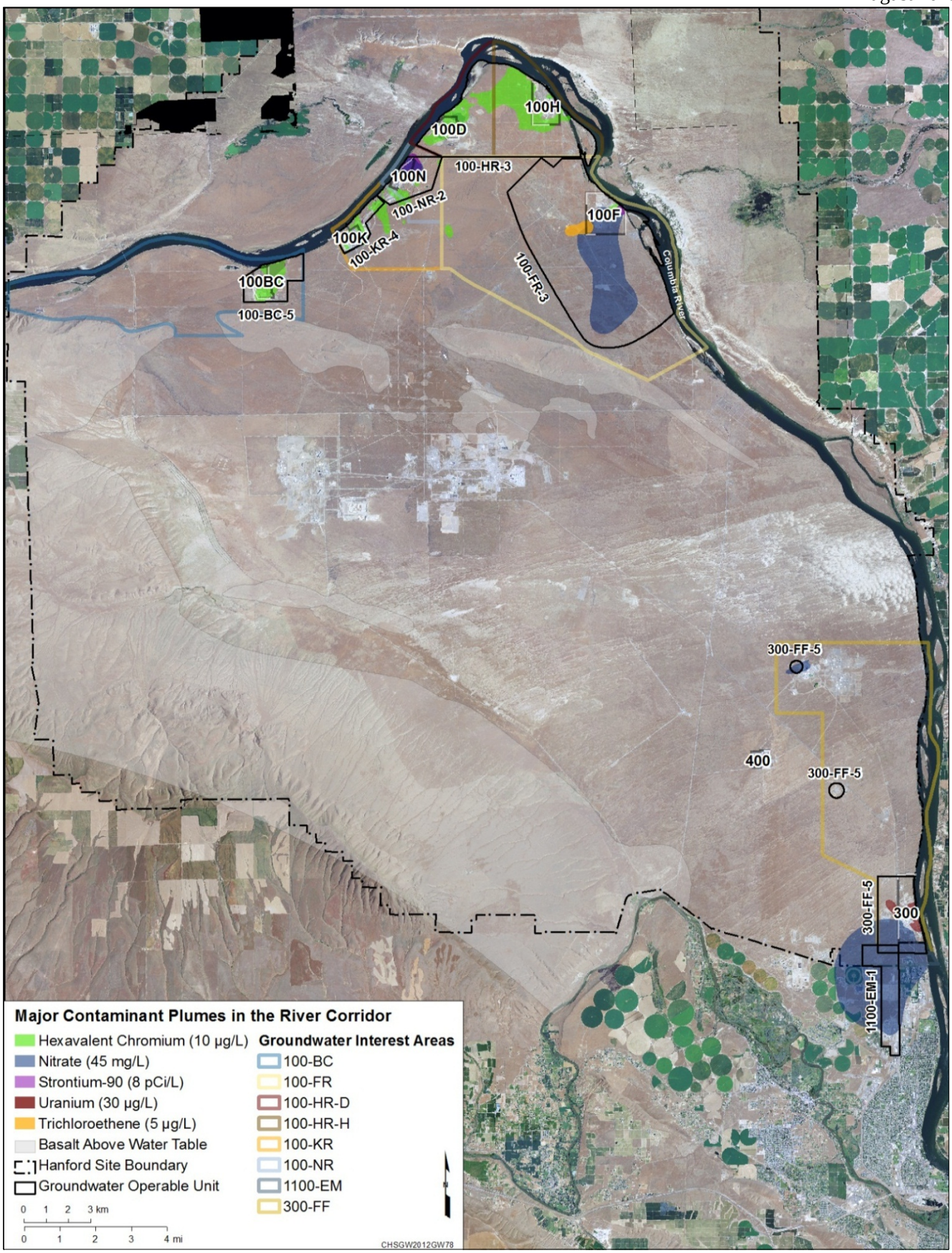
Strontium-90 is a slightly mobile contaminant in the subsurface and tends to sorb to soil. It was present in numerous 100 Area waste sites, including burial grounds and liquid waste sites, principally from decontamination solutions and contaminated reactor coolant or fuel storage basin water. Strontium-90 migrated through the vadose zone beneath some liquid waste disposal sites and moved a limited distance vertically and horizontally in groundwater.

