CRESP

Consortium For Risk Evaluation with Stakeholder Participation

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HANFORD SITE-WIDE RISK REVIEW PROJECT

INTERIM PROGRESS REPORT

REVISION 0

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Acknowledgements and Disclaimer

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Executive Summary

PROJECT GOAL

In January 2014, the Department of Energy (DOE) asked the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) to conduct an independent Hanford Site-wide evaluation of human health, nuclear safety, environmental and cultural resource risks (hereinafter referred to as the "Risk Review Project") associated with existing hazards, environmental contamination and remaining cleanup activities. The overarching goal of the Risk Review Project is to carry out a screening process for risks and impacts to human health and resources.[7] The results of the Risk Review Project are intended to provide the DOE, regulators, Tribal Nations and the public with a more comprehensive understanding of the remaining cleanup at the Hanford Site to help inform (1) decisions on sequencing of future cleanup activities, and (2) selection, planning and execution of specific cleanup actions, including which areas at the Hanford Site should be addressed earlier for additional characterization, analysis, and remediation[8].

BACKGROUND

Hanford Site is located along the Columbia River in Southeast Washington and is comprised of an area 586 square-miles (half the size of the State of Rhode Island). For over 40 years, the Site played a major role in the development and production of plutonium and other defense materials as part of the Manhattan Project during World War II and afterwards during the Cold War.

In 1989, Hanford's mission shifted from supporting weapons development to environmental cleanup of facilities, soil, and groundwater. Today, Hanford Site consists of waste management and former production areas, active and closed research facilities, waste storage and disposal sites, and huge swaths of natural resources and habitat. A map (Figure ES-1) showing Hanford Site may be found at the end of the Executive Summary. Cleanup at the Site has proven to be more costly, has taken longer, and is more technically challenging than expected when cleanup began. DOE's near term vision calls for reduction of the active cleanup footprint to 75 square miles in the center of the Site, reducing overhead costs, and shifting resources that would allow full scale cleanup of the Central Plateau. To date, considerable progress has been made in achieving this vision. For example, hazards near the Columbia River have been eliminated by completing cleanup of most of the River Corridor and treating contaminated groundwater near the Columbia River. While significant cleanup progress has been achieved, more than $100 billion are expected to be spent on cleanup at Hanford during the next 50 years.

OVERVIEW

Approximately 60 units, referred to as "evaluation units" (EUs) and composed primarily of geographically co-located areas of existing facilities, waste storage and environmental contamination, are to be evaluated and rated during the execution of the Risk Review Project. These units consist of remaining cleanup sites at Hanford Site as of October 1, 2015. The Risk Review Project will also provide a description of the remaining inventories of radionuclides and chemicals, including their forms, spatial

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[7] In this Risk Review Project, human health and resources evaluated include groundwater and the Columbia River, facility workers, co-located people, the public, and ecological and cultural resources. Collectively, humans and these resources also are referred to as "receptors".

[8] Additionally, while earlier studies have evaluated portions of the Hanford Site, there has never been a comprehensive, site-wide review of the risks to human health and resources from contamination, waste management, and cleanup activities.

distribution and barriers to future environmental contamination at the Hanford Site at the conclusion of cleanup based on current agreements and decisions. For example, several decisions have been made that necessitate that some areas of the Hanford Site will be dedicated to long-term waste management.

This interim progress report presents both the results for the first set of 25 EUs and the interim observations from the Risk Review Project to date.

For this report, the most recent, available information about hazards (i.e., contaminant inventories, physical chemical forms) and existing environmental contamination within each of the 25 EUs being reviewed has been gathered, described, and analyzed. At certain points in time and under various circumstances, such as facility degradation, seismic activity, accidents or fire, the identified hazards and environmental contamination may lead to the movement of radionuclides and chemical contaminants along multiple pathways, thereby potentially creating exposure or impact (referred to as "risk") to human health and resources. This is the "risk" that is to be evaluated and rated for the Risk Review Project, which is discussed in this report.

The screening process used, along with uncertainties and information gaps, necessarily focus the evaluation on order of magnitude factors that distinguish risks between EUs and receptors. Risks are considered in the context of each EU's current status, during cleanup activities and after cleanup activities. This includes taking account of current barriers to dispersion of contaminants, including engineered systems, natural systems and institutional controls, the mechanisms of barrier failures, and the likelihood and magnitude of adverse consequences to receptors. A map (Figure ES-1) showing the locations at Hanford Site of all EUs evaluated except groundwater EUs for this interim progress report may be found at the end of the Executive Summary; a separate map (Figure ES-2) provides an overview of the existing groundwater contamination and groundwater EUs.

WHAT THE PROJECT IS AND IS NOT

DOE, the State of Washington, and the Environmental Protection Agency (EPA) clearly recognize that the Risk Review Project results, including evaluations of hazards, current environmental contamination, and risks, are only one of many inputs to prioritization of future cleanup activities at Hanford.

The Risk Review Project focuses on risk characterization based on analysis and integration of existing information. Risk characterization is a necessary predecessor to risk management, but does ***not*** dictate risk management decisions. This review does not provide a rank ordered priority list of cleanup actions but rather provides groupings of relative risk (e.g., "high", "medium", etc.). The development of a prioritized list of future actions is the sole purview of DOE and its regulators, with consideration of many additional factors. Instead, the Risk Review Project is limited to considering a plausible range of current and future cleanup actions for different types of contaminant sources to better understand the range of potential risks and impacts to receptors that those cleanup actions may cause.

It is also important to be clear what the Risk Review Project is not. The Risk Review Project is neither intended to be a substitute for, nor preempt, any requirement imposed under applicable federal or state laws or treaties. As important, the Risk Review Project is not intended to make or replace any decisions made under the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) and/or 2010 Consent Order, or amendments. Furthermore, the Risk Review Project is neither a CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act) risk assessment nor a Natural Resources Damage Assessment evaluation. The Risk Review Project is not intended to interpret treaty rights that exist between the United States and Native American Tribes.

APPROACH USED

The Risk Review Project is led by a team of CRESP researchers in regular dialogue with a Core Team, comprised of senior management from DOE, EPA and the State of Washington Departments of Ecology and Health, which provides advice and guidance on the development and execution of the Risk Review Project. Pacific Northwest National Laboratory provides research, analytical, and other assistance to CRESP as part of the Risk Review Project.

For the first several months of the project, the focus was on developing an evaluation approach that would accomplish the Risk Review Project's goal of providing the DOE, regulators, and the public with a more comprehensive understanding of the current and future risks to receptors and to help inform decisions on sequencing of future cleanup activities, as well as associated selection, planning, and execution elements of the process. The draft methodology was made available for agency and public comment in September 2014 and then revised in response to the comments received. The methodology used to evaluate the 25 EUs discussed in this report, reflects the revisions made in response to input received on the draft methodology. The methodology also reflects the lessons learned from the pilot case studies completed in the summer of 2014, to test the draft version of the methodology, as well as input received from independent experts.

The methodology consists of the following elements[9]:

1. **Identification of Evaluation Units.** The remaining cleanup sites at Hanford as of October 1, 2015, have been divided into approximately 60 EUs, which are composed of geographically co-located sites to the extent possible, considering commonality among source types and the overlapping of impacts and risks to receptors[10]. There are five categories[11]: (1) legacy source sites, such as past practice liquid waste disposal and buried solid waste sites; (2) tank waste and farms and associated legacy contamination sources; (3) groundwater plumes; (4) inactive facilities undergoing decommissioning, deactivation, decontamination and demolition (D4); and (5) operating facilities used as part of the cleanup process. *See Chapter 2 for a complete list of all EUs and maps of their locations, including the 25 evaluated for this report; also Chapter 3 of the methodology (CRESP 2015).*

2. **Summary Evaluation Templates.** Each EU is described in detail using existing information as of January 2014, including regulatory documents, maps, and studies.[12] Information gathered on each EU includes the unit description and history; an inventory of waste and contamination history; selected or the potential range of cleanup approaches; and the ratings of risks to human resource and environmental receptors, by providing rough order of magnitude relative grouping or binning of risks to each different type of receptor. The primary groupings are Very High, High, Medium, Low, and Not Discernible. *See Chapter 3 and Appendices D-I for the completed*

[9] The entire methodology document may be found on CRESP's website: www.cresp.org

[10] The EU concept was developed by the Risk Review Project to provide a tractable basis for reviewing the myriad of cleanup challenges at the Hanford Site. Groupings of facilities, wastes and existing environmental contamination within each EU is based primarily on geographic location because the potential to impact receptors is fundamentally based on geographic location and spatial relations that may lead to exposure of receptors to hazards from specific sources. Thus, EU groupings are not based on, and may not correspond with, either the process history that produced the wastes or environmental contamination, nor the groupings used for regulatory purposes (e.g., operable units).

[11] The EU groupings used here were developed by the Risk Review Project to understand potentially overlapping risks and are not common practice at the Hanford Site.

[12] The information available for each EU is highly variable, depending on documentation of past site practices, the current regulatory status, currently planned near-term cleanup activities and other factors.

summary evaluation templates for each of the 25 EUs discussed in this report; Appendix B of the methodology (CRESP 2015) for the Summary Evaluation Template.

3. **Risk Ratings.** The receptors being rated or binned are facility workers, co-located people, public, groundwater and the Columbia River, and ecological resources. The groupings of risk ratings (e.g., "high", "medium", etc.) for each type of receptor are determined by application of the specific methodology developed for that receptor. Demarcation between ratings uses recognized regulatory or literature thresholds applicable to the specific receptor, if they exist, as screening levels, as well as other factors. This approach is intended to provide relative risk ratings *within* receptor categories (i.e., relative binning of risks to the Columbia River, groundwater, ecology, etc.). Risk ratings for each receptor are then used to inform the urgency of addressing specific hazards. An overall risk rating is not provided for cultural resources; however, information about cultural resources within each EU and near (within 500 m) each EU is gathered, described, and analyzed as a planning guide or tool for future cleanup activities.

   Although the integration across receptor categories is assumed to be inherently driven by individual and collective values, the Risk Review Project will provide examples illustrating how grouping or binning that integrates the ratings across receptor categories (e.g., integrated risk binning that combines risks to human health with risks to ecology and groundwater) could be carried out.[13] *See Chapter 2 for summaries of each receptor methodology; Chapters 5 through 8 of the methodology (CRESP 2015) for detailed descriptions of each receptor methodology.*

4. **Temporal Evaluation Periods.** Risks are evaluated based on distinct time periods: the current status of the EU, typically prior to cleanup although cleanup has been initiated for some EUs; active cleanup period (or until 2064); near-term post-cleanup (until 2164, or assuming a 100 year duration for institutional controls associated with areas transferred from federal control); and long-term post-cleanup (or until 3064).[14] Each EU and selected EU components are evaluated as if cleanup were not to occur for 50 years to provide insights into the potential risks of delay, which will help inform sequencing of cleanup actions. However, this is not to infer that delay of cleanup for 50 years is recommended. *See Chapter 2 for a more detailed description of the evaluation periods.*

5. **Initiating Events.** The likelihood of initiating events, both localized and regional in scale, which may occur during any or all of the evaluation periods, such as fire, volcanic eruptions, loss of power, and loss of cooling water, are described. This is to establish a consistent basis for identifying and categorizing phenomena that may remove or degrade barriers thus placing receptors at risk from contaminants. Nuclear safety is considered in the context of potential initiating events and risks to receptors. *See Chapter 2 for a summary of initiating events; Chapter 4 of the methodology (CRESP 2015) for a detailed analysis.*

RESULTS AND INTERIM OBSERVATIONS

The Risk Review Project relies primarily on previously obtained primary data, safety analyses, risk analyses, environmental impact assessments, remedial investigations, and other sources of information. Tens of thousands of pages of information and electronic databases have been reviewed and integrated to form the basis for this report. The methodology used reflects input from state and federal regulatory agencies, Tribal Nations, non-governmental agencies, the public, and independent experts (CRESP 2015).

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[13] This will be included in the final report but is not in the interim progress report.

[14] Where information is available that indicates risks that may be present beyond the year 3064, such information is noted (such as with slow groundwater migration of contaminants).

Still, important uncertainties and data gaps remain that required assumptions to carry out the project and are indicated in the detailed analysis provided in the main body of this report and its appendices.

The major current risks that have been identified within the EUs considered in this report are as follows:

The current risks that are in the highest risk rating group are at specific EUs from (1) loss of nuclear safety controls from major natural hazards (e.g., from seismic events, volcanic ashfall, or wildfire) or other external events (e.g., prolonged loss of power or water), or operational accidents (including facility fires) that can effect human health and a broad range of receptors; and (2) contamination of groundwater from further spread of existing groundwater contamination, migration of contaminants from legacy surface disposal sites and the vadose zone, or unplanned release of contaminants from engineered facilities (e.g., waste tanks).

Current significant threats to the Columbia River from contaminants in the River Corridor are being treated, and significant threats from groundwater contaminants to the Columbia River from the Central Plateau are either being treated, or would not be realized for a long time and only if they are not treated during the active cleanup period (i.e., over the next 50 years).

The highest rated risks during cleanup are (1) to workers, co-located people, and controlled access groups from operational accidents; and (2) to ecological and cultural resources from physical disruption or introduction of invasive species, either because of insufficient planning, selected cleanup methods, or lack of a prior knowledge.

The major risks remaining after cleanup are from potential failure of institutional or engineered controls, which may impact human health, water resources, and ecological resources. In addition, ***safety of consumptive practices*** (such as those associated with some Tribal Nation cultural practices and some recreational activities) cannot be assured without both risk assessment and appropriate biomonitoring.

Several interim observations can be made from the work completed to date. Observations fall into one of three categories that are offered to inform management considerations surrounding (1) sequencing of cleanup, (2) planning for and activities associated with cleanup, and (3) key information gaps that have affected the completion of evaluations. These observations must be regarded as preliminary because they may be altered for the final report after all EUs have been evaluated for risks and impacts to human resources, groundwater and the Columbia River, and ecological and cultural resources. However, they have been carefully formulated from the evaluations completed for this interim progress report, and therefore may be considered in conjunction with the full range of other factors that affect cleanup decisions at the Hanford Site. *See Chapter 5 for detailed results and observations for the first set of 25 units evaluated.*

In addition to specific observations, five general interim observations can be made at this point in the Risk Review Project.

GENERAL OBSERVATIONS

1. At the Hanford Site, current hazard and risk conditions reflect the inventory, site access controls that are in place, and cleanup actions already completed. These controls and completed actions have greatly reduced threats to human health and ecological resources, as well as addressing some of the groundwater contamination. When considering future cleanup, different hazard and risk considerations are important for different decisions as follow:
    a. **To inform sequencing of cleanup activities –** *nuclear, chemical, and physical safety* (i.e., hazards, initiating events and accident scenarios) *and the threats to groundwater* and the Columbia River *are the primary risk considerations*.

b. **To inform selection, planning and execution of specific cleanup actions –** potential *risks and impacts to worker safety, ecological resources, and cultural resources are the primary risk considerations*.
c. **To inform cleanup criteria** (i.e., cleanup levels to meet regulatory standards) **–** *future land use, protection of water resources, land ownership and control, durability of institutional and engineered controls, and legal/regulatory requirements are the primary considerations that influence future human health risk estimates*. Risks to human health should be considered in combination with risks to environmental and ecological resources for establishing cleanup criteria. The establishment of end-state cleanup criteria is not the focus of the Risk Review Project.

2. Currently, members of the public, whether located at the official Hanford Site boundary or at the controlled access boundary (river and highways), usually have Low to ND (non–discernible) risks, even if postulated radioactive contaminant releases are realized.

3. Timing of cleanup of a specific EU **may reduce** worker risk (e.g., by radioactive decay) **or may increase worker risk** (e.g., by facility deterioration, workforce availability with institutional knowledge, repetitive or chronic exposures due to maintenance, potential for complacency).
    a. Worker risk varies with respect to the nature of hazards, complexity, duration of project, technical approaches, and controls or mitigation measures in-place to ensure worker health and safety.
    b. DOE and its contractors have accident rates approximately two-thirds less than comparable non-DOE work. Ongoing vigilance is needed to maintain this excellent record.

4. The ecological resources on the Hanford Site are very important to the Columbia River Basin Ecoregion, where the shrub-steppe habitat has decreased at a far greater rate region-wide than on the Hanford Site. Stewardship by the DOE has helped protect these resources.

5. The historical and cultural significance of the Hanford Site to Tribal Nations stretches over 10,000 years. The Hanford Site also is considered to have important historical significance to western settlement, which began in the early 1800s and only ended at the site to make way for the Manhattan Project. Finally, the site played a major role during the Manhattan Project Era and after World War II during the Cold War Era. DOE's stewardship helps assure that the site's historical and cultural significance will continue to be recognized.

INFORMING CLEANUP SEQUENCING

The following is a list of interim observations related to sequencing of cleanup only, with additional details provided in Chapters 3 and 4. All other observations may be found in Chapter 5 of this report. Detailed discussions of each EU are provided in appendices as noted. However, with regard to planning for and activities associated with cleanup, observations cover a wide range of issues from identifying the greatest risks to workers to the most important pathways and mechanisms for impacts to ecological resources and cultural resources (e.g., by contaminants and physical disruption).

1. **Address parts of specific EUs earlier.** For several EUs, specific activities, hazards, or risk characteristics warrant being addressed before the EU as a whole.
2. **Highest priority group based on evaluation of potential risks to human health and the environment.** For the facilities and activities evaluated under the Risk Review Project to date,

the major cleanup activities that are in the highest priority group based on evaluation of potential risks to human health and the environment are as follows (*not in any specific order*):

a. **Reduction of threats posed by tank wastes.** (Appendix E) Hydrogen gas generation[15] poses a threat to nuclear safety and human health through hydrogen flammability events that may result in atmospheric or subsurface release of waste or contaminants from containment (worker risk from tank vapors are discussed below). Tc-99 and I-129, both being persistent and highly mobile in the subsurface, pose threats to groundwater through potential leakage from tanks[16]. Risks posed by hydrogen gas generation can be somewhat reduced through removal of water soluble Cs-137. Groundwater threats can be substantially reduced by removal of water-soluble constituents from a selected set of tanks[17]. This interim observation is consistent with the priority given by the agencies to treat LAW at WTP as early as possible if Cs-137, Tc-99 and I-129 separated from the waste are not returned to the tanks. However, the risk profile will not be reduced significantly nor increased if Cs-137, Tc-99 and I-129 are returned to the tanks during LAW treatment.

b. **Reduction or elimination of risks associated with external events and natural phenomena (severe seismic events, fires, loss of power for long duration).** Facilities affected are the Waste Encapsulation and Storage Facility (WESF) (cesium and strontium capsules), Central Waste Complex, and Plutonium Uranium Extraction Plant (PUREX) waste storage tunnels.

    i. **For WESF** (Appendix H.4)**:**

    The primary scenario that causes release of radionuclides from capsules stored in the WESF pool cells is an accident that results in the loss of all water from the pools cells, which provides cooling and radiation shielding. The design basis seismic event alone cannot cause the loss of all pool cell water by itself: release of significant quantities of radionuclides can only be caused if multiple root causes occur (some in sequence, some in parallel) that include man-made errors, natural events, and external events. The storage pool structures have been exposed to high radiation fields for an extended period of time. An initial assessment completed indicates that the storage pools currently are safe, although the long-term integrity of the structures is uncertain.[18] DOE proposes to over-pack and then transfer cesium and strontium capsules to onsite dry storage.[19]

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[15] Hydrogen generation rate is primarily related to Cs-137 and Sr-90 content of the waste.

[16] The threat to groundwater from tank leakage has been mitigated in the near-term through interim stabilization of single shell tanks (SSTs) by removal of pumpable liquids.