Mobile and moderately mobile contaminants common to the 100 Area include tritium, nitrate, and hexavalent chromium (Map RC.2). Large volumes of water containing these contaminants were discharged to the soil via trenches, cribs, and leaks from pipelines and retention basins. Wastewater was also released through outfall piping to the Columbia River. Large groundwater mounds developed beneath high-volume surface discharge sites and helped spread mobile contaminants in groundwater in a radial pattern during operations.

Sodium dichromate was added to reactor cooling water as an anti-corrosion agent. Typical sodium dichromate concentrations in the cooling water during the early years of reactor operations were 2,000 µg/L (~700 µg/L as hexavalent chromium). They decreased to 1,000 µg/L in the mid-1960s, and then 500 µg/L (~170 µg/L as hexavalent chromium) in the last stages of operations.

Historical process information suggests that small volumes of high-concentration solutions (up to 70 percent by weight) of sodium dichromate leaked or spilled in the 100 Areas (for example, during the transfer of sodium dichromate from rail cars to storage tanks). In some locations in the 100-D and 100-K Areas, concentrations of hexavalent chromium in groundwater exceed the concentrations found in reactor cooling water, indicating a high-concentration source. Residuals from the high-concentration sodium dichromate solutions may remain in the vadose zone at some locations and provide a secondary source of groundwater contamination until remediation is completed. Remedial actions have included excavation of contaminated soil. Some of these excavations have extended to groundwater (e.g., 100-C-7:1).

The 1100-EM groundwater interest area encompasses a variety of onsite and neighboring offsite land uses. Numerous municipal, industrial, and agricultural activities may affect groundwater quality in this area. The areas that make up the Hanford Site's former 1100 Area have been converted to a variety of uses, including commercial activities, manufacturing, and equipment storage




**Map RC.2 River Corridor Plumes**

## River Corridor – Hydrogeology

The geologic units beneath the River Corridor are a subset of those that underlie the Hanford Site as a whole. The stratigraphy of the 100 Area is distinct from that of the 300 and 1100 Areas.

Figure RC.1 illustrates the general stratigraphy and hydrogeologic units of the 100 Area. The vadose zone comprises the sand and gravel of the Hanford formation and, in some locations, a portion of the Ringold Formation unit E. The vadose zone can be less than a meter thick near the Columbia River to as much as 30 meters beneath inland portions of the River Corridor.

The unconfined aquifer consists of the sand and gravel of Ringold unit E in the western 100 Areas and the Hanford formation in 100-H and 100-F. In 100-BC, the upper part of the aquifer is in the Hanford formation. This unconfined aquifer is thickest in the western portion of the region (up to 48 meters in 100-BC) and thinnest near 100-H and 100-F, where in some places it is less than 2 meters thick. The base of the unconfined aquifer is one of a number of fine-grained units of the Ringold Formation informally known as the Ringold upper mud unit. Below the contact with the unconfined aquifer, the unit contains numerous distinct layers of sand and gravel. These layers typically contain water and act as local confined aquifers. A series of confined aquifers within and beneath the upper mud are present through most of the 100 Areas. Basalt aquitards and basalt-confined aquifers are present beneath the Ringold Formation. Few wells are screened in the deeper units.

Beneath the 300 Area and 1100-EM-1, the vadose zone is entirely within the gravel and sand of the Hanford formation. The unconfined aquifer includes the lower portion of the Hanford formation. Beneath the 300 Area, the undulating contact between the bottom of the saturated Hanford formation and the underlying Ringold unit E sediment reveals paleochannels that act as preferential pathways for groundwater flow. Saturated Hanford formation sediment is much more permeable than the underlying Ringold sediment. The Ringold lower mud unit underlies unit E. Coarse-grained sediments of Ringold unit A underlie the lower mud in some areas; elsewhere, the mud overlies basalt.

As shown on Map RC.3, groundwater in the unconfined aquifer generally flows from upland areas in the west toward the regional discharge area north and east along the Columbia River, which forms a groundwater discharge boundary. Steep hydraulic gradients occur in the western, eastern, and northern regions of the Site. Shallow gradients occur southeast of 100-F and in a broad arc extending from west of 100-BC toward the southeast between Gable Butte and Gable Mountain (Gable Gap), through the 200 East Area and into the central portion of the Site. In each of the 100 Areas, the local groundwater flow is generally toward the Columbia River; although, groundwater pump-and-treat systems in 100-KR-4 and 100-HR-3 alter this flow pattern locally.

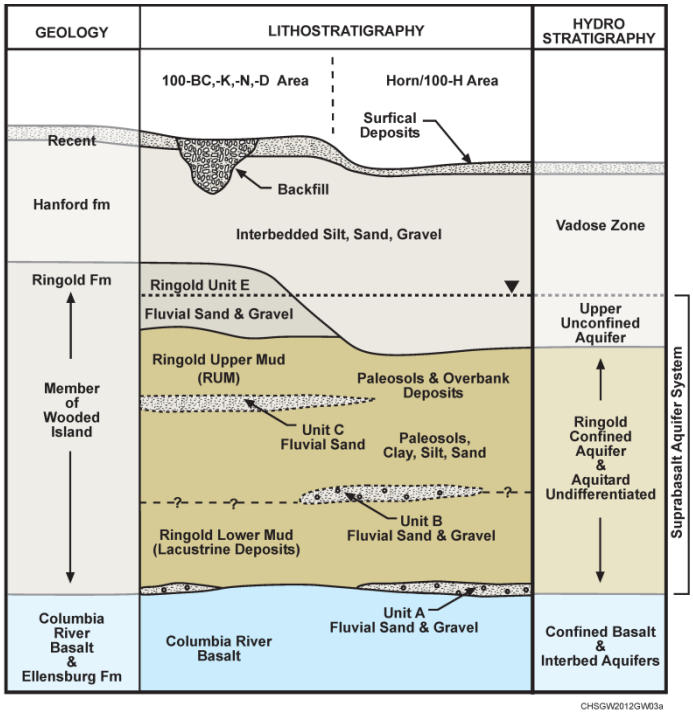
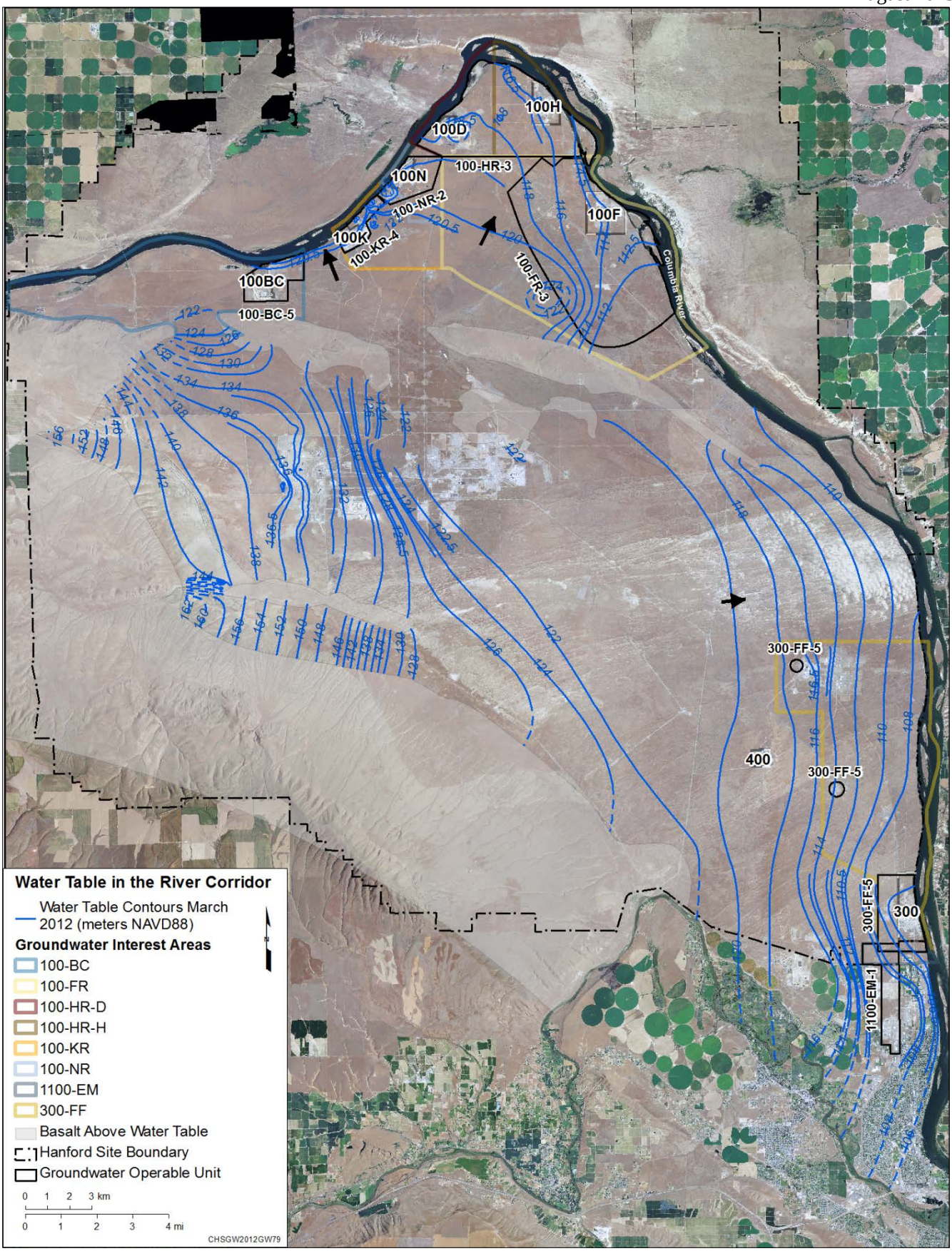