[17] For hydrogen generation – 200 East DSTs, 200 West DST SY-103 and single shell tanks East B-202, B-203, B-204, and West T-201 have times to 25% of the lower flammability limit of less than 6 months under unventilated conditions. Cs-137 removal would most significantly increase time to 25 percent of the lower flammability limit for tanks AZ-101, AN-102, AN-107, AP-101, AP-103 and AP-105. For groundwater threat, greater than 70% of the GTM is from – 200 East DSTs, SY-101 and SY-103 (200 West DSTs) and single shell tanks, AX-101, S-105, S-106, S-108, S-109, SX-106, TX-105*, TX-113*, TX-115*, U-109, U-105 (* indicates assumed SST leaker).

[18] A separate DOE-initiated review of the condition of the WESF concrete structure and the reliability of the initial DOE estimate is in progress.

[19] The capsules may experience significantly higher temperatures in dry storage than in pool storage. The elevated temperatures, combined with the variable and uncertain chemical composition of some capsules, could raise concerns about the integrity of the capsules over time as storage is likely for at least decades (see Appendix H.4). This concern would be addressed as part of the safety analysis associated with the dry storage design process.

ii. **For Central Waste Complex** (Appendix H.3)**:**
Estimated unmitigated doses from incident scenarios to the co-located person exposed to the worst design basis event at the Central Waste Complex is from a large fire involving more than eight drums or 82.5 Ci (dose equivalent) of material with 770 rem. The risk may increase because the Central Waste Complex continues to receive wastes, but currently is unable to ship wastes to off-site disposal, due to WIPP being closed and also because budgets have been insufficient to support repackaging wastes into standard containers. Localized accumulation of material at risk without a disposition pathway can increase overall risk. Consideration also should include reductions in the amount of material at risk for similar facilities that require interaction with other offsite facilities that may not be available.

iii. **For PUREX** (Appendix D.4)**:**

1. A design basis seismic event could lead to a total structural failure of the 202-A building and both tunnels, causing an estimated unmitigated combined 250 rem dose to the co-located person.
2. The wood ceiling and wall structure of Tunnel #1 are vulnerable to collapse in about 30 years[20] due to ongoing degradation occurring from continued exposure to the gamma radiation from equipment being stored, or due to a fire. These events could release a large fraction of the 21,200 Ci radiological inventory to the environment.[21]

c. **Dependence on active controls (e.g., reliance on power, cooling water, active ventilation) to maintain safety for additional facilities with large inventories of radionuclides.** These conditions are (1) air handling ducts at WESF, and (2) sludge at K-Basins (sludge treatment project; Appendix H.2).

i. During the design basis event earthquake, contaminants from WESF's hot cell and ventilation system are the hazard sources that produce doses to the co-located person [Co-located person: 21 rem].

ii. Current safe storage relies on maintaining the K-Basin sludge submerged under water to reduce radiation exposure to workers and prevent fires of reactive metal fragments. Safe processing of K-Basin sludge also requires keeping it wet during retrieval, transfer, interim storage, and processing to prevent pyrophoric constituents from igniting.

3. **Cleanup actions that could cause substantial human health risks.** The following cleanup activities themselves could cause substantial risks to human health and therefore warrant consideration of interim actions, and different cleanup approaches and timing (recognizing that mitigation measures would be both necessary and implemented before and during remedial actions):

a. **Retrieval, treatment, and disposal of contaminated soils underlying Building 324 and disposal of the building after grouting the contaminated soils in the building** (Appendix F.2)**.** Currently, no migration of soil contamination to groundwater has been indicated, suggesting that required cleanup is not urgent. In addition, the excavation and transfer of the soils through the B-Cell floor may not be technically feasible and/or may present

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[20] The time estimate of 30 years has large uncertainty, and can be shorter or longer.

[21] The documented safety analysis for this facility provides a detailed analysis of potential upset events (see Appendix F.4).

challenging risk scenarios. As a result, approaches that allow for immobilization and in situ decay of the soil contaminants (Cs-137, Sr-90) warrant further consideration.

b. **Retrieval, treatment, and disposal of materials from 618-11 within caissons, vertical pipe units, and burial grounds** (Appendix D.2) because of the characteristics of wastes (high activity, pyrophoric, poorly characterized) to be retrieved. The possible event of a fire and/or release from 618-11, jeopardizes continued operations and worker safety at the Columbia Northwest Generating Station because of the proximity of the two facilities. The current cover over the buried wastes, but not present over the caissons and vertical pipe units, is effective in limiting water infiltration to the wastes where the cover is present. These conditions warrant consideration of instituting interim mitigation measures and delaying waste retrieval until closure of the generating station.

4. **Groundwater threats** (Appendix G)**.** Many of the threats and current impacts to groundwater are being interdicted and/or treated. The greatest threats and impacts to groundwater that are not currently being addressed are from:

   a. **Groundwater plumes not currently being actively addressed.** Tc-99 and I-129 are already in groundwater in 200 East Area (200-BP-5; EU CP-GW-1). The 200-BP-5 I-129 plume extends to the southeast (200-PO-1; EU CP-GW-1), but may be too dispersed for effective remediation other than natural attenuation.

   b. **Vadose zone threats to groundwater not currently being addressed.** Tc-99, I-129, and Cr(VI) are in the vadose zone associated with BC Cribs and Trenches (EU CP-LS-1; Appendix D.4) and the legacy sites associated with B-BX-BY tank farms (EU CP-TF-6; Appendix E.7), both located in the 200 East Area. Sr-90 results in a very high rating in B-BX-BY because of the large inventory but also is relatively immobile and will naturally decay. Infiltration control (e.g., capping) and other approaches may reduce the flux of these contaminants from the vadose zone into groundwater. Uranium currently is being extracted from perched water in B-Complex.

   c. **324 Building, where relatively modest interim actions could reduce threat.** The largest risk for migration of Cs-137 and Sr-90 from the soils until cleanup can be completed (through a combination of D4, soil treatment and/or removal and natural attenuation) is from breakage of a main water pipe and infiltration of precipitation and run off in close vicinity of the building. Building 324 is currently being maintained in a safe surveillance and maintenance mode pending completion and evaluation of a pilot project and assurances that resources are available to complete a multi-year soil remediation and D4 activities. Current risks from potential water infiltration and resultant contaminant migration may be mitigated through water supply modifications, infiltration controls, and additional groundwater monitoring[22].

   d. **618-11 waste site, where relatively modest interim actions could reduce threat**. At 618-11, the potential for release of additional contaminants to groundwater can be mitigated by providing a cover that prevents infiltration but maintains gas venting over the caissons and vertical pipe units (currently gravel covered area).

5. **Operating facilities have a time-dependent risk, which create additional challenges.** Unplanned changes in inventory can occur over time, with delays in planned processing resulting in increased risk. The hazard and risk profiles change as funding is available to

[22] While groundwater monitoring does not prevent infiltration or contaminant migration, it does mitigate risks by providing early warning of a change in the subsurface contaminant spatial distribution.

implement identified plans. For example, with processing delays along with aging infrastructure and without sufficient maintenance, waste storage conditions will deteriorate and/or additional waste may accumulate. In addition, operating facilities rely on interfaces with existing facilities (e.g., WIPP, T Plant, off-site processing and disposition facilities) and planned facilities (e.g., dry capsule storage for cesium and strontium capsules, Phase 2 K-Basin Sludge Processing). Outages or delays in availability of interfacing facilities will likely result in processing disruptions.

Why the Risk Review Project is Unique

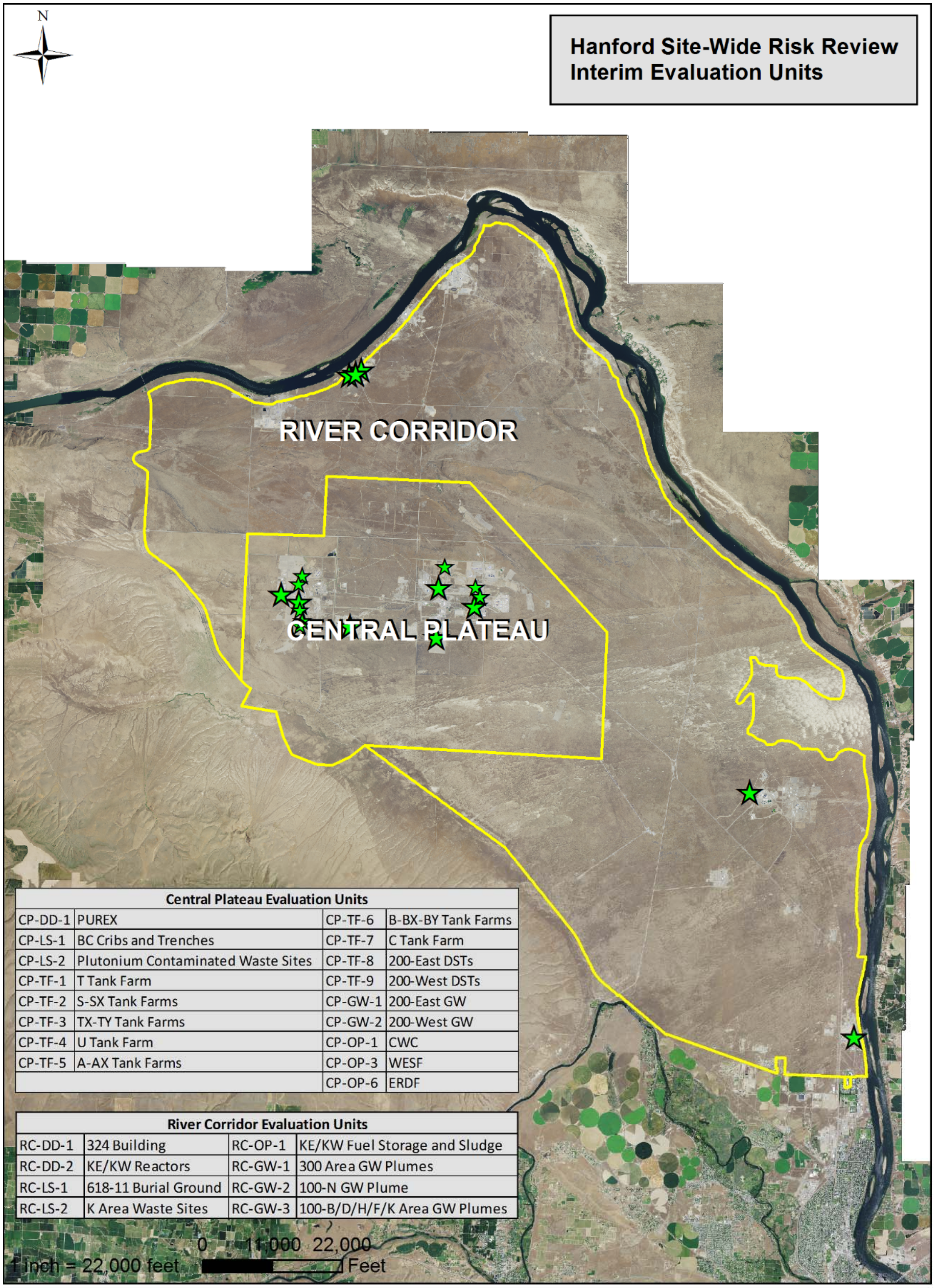
For the Hanford Site, the overall Risk Review Project provides DOE and its regulators with risk evaluations on EUs awaiting remediation gathered from existing information and using a new approach. Not only are sources, inventories, pathways, and receptors documented and evaluated for each EU using this approach, but the results provided by the Risk Review Project include integrated analyses of the quantity and location of contamination sources, present state of containment, potential releases, and risks to receptors. Receptors evaluated include groundwater and the Columbia River, facility workers, co-located people, the public, and ecological and cultural resources. Specifically, the Risk Review Project should be considered unique because it provides for the remaining cleanup areas within the Hanford Site on a consistent basis:

1. An in-depth examination of diverse EU categories (legacy waste sites, facilities for decontamination and decommissioning, tank waste and farms, operating units, and groundwater plumes), with comparisons within EU categories (e.g., tank waste and farms) provided, where practical.
2. The first compilation of potential risks to a broad range of receptors in their current conditions, during cleanup (to 2064), and in the 100 years following cleanup (to 2164).
3. The potential effects of different initiating events and releases on risks to receptors.
4. A compilation of the range of cleanup options and methods being considered (or selected) for each EU.
5. Consideration of groundwater movement and the potential risk from groundwater plumes to the riparian zone and benthic organisms in the Columbia River (benthic organisms are more sensitive than other biota or humans to chemicals and radionuclides).
6. Evaluation of the potential risk to humans in different categories (facility workers, co-located individuals, and the public outside the controlled access boundary).
7. A list of functional effects of remediation on biota and ecosystems and cultural resources.
8. A field evaluation and compilation of the percent of each ecological resource level in both the EUs and the surrounding buffer for all 25 EUs considered in this interim progress report.
9. A review by a professional archaeologist of information in existing records about cultural resources within an EU and the buffer area of up to 500 m from the EU boundary that is compiled in a publicly available report for that EU.
10. A comparison of the risks (current, during active cleanup, near-term post-cleanup) for each EU for the range of receptor groups.
11. Summary tables that allow quick comparison of contamination sources and receptor risk ratings.

Project Consultation and External Review

CRESP is a multi-disciplinary consortium of universities with a mission to advance environmental cleanup by finding ways to improve the scientific and technical basis for management decisions, and to engage stakeholders and the public. CRESP has completed risk-informed characterization projects involving complex issues at DOE Office of Environmental Management sites around the country.

Written comments on this interim report will be solicited from Tribal Nations, governmental entities, stakeholders, and interested members of the public. Independent experts also will provide review of this report. Comments received are expected to inform the final report prepared on the Risk Review Project. The final report is planned to include evaluations and results of all remaining units not evaluated for this report as well as final observations. Written public comments will be solicited on the draft final report. All three major products of this Risk Review Project (the methodology report, interim progress report, and the final report) will be public documents.



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 ES-1. General location all evaluation units included in this interim report except groundwater EUs.

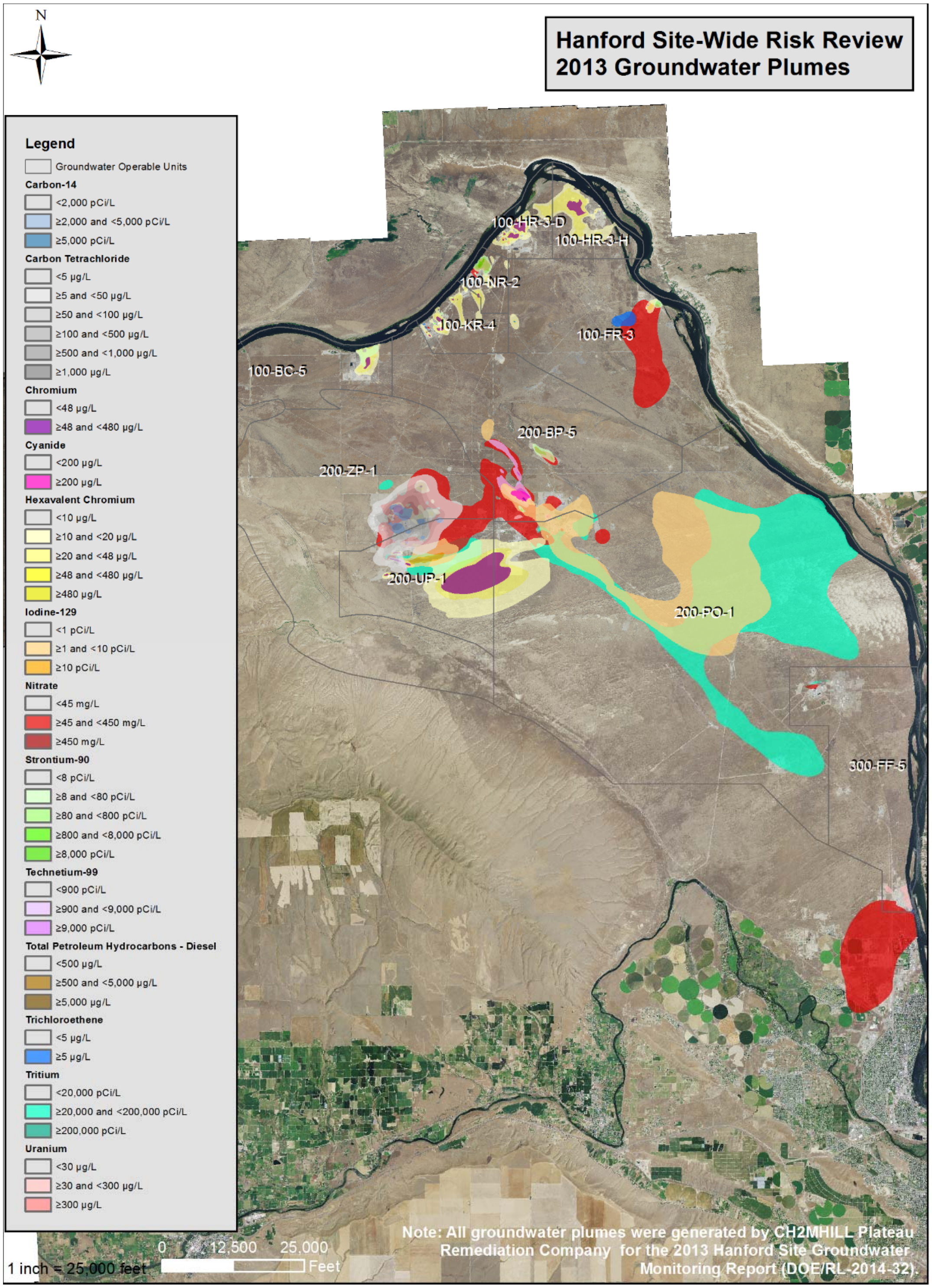


Figure ES-2. Hanford Site-Wide Risk Review 2013 Groundwater Plumes

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Abbreviations and Acronyms

AWQC	ambient water quality criteria
BCG	Biota Concentration Guide
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHPRC	CH2M Hill Plateau Remediation Company
CLUP	Comprehensive Land Use Plan
CRESP	Consortium for Risk Evaluation with Stakeholder Participation
CSB	Canister Storage Building
CSM	conceptual site model
CWC	Central Waste Complex
D&D	deactivation (decontamination) and decommissioning
D4	deactivation, decontamination, decommissioning, and demolition
DOE	Department of Energy
DSA	documented safety analysis
DST	double-shell tank
ECRTS	Engineered Container Removal and Transfer System
EIS	environmental impact statement
EPA	Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
EU	evaluation unit
GIS	Geographic Information System
GTM	groundwater threat metric
GW	groundwater
HA	hazard analysis
HAMMER	Volpentest Hazardous Materials Management and Emergency Response Federal Training Center
HGR	hydrogen generation rate
HLW	high-level waste
IS	insufficient information
LAW	low-activity waste
LFL	lower flammability limit
LIGO	Laser Interferometer Gravitational Wave Observatory
MOI	maximally exposed offsite individual
NA	not applicable
NP	Not present at significant quantities for indicated EU
NRC	Nuclear Regulatory Commission
OU	operable unit
PAC	protective action criteria
PC	primary contaminant
PCB	polychlorinated biphenyl
PFP	Plutonium Finishing Plant
PNNL	Pacific Northwest National Laboratory
PUREX	Plutonium Uranium Extraction Plant
RCRA	Resource Conservation and Recovery Act
REDOX	Reduction-Oxidation Plant
ROD	record of decision

RTD	remove, treat, dispose
SARAH	Safety Analysis and Risk Assessment Handbook
SHPO	State Historic Preservation Officer
SSE	safe storage enclosure
SST	single-shell tank
TBD	to be determined
TC&WM	Tank Farm Closure and Waste Management
TCE	trichloroethylene
TED	total effective dose
TEDE	total effective does equivalent
TRU	transuranic
UCL	upper confidence limit
WCH	Washington Closure Hanford
WESF	Waste Encapsulation and Storage Facility
WMA	waste management area
WIPP	Waste Isolation Pilot Plant
WQS	water quality standard
WRAP	Waste Receiving and Processing Facility
WRPS	Washington River Protection Solutions
WTP	Waste Treatment and Immobilization Plant