**Figure RC.1 River Corridor Geology**




**Map RC.3 River Corridor Groundwater Flow**

Daily, monthly, and seasonal changes in the Columbia River stage affect the flow of groundwater in the near-river environment. During periods of high river stage, the Columbia River temporarily recharges the adjacent aquifer all along the river (bank storage effects); whereas, during periods of low or moderate river stage, groundwater discharges from the aquifer to the river.

The stage of the Columbia River varies over time on short (e.g., hourly) and long (e.g., seasonally) intervals in response to natural influences plus the operation of Priest Rapids Dam. Both groundwater level and groundwater sample data obtained from wells located on the Hanford Site exhibit time-varying patterns that are qualitatively similar in frequency to variations Columbia River stage, suggesting that changes in the stage of the Columbia River affect both water levels and sampled concentrations for several contaminants of interest (COIs) and indicator parameters. These relationships are most evident in wells that are located closest to the Columbia River; although, apparent relationships are also evident in water levels and sample data obtained from wells hundreds of meters inland of the shoreline.

Groundwater level responses to cyclical river stage fluctuations increasingly attenuate in amplitude and lag in time with increasing distance to the river (Figure RC.2). This attenuation in amplitude and time lag can be used to estimate aquifer parameters or can be incorporated within trend analyses of water level data and sampled concentrations. Additional details are provided in ECF-Hanford-12-0076, *Evaluation of the Relationship Between River Stage and Sampled Value for Several Analytes in the Hanford 100 Areas*.

With some exceptions and with some variability, the following broad patterns emerge:

- Locations at 100-D, 100-N, and 100-K generally exhibit the longest lag times per unit distance.
- Locations in the 300 and 100-EM areas generally exhibit the shortest lag times per unit distance.
- Locations at 100-BC, 100-F, and 100-H generally exhibit intermediate lag times per unit distance.