List of Radionuclides and Other Contaminants

Am-241	americium-241
C-14	carbon-14
Cl-36	chlorine-36
Cr(VI)	chromium, hexavalent
Cr (total)	chromium, total
Cs-137	cesium-137 (radionuclide)
CT or CCl_4	carbon tetrachloride
H-3 or ^3H_2O	tritium or tritiated water
Hg	mercury
I-129	iodine-129 (radionuclide)
NO_3	nitrate
Pb	lead
PCBs	polychlorinated biphenyls
PCE	tetrachloroethene
Pu	plutonium (either specific isotopes or total, as indicated)
Sr-90	strontium-90 (radionuclide)
Tc-99	technetium-99 (radionuclide)
TCE	trichloroethylene
TPH-diesel	diesel as total petroleum hydrocarbons
U (total)	uranium, total

Probability and Consequence Ratings

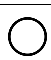
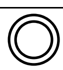
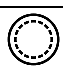
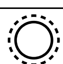
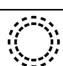
A	Anticipated
BEU	Beyond Extremely Unlikely
EU	Extremely Unlikely
H	High
L	Low
M	Moderate
ND	Not Discernible
U	Unlikely
VH	Very High
	Not Anticipated

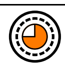
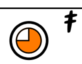
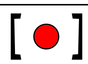
Risk Review Project Risk Ratings

	Low
	Medium
	High
	Very High
ND	Not Discernible

Symbology Used For Risk Review Project Summary Rating Tables

Symbols used in the rating tables indicate the highest rating when a rating range is present. Symbols within each entry in rating tables are a combination of a risk rating symbol and additional symbols used to indicate 1) the presence of engineered barriers to prevent release to the environment or further dispersion of radionuclides and chemicals, 2) when treatment, waste retrieval or remediation is in progress, and 3) if interim stabilization has occurred (only applicable to single-shell tanks; through removal of pumpable liquid).

Symbol	Meaning
	Risk Rating Symbols
	ND Rating
	Low Rating
	Medium Rating
	High Rating
	Very High Rating
	Barrier Symbols
	One engineered barrier, Intact (barriers include tanks, covers, liners, buildings, etc.)
	One engineered barrier, barrier compromised (e.g., leaking tank)
	Two engineered barriers, both barriers intact
	Two engineered barriers, inner barrier compromised and outer barrier intact
	Two engineered barriers, inner barrier intact and outer barrier compromised
	Two engineered barriers, both barriers compromised.
	Treatment, Remediation and Waste Treatment Symbols
[ ]	Treatment, remediation or waste retrieval in progress
ǂ	Interim stabilized (single shell tank, stabilization through removal of pumpable liquid)

Symbol	Meaning
	Examples of Combined Rating, Barrier and Treatment Symbols
	Low rating, no engineered barriers or treatment present
	Medium rating, no engineered barriers or treatment present
	High rating, no engineered barriers or treatment present
	High rating, one engineered barrier that is compromised (i.e., leaking)
	High rating, two engineered barriers, inner barrier compromised, outer barrier intact
	High rating, one engineered barrier present (i.e., single shell tank) with interim stabilization
	Very high rating, currently undergoing treatment

Terminology and Definitions

The primary objective of the Risk Review Project is to characterize risks and impacts to human health (facility worker, co-located persons, and public) ecological resources, cultural resources, groundwater, and the Columbia River. These terms are collectively referred to as "receptors." For the purposes of this document, the following definitions apply:

> Bioindicator – species (species group) or characteristic of a species (or species group) that is used to assess the condition of a species, population, community, or ecosystem.
>
> Biomonitoring – regular, periodic assessment of human or ecological health and well-being.
>
> Buffer – area around the evaluation unit (EU), equal to the widest diameter of the EU. It is an area potentially impacted by remediation activities on the EU.
>
> Co-Located Person – a hypothetical onsite individual located at the distance from the point of potential contaminant release at which the maximum dose occurs (at a point equal to or greater than 100 m from the point of release, the boundary of the facility *or the activity boundary)*. If the release is elevated, the onsite individuals assumed to be at the location of greatest dose, which is typically where the plume touches down. (*This is functionally equivalent to the "Co-located Worker" as defined and used in the* DOE-STD-3009-2014 and the *DOE Safety Analysis and Risk Assessment Handbook (SARAH).*)
>
> Completed Pathway – the transport (transfer or movement) of radionuclides or chemical contaminants from existing environmental contamination sources, hazards (i.e., contained contaminant inventories, physical-chemical forms), or facilities (including those used for materials and waste processing, storage, and disposal) through air, water, or soil to any receptor through a specific set of mechanisms or transport paths. If the transfer is currently occurring, the pathway is referred to as "complete." If the transfer may occur in the future, the pathway may become complete. Other potential pathways may never become "complete" if there is cleanup or interdiction (barriers) or if receptors are kept out of harm's way, for example, by future land use restrictions or institutional controls.
>
> Conceptual Site Model – a comprehensive depiction of sources, potential initiating events, and completed or potential pathways that may result in (or prevent) exposure, risks, and/or impacts to receptors and resources, as well as barriers that interdict the exposure or mitigate the impacts.
>
> Contaminant Sources (or Sources) – chemical and/or radiological contaminants or waste present in a specific form and geographic location. Example sources include contaminated soils, vadose zone, groundwater, buildings, tanks and drums, as well as historical, current, and future waste disposal areas, waste storage, and processing facilities.
>
> Controlled Access Person – an individual, who is granted limited access to the site, within the current site security boundary, for a specific purpose or set of activities. (*This is functionally equivalent to the "Onsite Public" as defined and used in the DOE-STD-3009*.)
>
> Criticality – an inadvertent self-sustaining nuclear chain reaction, with the potential release of high levels of radiation.
>
> Cultural Resources – a collective term applicable to 1) pre-historic and historic archaeological sites and artifacts designating past Native American use of the Hanford Site; 2) historic archaeological sites and artifacts indicating post Euro-American activities relating to the pre-

Hanford period; 3) Hanford Site Manhattan Project and Cold War Era buildings, structures, and artifacts; 4) landscapes, sites, and plants and animals of cultural value to the Native American community; and 5) landscapes, sites, and materials of traditional cultural value to non-Native Americans.

D&D or D4 – D&D officially refers to deactivation and decommissioning of facilities that are no longer used. D4 is a more comprehensive term including deactivation, decommissioning, decontamination, and demolition of excess facilities.

Ecological Resources – any living resource, including species, populations, communities, and ecosystems.

Ecosystem – the physical and living resources in a defined area, including topography, physical structures, water resources, plants, and animals (species to communities).

Evaluation Period – the timeframe considered over which risks or impacts may occur. This Risk Review Project considers three time intervals in addition to the current condition: 1) active cleanup, 2) near-term post-cleanup, and 3) long-term post-cleanup.

Evaluation Unit Summary Template (or Evaluation Template) – a standardized format used to summarize information and risk ratings for each evaluation unit.

Evaluation Units (EUs) – groupings of sources, aggregated for evaluation as part of this Risk Review Project. Sources may be aggregated into an EU based on potential impacts to a common set of receptors or receptor geographic area, common past waste management practices, or integration in the waste management process. The grouping of sources to form specific EUs is discussed in Chapter 3.

Facility Worker – any worker or individual within the facility or activity geographic boundary as established for DSA and located less than 100 m from the potential contaminant release point. This definition is consistent with the DOE-STD-3009-2014 and SARAH definition of a facility worker (HNF-8739 2012).

Groundwater – the water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations.

Groundwater Sites – groundwater areas at the Hanford Site that have been adversely impacted by contamination.

Hazard – any source of potential damage, harm, or adverse health effects. Hazard must be distinguished from risk, since risk should reflect any actions that may have been implemented to reduce the hazard and exposure to receptors.

Impacts – the damage or consequences (death, illness, reduced reproduction, resource impairment, or access limitation) from current or post-remediation residual contamination, or from cleanup, including degradation of resources (including ecosystems, cultural resources, economic assets, groundwater, and surface water above defined thresholds).

Indicator – a physical or biological endpoint used to assess the health and well-being of humans, other species, or ecosystems.

Initiating Events – natural or anthropogenic (man-made) events or processes that may result in the release or accelerated movement of contaminants from a source. Examples include water infiltration, earthquakes, fires, cleanup activities, volcanic eruptions, and sudden structural collapses or failures. Initiating events relevant to this Risk Review Project are discussed in Chapter 4.

Insufficient Information (IS) – adequate data or other forms of information are not available to complete the indicated part of the Evaluation Template.

Key Sources – the set of contaminated areas, wastes, and facilities within an EU that pose the primary risks from the EU. Key sources would not include minor contributors to the overall risks.

Legacy Source Sites – sites containing contaminant releases to the ground, surface, or subsurface resulting from prior actions, including waste disposal actions that are no longer being carried out at a particular location and that are potentially subject to cleanup.

Maximally Exposed Offsite Individual (MOI) – hypothetical individual defined to allow dose or dosage comparison with numerical criteria for the public. This individual is an adult typically located at the point of maximum exposure on the DOE site boundary nearest to the facility in question (ground level release), or may be located at some farther distance where an elevated or buoyant radioactive plume is expected to cause the highest exposure (airborne release). (*MOI used here is not the same as the Maximally Exposed Individual or the Representative Person used in DOE Order 458.1 for demonstrating compliance with DOE public dose limits and constraints.*)

Mitigated Hazards, Exposures, or Risks – there are many hazardous facilities and materials that could reach and harm receptors (see Unmitigated Hazards, Exposures, or Risks). Before and during remediation a variety of engineered and administrative controls are used to reduce sources and interdict exposure pathways, thereby mitigating exposures and reducing risks.

Monitoring – the regular, periodic assessment of the condition of humans or ecosystems (and their component parts). Usually involves surveillance for humans, and bioindicators for ecosystems.

Not Applicable (NA) – the indicated part of the Evaluation Template that is not applicable to the specific EU or evaluation period being considered.

Not Discernible (ND) – the indicated risk or potential impact is not distinguishable from surrounding conditions.

Novel Remediation Approach – a remedial approach that is unprecedented or contains components that are unprecedented.

Operable Units (OU) – group of land disposal sites placed together for the purposes of a remedial investigation/feasibility study and subsequent cleanup actions under CERCLA. The primary criteria for placing a site into an operable unit includes geographic proximity, similarity of waste characteristics and site type, and the possibility for economies of scale. NOTE: OU can also be applied to areas of groundwater contamination.

Operating Sites – operating facilities at the Hanford Site that are currently being used as part of the cleanup process.

Primary Contaminants (PCs) – contaminants that are considered either risk drivers from specific contaminant sources or site-wide contaminants (uranium, plutonium, technetium, etc.) for the Hanford Site. The terminology "primary contaminants" is used to differentiate the usage in this Risk Review Project from the regulatory usage of the terminology of "contaminants of potential concern."

Primary Sources – the origin of a potential or known release of contaminants to the environment (e.g., tanks, buildings, burial grounds, lagoons, cribs, plants that carry contaminants).

Public – represented by the MOI, a hypothetical receptor located at or beyond the Hanford Site boundary at the distance and in the direction from the point of release at which the maximum dose occurs. (*This is functionally equivalent to the "Offsite Public" as defined and used in the DOE-STD-3009-2014 and SARAH.)*

Pyrophoric – the property of some compounds (such as fine metal shavings of uranium) to spontaneously ignite in air.

Receptors – human populations, biota and ecological systems, environmental resources (ground and surface water), and cultural resources that may be exposed to contaminants via one or more contaminant transport and uptake pathways or otherwise adversely impacted by the contamination or cleanup actions.

Resources – a source, either material or non-material, that is considered an asset or from which a benefit is produced or derived. Resources have three main characteristics: utility, limited availability, and potential for depletion or consumption.

Risk – the potential (likelihood and magnitude) for adverse consequences to receptors. For human health, risks originate from exposure to contaminants or trauma associated with the presence of contaminants and/or cleanup of contaminant sources. For other receptors, such as groundwater and ecological and cultural resources, risks reflect the potential for damages or losses of the resource. Risk does not exist in the absence of exposure, although exposure and risks can be identified as "potential" (see also Mitigated and Unmitigated). Mitigated risk reflects those actions that have been implemented to reduce hazards, probability, and consequences of adverse events (e.g., source reduction or engineered barriers that prevent or reduce the transport of contaminants of concern from a source to a receptor).

Risk Assessment – used to characterize the nature and magnitude of health risks to humans (e.g., residents, workers, recreational visitors) and ecological receptors (e.g., birds, fish, wildlife) from radiological and chemical contaminants and other stressors that may be present in the environment.

Risk Characterization – a review of available information, including identification of key information gaps, to provide a comparative qualitative and semi-quantitative (order of magnitude) evaluation of relative risks to a set of receptors posed by a wide range of existing contamination of environmental media and sources of potential future additional environmental contamination. Risk characterization is in contrast to a regulatory risk assessment, which provides quantitative estimates of human health risks.

Risk Evaluation – an evaluation of the available information to evaluate potential harm to receptors and their ecosystems. It falls short of a formal risk assessment, and relies on available information.

Rough Order of Magnitude Relative Rating – binning to distinguish major differences in a risk to a specific receptor (i.e., human health, ecology, etc.) between multiple EUs by assigning values of Very High, High, Medium, Low, or ND (i.e., relative risks posed when comparing amongst EUs).

Secondary Sources – locations in the environment that have received material from a primary source such that they can also act as sources (e.g., soil, groundwater, sediments).

Tank Waste Sites – areas at the Hanford Site (often referred to as tank farms) that contain single- and double-shell underground tanks that house high-level radioactive and chemical wastes that are the byproduct of "reprocessing" spent nuclear fuel.

Unmitigated Hazards, Exposures, or Risks – there are many hazardous facilities and materials that could reach and harm receptors if not mitigated. The Risk Review Project considers these in terms of probability and consequence, assuming no effective mitigation measures (engineered and administrative controls) are in place (see Mitigated Hazards, Exposures, or Risks).

Urgency – higher urgency refers to projects where the risks or impacts to receptors are likely to increase due to degradation at the source, further dispersion of contamination in groundwater, loss of structural integrity, or loss of institutional memory. Lower urgency refers mainly to passively stable hazard configurations and when radiologic decay significantly reduces risk depending on the half-life of each radionuclide.

Vadose Zone – zone of soil or rock between the land surface and the subsurface water table. Pore spaces in the vadose zone are partly filled with water and partly filled with air. The vadose zone is bounded by the land surface above and by the water table below.

CHAPTER 1. INTRODUCTION, PROJECT GOAL, OBJECTIVES, AND SCOPE

1.1. BACKGROUND

In January 2014, the Deputy Under Secretary of the Department of Energy (DOE) asked the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) to conduct a Hanford Site-wide evaluation of human health, nuclear safety, environmental, and cultural resource risks associated with existing hazards, environmental contamination and cleanup activities (See Appendix A); hereinafter referred to as the "Risk Review Project." This report provides the results of the first set of evaluations completed for the project, as well as preliminary observations. A final report is expected to be issued in 2016.

From the beginning, the Risk Review Project's goal has been to carry out a screening process to help inform future cleanup sequencing at Hanford. Accomplishing this goal includes identifying and characterizing potential risks to the public, workers, groundwater and the Columbia River, and ecological and cultural resources (collectively referred to as "receptors").

Project results are expected to provide DOE and regulators with a common understanding of the risks posed by hazards (i.e., contained radionuclide and chemical contaminant inventories, physical-chemical forms, structural integrity, vulnerability to initiating events), existing environmental contamination, and cleanup actions (including mitigation measures that offset or reduce risk associated with cleanup). Specific objectives of the Risk Review Project are to:

- Review hazards and existing environmental contamination site-wide and determine the potential for contaminants and cleanup actions to cause risks to receptors, and identify key uncertainties and data gaps;
- Provide relative ratings of risks to receptors from hazards and existing environmental contamination, and identify the most urgent risks to be addressed, to better enable the Tri-Parties (DOE, the Environmental Protection Agency (EPA), State of Washington) to make decisions on the sequencing of Hanford cleanup activities; and,
- Provide context for understanding how the hazards, existing environmental contamination, current risks and risks posed by cleanup at the Hanford Site compare to risks and impacts posed by other large-scale regional sites and analogous cleanup activities[23]

Meeting all three objectives described above is daunting. Within the Risk Review Project, risk characterization relies on existing information about the Hanford Site that then is assembled and evaluated to characterize risks. These risks are grouped or binned for each type of receptor as "Very High," "High," "Medium," "Low," or "Not Discernible" (ND). This approach is intended to provide relative risk ratings *within* receptor categories (i.e., relative binning of risks to human health, groundwater, ecology, etc.). However, the Risk Review Project ratings are not normalized across receptor categories (i.e., a rating of "Very High" for groundwater should not be equated to a rating of "Very High" for ecology).

The Risk Review Project is being carried out in multiple stages, which are:

[23] This part of the Risk Review Project objective is not covered in this interim progress report, but will be addressed as part of the final report.

- Development of the risk characterization methodology and testing the developed methodology on pilot case sites representing the primary sources of contamination at Hanford (e.g., operating facilities and tank waste and tank farms). The methodology has been adapted from prior risk characterization approaches used at Hanford and elsewhere and suitably tailored to fit the Hanford Site's unique cleanup and waste management activities and diversity of information, as well as the goal and objectives of the Risk Review Project. The methodology document may be found on CRESP's website (www.cresp.org/hanford) (CRESP 2015).
- Completion of an interim progress report that provides risk characterization of approximately half of the contaminant sources at the Hanford Site. As noted, results of the characterizations are the subject of this report.
- Completion of a final report that includes risk characterization of the full set of contaminant sources at the Hanford Site included in the Risk Review Project. The final report is expected to be completed in 2016.

Beginning in 1943, the area now known as Hanford Site, which is located along the Columbia River in southeast Washington and covers 586 square miles, was transformed from primarily an agricultural area into an industrial complex designed to produce plutonium to use as a military deterrent during World War II. This mission continued until the Cold War ended, and in 1989 the mission evolved to waste management and cleanup of the contamination remaining on Hanford Site from work conducted during the Manhattan Project and Cold War eras.

Cleanup at the Hanford Site has several goals, but three of the most important are protecting human health and the Columbia River and restoring groundwater to its beneficial use. Cleanup consists of three major components: River Corridor, Central Plateau, and tank waste. Cleanup activities for all three are considered complex, involve multiple projects, and will cost billions of dollars before requirements can be considered met. In fact, cleanup at Hanford has proven to be much lengthier, more complex, more technically challenging, and more expensive than was envisaged in 1989, when Hanford's mission was refocused to waste management and cleanup. Additionally, in some areas at the site, cleanup will continue for many years and active systems may need to remain operational for long periods. Despite the difficulties, considerable progress has been made in cleaning up the Site (e.g., treating contaminated groundwater near the Columbia River). (DOE/RL-2014-11 2014*)*

The Hanford Site is located along the Columbia River in southeast Washington. It covers 586 square miles, which is about half the size of Rhode Island.

Since the early 1990s, cleanup urgency in the River Corridor has been driven by the threats to the Columbia River posed by hundreds of waste sites and contaminated facilities, including nine retired plutonium production reactors. The corridor consists of 220 square miles, but considerable portions were never directly involved in or affected by weapons production activities.

The Central Plateau is composed of 75 square miles and located, as the name suggests, in the central portion of the Hanford Site. The Central Plateau contains waste sites, active treatment and disposal areas, historical waste disposal (burial) grounds, and surplus facilities. Additionally, there are areas with deep soil contamination and an estimated 60 square miles of contaminated groundwater. About 10 square miles comprise the inner area within the Central Corridor and the remaining acreage is referred to as the outer area. The inner area serves as the area for long-term waste management and containment of residual contamination.