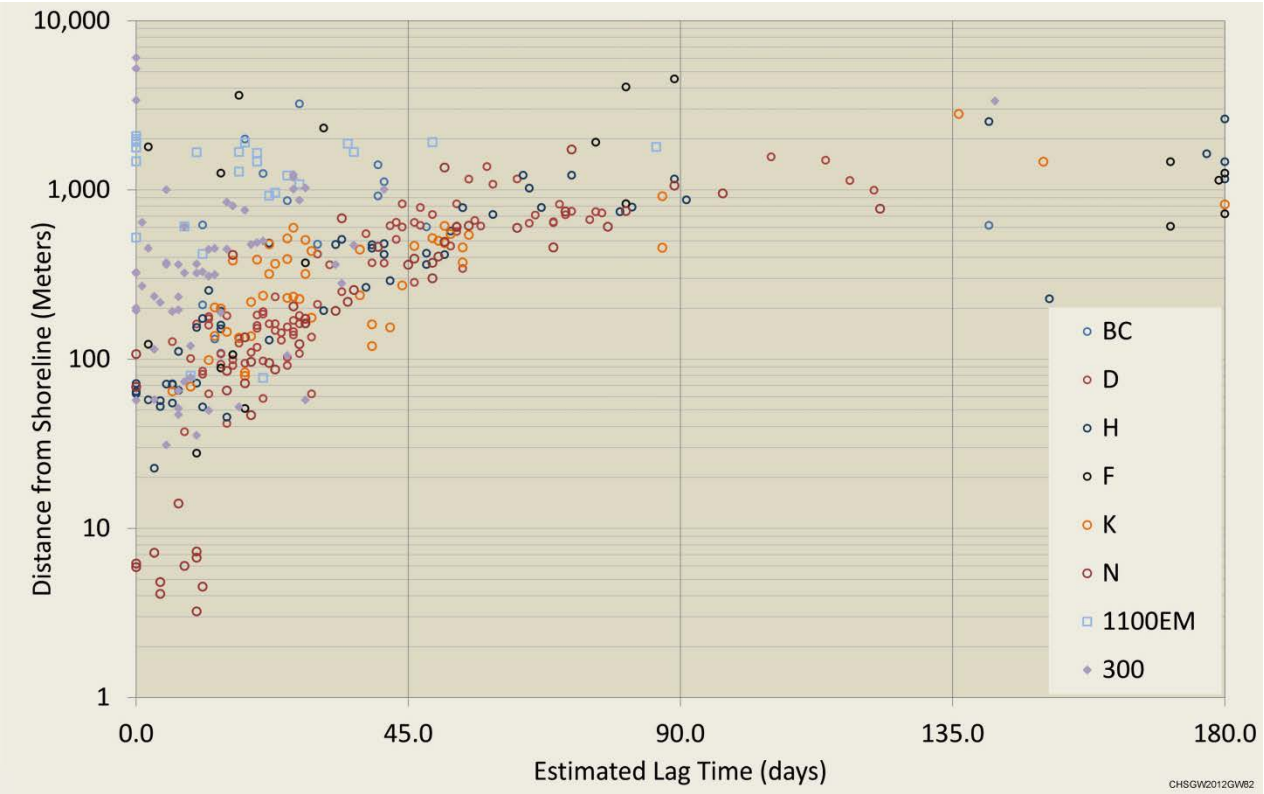



**Figure RC.2 Relation of Lag Time to Distance from the River**

## River Corridor – Clean Up

The only groundwater OU in the River Corridor, for which final cleanup decisions have been made, is 1100-EM-1. The 1100-EM-1 OU was removed from the National Priorities List (40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," Appendix B, "National Priorities List") in 1996. The selected remedy for groundwater was monitored natural attenuation of volatile organic compounds with continuation of institutional controls for groundwater and land use at the Horn Rapids Landfill (EPA/ROD/R10-93/063, *Declaration of the Record of Decision for the USDOE Hanford 1100 Area*).

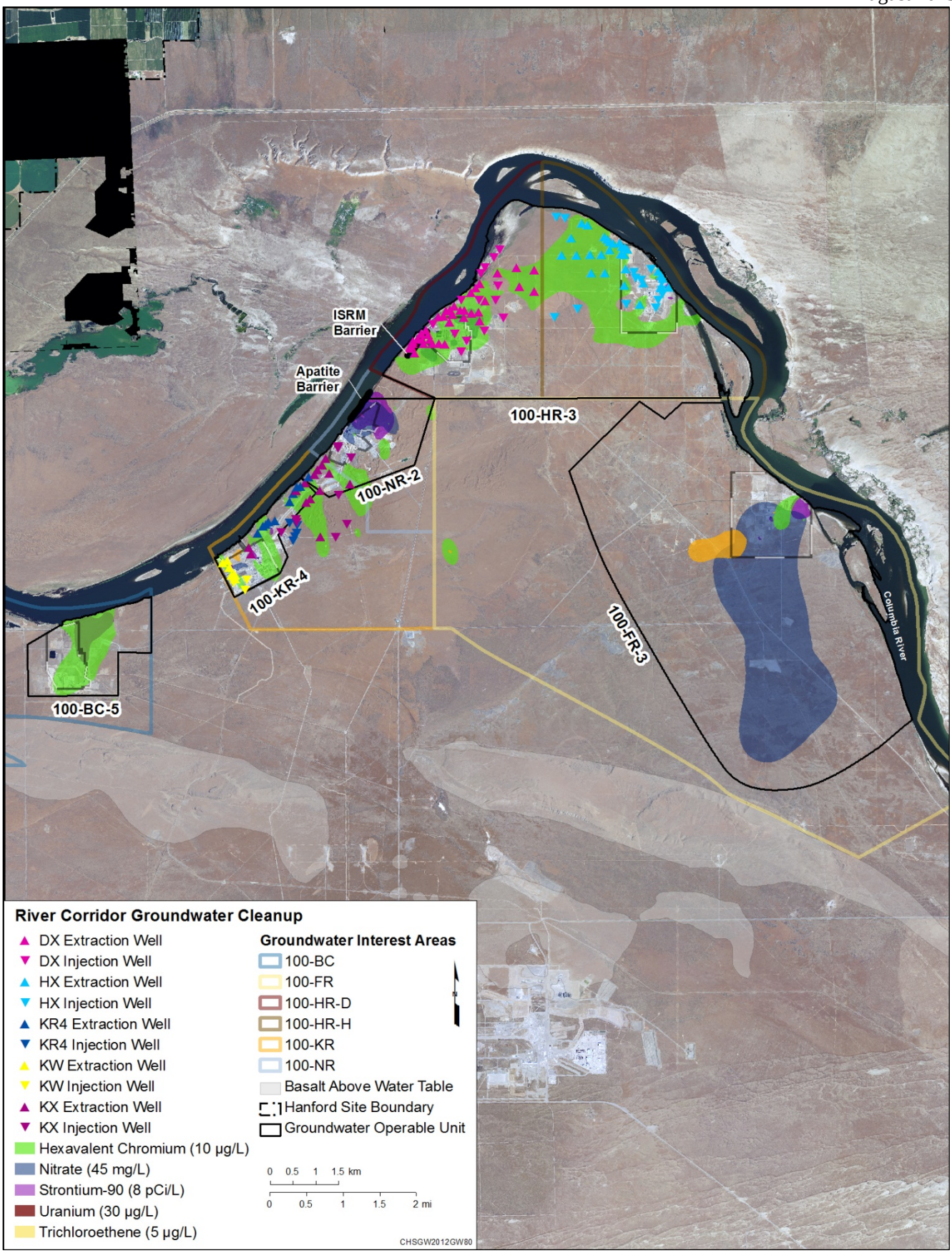
In the early 1990s, the U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), and Washington State Department of Ecology (Ecology) decided that sufficient information about contaminated soil and groundwater in the Hanford Site River Corridor was available to begin interim remediation with a focus on protecting the Columbia River. This decision led to an early start for cleanup of contaminated soil and groundwater in the River Corridor. Key components of the early cleanup included removing contaminated facilities and soil (waste sites) near the river, and implementing interim cleanup actions in the 100-KR-4, 100-NR-2, and 100-HR-3 OUs (Map RC.4). Interim remedial actions in 100-KR-4 and 100-HR-3 focus on hexavalent chromium, and the interim action for 100-NR-2 focuses on strontium-90. The goal of the interim groundwater remediation is to prevent or reduce the movement of contaminated groundwater into the Columbia River.