The third component of Hanford cleanup is tank waste, which is found in so-called tank farms in the inner area of the Central Plateau. The farms contain approximately 55 million gallons of radioactive waste stored in 177 tanks that are scattered throughout the inner area of the Central Plateau and intermingled with other waste sites. Intentional discharges, unintentional discharges and leaks have occurred and some releases have reached groundwater; furthermore, some tanks are known or assumed to be currently leaking at a very slow rate. In addition to containment and retrieval, the tank waste strategy includes treatment and disposal (Hanford Site Cleanup Completion Framework, DOE/RL-2009-10, Rev. 1).

Cleanup at the Hanford Site is governed by environmental laws, primarily the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), P.L. 96-510, 42 U.S.C. 9601 (1980, et seq.) and the Resource Conservation and Recovery Act (RCRA) and their regulations and guidance documents. The purpose of both statutes is to reduce the risk from contamination at sites to levels that protect human health and the environment. Under CERCLA, cleanup is DOE's responsibility and implementation is overseen by EPA and state regulatory agencies through federal facility agreements and regulatory permits. The legal framework relied on at Hanford is the 1989 Tri-Party Agreement executed by the DOE and its regulators, EPA and the State of Washington Department of Ecology. That federal facility agreement document establishes milestones for completing agreed-upon cleanup activities and is regularly updated. Another important legal document is the 2010 consent decree, which establishes milestones for cleanup of tank waste and farms.

Since cleanup began, DOE has maintained a dialogue with a broad spectrum of interested community members, neighboring state Oregon, four Native American Tribes having historical and cultural ties to the Hanford Site (Nez Perce, Confederated Tribes of the Umatilla Indian Reservation, Confederated Tribes and Bands of the Yakama Nation, and Wanapum), local governments, and stakeholder groups. Federal law, including CERCLA, also gives individuals, Tribes, governments, and stakeholder groups the opportunity to comment on documents that guide cleanup.

The Risk Review Project is being carried out in regular dialogues with senior management from DOE, EPA, and the State of Washington Departments of Ecology and Health through a Core Team that provides advise on the development and execution of the Risk Review Project. Pacific Northwest National Laboratory (PNNL) provides analytical and research assistance, which includes gathering existing information on each unit being evaluated.

The Risk Review Project is led by CRESP, and CRESP is responsible for its execution, results, conclusions, and recommendations. CRESP is a consortium of universities supported by DOE through a cooperative agreement.[24] The CRESP mission is to advance environmental cleanup by improving the scientific and technical basis for management decisions while fostering opportunities for public participation. CRESP has completed risk-informed characterization projects involving complex issues at both large and small DOE Office of Environmental Management sites.

1.2. PURPOSE OF THE INTERIM PROGRESS REPORT

The purpose of this interim progress report for the Risk Review Project is to present the results of 25 of the approximately 60 units identified for evaluation. The evaluation results for the remaining units will be in the final report. Results include completed templates for each evaluation unit (EU) (Appendix) together with the qualitative and order-of-magnitude relative rating and binning of risks to receptors that include human health, groundwater and the Columbia River, and ecological resources. An overall

[24] CRESP is supported by DOE under Cooperative Agreement Number DE-FC01-06EW07053, titled The Consortium for Risk Evaluation with Stakeholder Participation III, and awarded to Vanderbilt University.

risk rating is not provided for cultural resources; however, information about cultural resources has been gathered, described, and analyzed as a planning guide or tool for future activities. Details on the outcomes of the ratings or binning of risks to receptors are given in Chapter 4.

Cleanup sites remaining at Hanford have been divided into approximately 60 EUs organized into five categories: (1) legacy source sites, (2) tank waste and farms, (3) groundwater plumes, (4) inactive facilities undergoing D&D, (5) and operating facilities. Chapter 3 of this report provides results from each category and makes comparisons where appropriate (e.g., tank waste and farms). Chapter 3 also compares inventories and physical/chemical states and provides a table of the impacts of the most important initiating events.

An important feature of this interim progress report is the interim observations from project work completed to date, which are described in Chapter 5.

In addition to the results of the remaining units identified for evaluation under the Risk Review Project, the final report will include the status of contaminants likely to be present during the long-term, post-cleanup evaluation period.

Integration across receptor categories will not occur. However, the final report will include examples of ways to carry out difficult grouping or binning that integrates the ratings across receptor categories (e.g., integrated risk binning that combines risks to human health with risks to ecology and groundwater).

The Hanford Site needs to be viewed in the context of the regional economy, important onsite or adjacent economic assets, and the multiple relevant sources of human health risks and impacts to resources near the Hanford Site. Examples include the Energy Northwest Columbia Generating Station (nuclear) and PNNL facilities in the Hanford 300 Area, the U.S. Ecology waste disposal site in the Central Plateau, and discharges from non-Hanford sources to the Columbia River of contaminants found on the Hanford Site (e.g., discharges from agricultural and industrial activities). The Risk Review Project will also seek to put the Hanford risks, potential impacts, and cleanup in context with other large cleanup efforts in the region. In addition, the Risk Review Project in the final report will provide a regional context for the relationships between the Hanford Site cleanup and the regional economy.

Finally, the final report will include overall observations and final recommendations.

1.3. WHAT THE RISK REVIEW PROJECT IS AND IS NOT

To better understand the context for the interim progress report, it is important to describe the parameters for the Risk Review Project, including what the project is not:

- The Risk Review Project is neither intended to substitute for nor preempt any requirement imposed under applicable federal or state environmental laws. As important, the Risk Review Project is not intended to make or replace any decision made under the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) and/or 2010 Consent Order, or amendments.
- The Risk Review Project is not intended to interpret treaty rights that exist between the United States and Native American Tribes.
- The Risk Review Project is focused only on portions of the Hanford Site where cleanup or waste management activities are ongoing and will continue past October 1, 2015, or where cleanup or waste management activities will occur beginning October 1, 2015, or later. Cleanup actions

considered completed by the Tri-Parties are not part of the Risk Review Project and therefore will not be evaluated. Specific areas of the Hanford Site that are included as well as those that are excluded from the Risk Review Project are described in Chapter 3 of this document.

- The Risk Review Project is focused on risk characterization, which is a necessary predecessor to risk management, but does not focus on risk management decisions. Nonetheless, cleanup actions can cause risks to receptors, which are a part of risk management decisions. The Risk Review Project, however, will not recommend which cleanup option should be selected. Instead, the Risk Review Project considers a plausible range of cleanup actions for different types of hazards and existing environmental contamination to better understand the range of potential risks that may be caused by future cleanup actions.
- The Risk Review Project is not carrying out a CERCLA risk assessment or a Natural Resources Damage Assessment evaluation. Evaluations of hazards, existing environmental contamination, and rough order-of-magnitude estimates of risks to receptors using existing information are the basis for developing groupings, or bins, of risk and identifying the most urgent risks to be addressed.

CHAPTER 2. METHODOLOGY OVERVIEW

2.1. OVERARCHING METHODOLOGY AND APPROACH

To accomplish the Risk Review Project's goal of carrying out a screening process to help inform future cleanup sequencing at Hanford, the most recent, available information about hazards (i.e., contaminant inventories, physical chemical forms), existing environmental contamination, and events that may adversely impact receptors at the Hanford Site is gathered, described, and analyzed. The Risk Review Project is using information and reasonable planning assumptions that are available as of January 2015 for the interim progress report.

The general risk characterization paradigm that is being used to evaluate risks to human health and other receptors includes the following steps (Figure 2-1):

- **Identification of EUs.** The remaining cleanup sites[25] at Hanford as of October 1, 2015, have been divided into approximately 60 EUs, which have been organized into five categories composed of geographically co-located sites to the extent possible, considering commonality among source types and the overlapping of impacts and risks to receptors.[26] The five categories are (1) legacy source sites, such as past practice liquid waste disposal and buried solid waste sites; (2) tank waste and farms and co-located legacy contamination sources; (3) groundwater plumes; (4) inactive facilities undergoing decommissioning, deactivation, decontamination, and demolition (D4); and (5) operating facilities used as part of the cleanup process. Table 2-1 lists all the EUs and Figure 2-2 provides a map showing the locations of EUs evaluated in this interim report. Further descriptions of the grouping methodology and sources included in each EU are provided in Chapter 3 of the methodology document (CRESP 2015).
- **Summary Evaluation Templates.** Each EU will be described in detail using existing information, including regulatory documents, maps, and studies (environmental impact statements (EISs), CERCLA remedial investigations, preliminary documented safety analyses (DSAs), etc.). Information gathered on each EU includes the unit description and history; an inventory of waste and contamination history; and selected or the potential range of cleanup approaches. The ratings of risks to receptors then are based on a rough order of magnitude relative grouping[27] or binning of risks to each different type of receptor. The primary groupings are Very High, High, Medium, Low, and Not Discernible. A standardized summary report structure, referred to as an Evaluation Template, is used to present the resulting information about each EU. The EU template may be found in Appendix B of the methodology document (CRESP 2015).
- **Risk Ratings.** Potential receptors that may be at risk are characterized and rated using a defined rating scale derived from the evaluation methodology developed for each receptor type. The rating scale for each type of receptor is determined from the specific methodology developed for that receptor using recognized thresholds, if they exist, as screening levels, as well as other

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[25] The Hanford Site has been divided into more than 2500 individual contaminated areas (i.e., operable units) and RCRA permitted facilities for regulatory purposes.
[26] The EU concept was developed by the Risk Review Project to provide a tractable basis for reviewing the myriad of cleanup challenges at the Hanford Site.
[27] "Rough order of magnitude grouping" refers to drawing distinctions between groupings that are approximately a factor of 10 different when based on quantitative information (or substantially different for qualitative assessments), recognizing the inherent uncertainties and data gaps.

factors. The receptors being rated using a defined rating scale are facility workers, co-located people, public, groundwater and the Columbia River, and ecological resources. Non-human receptors are also referred to as resources. This approach is intended to provide relative risk ratings *within* receptor categories (i.e., relative binning of risks to the Columbia River, groundwater, ecology, etc.), which will be used to inform urgency of addressing specific hazards and existing environmental contamination. An overall risk rating will not be provided for cultural resources; however, information about cultural resources within or near (within 500 m of) each EU will be gathered, described, and analyzed as a planning guide or tool for future activities. Although the integration across receptor categories is considered inherently driven by individual and collective values, the Risk Review Project will provide examples that illustrate how grouping or binning that integrates the ratings across receptor categories (e.g., integrated risk binning that combines risks to human health with risks to ecology and groundwater) could be carried out.[28] Economic assets are described briefly at the end of this chapter, but identified economic assets are not evaluated individually in detail in this document. EU evaluations indicate when the current status, delay, or cleanup activities may affect DOE or non-DOE economic assets directly. The receptor methodologies or approaches are summarized in Section 2.3 of this chapter. More detailed descriptions of the methodologies for each receptor are in Chapters 5 through 8 of the methodology document (CRESP 2015).