Groundwater cleanup under interim action records of decision (RODs) continued in 2012, with expanded pump-and-treat systems at 100-HR-3. The goal of the interim groundwater remediation is to prevent or reduce the movement of contaminated groundwater into the Columbia River. As defined in the current interim action RODs, the remedial action goal for hexavalent chromium is 20 µg/L in compliance wells. The surface water quality standard is 10 µg/L. The remedial action goal is based on the estimated 1:1 mixing of groundwater (and the associated hexavalent chromium) with infiltrated river water before the water is accessible to aquatic life in the river.

With respect to source remediation, DOE has evaluated approximately 1,800 potential waste sites in the River Corridor. During these evaluations, many of the sites were determined not to be waste sites (classified as "rejected" or "not accepted"). Others were determined to be low-risk sites that did not require remediation (classified as "no action"). Hundreds more sites have undergone remediation under interim action RODs. Interim remediation is nearly finished in 100-BC and 100-F and is under way at the other River Corridor OUs. By the end of 2012, approximately 75 percent of the sites in the River Corridor had been remediated or classified as not requiring remediation.

In 2012, progress toward final cleanup decisions along the river corridor continued. Final decisions for each of the River Corridor sites will develop remedial alternatives that protect human health and the environment. *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan* (DOE/RL-2008-46) summarized how cleanup of the River Corridor is managed. From 2009 through 2011, DOE issued a series of addenda and sampling and analysis plans for each of the River Corridor units and conducted CERCLA investigations. Tri-Party Agreement (Ecology et al., 1989) Milestone M-015-00D required completion of the remedial investigation (RI)/feasibility study (FS) process through submittal of RI/FS reports and proposed plans for all of the River Corridor OUs. In 2011 and 2012, DOE submitted draft RI/FS documents for 100-K, 100-D/H, 100-F/IU, and the 300 Area to regulatory agencies for review. Documents for 100-N will be submitted in 2013.

In 2012, DOE submitted a draft Tri-Party Agreement (Ecology et al., 1989) Change Control Form (M-15-12-03, *Add six new interim milestones and delete two target dates for River Corridor Decision Documents, and revise interim milestone M-015-00DD*) to Ecology and EPA. The change, which was approved in April 2013, replaces the original milestone with six new interim milestones, postponing the 100-N documents until 2013 and requiring additional studies at 100-BC.




**Map RC.4 River Corridor Groundwater Cleanup**

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