- **Initiating Events.** The likelihood of initiating events, both localized and regional, which may occur during any or all of the evaluation periods, including operational events such human error and external episodic events such as fire, volcanic eruptions, and loss of power, are described. This is to establish a consistent basis for identifying and categorizing phenomena that may remove or degrade barriers, thus placing receptors at risk from contaminants. Nuclear safety is considered in the context of potential initiating events and risks to receptors and is described in more detail in Chapter 4 of the methodology document (CRESP 2015). Furthermore, contaminants in environmental media (e.g., soils, vadose zone, groundwater) will flow, move, diffuse, and disperse under long-term prevailing conditions without the presence of specific episodic initiating events.
- **Temporal Evaluation Periods.** Risks are evaluated based on distinct time frames or evaluation periods. The evaluation periods are (1) active cleanup period (or until 2064), including the current status of the EU prior to cleanup, where applicable, and during active cleanup (or until 2064); (2) near-term post-cleanup (until 2164, or assuming a 100-year duration for institutional controls associated with areas transferred from federal control); and (3) long-term post-cleanup (or until 3064). Each EU and selected EU components are evaluated as if cleanup were not to occur for 50 years to provide insights into the potential risks of delay to help inform sequencing of cleanup actions. However, this is not to infer that delay of cleanup for 50 years is recommended. Section 2.4 of the methodology document provides additional assumptions relative to each evaluation period (CRESP 2015). Using the specific methodology to rate risks for each receptor (described in Chapters 5 through 8 of the methodology document (CRESP 2015)), each EU will receive a rating for each applicable receptor during the active cleanup period (including current status and as a result of cleanup actions where applicable) and the near-term post-cleanup period.[29] The long-term post-cleanup period will be considered for the remaining

[28] This will be included in the final report but not this interim progress report.
[29] The human health risks associated with potential failure of institutional controls during the near-term post-cleanup period will be evaluated in the final report but not in this interim report.

contaminant inventory and physical/chemical form, engineered and natural containment barriers to contaminant release, and potential risk pathways. However, a rating for specific receptors will not be assigned to the long-term post-cleanup period.

- **Economic Assets.** The Hanford Site and its vicinity include a range of economic assets that may be impacted by cleanup activities at Hanford. DOE economic assets include the Hanford Site infrastructure. Commercial activities on the Hanford Site include the U.S. Ecology low-level waste disposal facility, Energy Northwest nuclear power generation, and multiple PNNL research laboratories. Furthermore, the regional economy may be impacted by public perceptions of cleanup activities at the Hanford Site. EU evaluations indicate when the current status, delay, or cleanup activities may directly affect DOE and non-DOE economic assets.

The overall methodology is illustrated in Figure 2-1 below and brief descriptions of the methodology followed for each of the receptors evaluated are discussed later in this chapter.

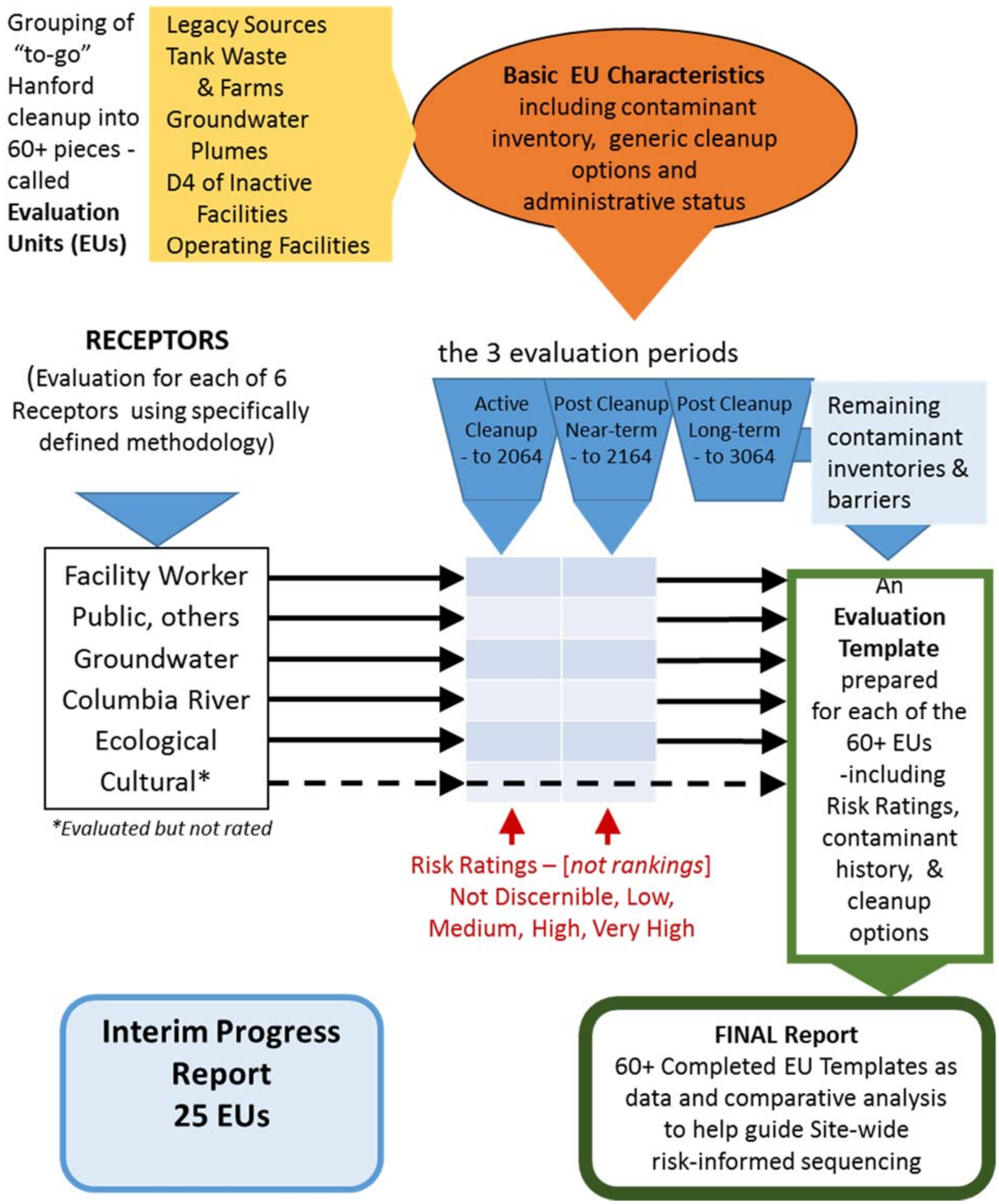


Figure 2-1. Methodology overview for the Hanford Site-wide Risk Review Project.

List of Evaluation Units / Maps of Evaluation Unit locations

Table 2-1. Listing of evaluation units. (EUs highlighted in blue are included in the interim report.)

The general locations of the EUs, except the groundwater EUs analyzed in this report, are shown in Figure 2-2. More detailed maps of all EU locations can be found in Chapter 3.

EU ID	Group	EU Name	Description & Comments	Operable Unit Crosswalk	Related EUs
Legacy Sites					
RC-LS-1	Legacy Source	618-11 Burial Ground	618-11 Burial Ground	300-FF-2	CP-GW-1
RC-LS-2	Legacy Source	K Area Waste Sites	Legacy waste sites within the fence at 100-K, where remediation is post 2015	100-KR-1, 100-KR-2	RC-DD-2
RC-LS-3	Legacy Source	Orchard Lands	Pre-Hanford orchard lands	100-OL-1	
RC-LS-4	Legacy Source	618-10 Burial Ground	618-10 Burial Ground	300-FF-2	
CP-LS-1	Legacy Source	BC Cribs and Trenches	Cribs, trenches, and tank located to the south of the 200 E Area	200-BC-1	CP-LS-17, CP-GW-1
CP-LS-2	Legacy Source	Plutonium Contamin-ated Waste Sites	Plutonium (Pu) contaminated cribs and trenches associated with the Plutonium Finishing Plant (PFP) in central part of 200 W Area	200-PW-1,3,6 200-CW-5	CP-DD-5, CP-GW-2
CP-LS-3	Legacy Source	U Plant Cribs and Ditches	Liquid waste discharges in the central part of 200 W Area associated with U Plant operations	200-DV-1, 200-WA-1	CP-LS-7, CP-DD-3, CP-GW-2
CP-LS-4	Legacy Source	REDOX Cribs and Ditches	Liquid waste discharges in the southern part of 200 W Area associated with Reduction-Oxidation Plant (REDOX) (S Plant) operations	200-WA-1, 200-DV-1	CP-DD-4, CP-GW-2
CP-LS-5	Legacy Source	U and S Pond	Liquid waste discharges in the southern part of 200 W and outside the fence of 200 W associated with U and S ponds and closely related trenches, ditches, and cribs	200-CW-1, 200-OA-1	CP-GW-2
CP-LS-6	Legacy Source	T Plant Cribs and Ditches	Liquid waste sites on the northern end of 200 W Area (associated with T Plant operations)	200-WA-1, 200-DV-1	CP-GW-2

EU ID	Group	EU Name	Description & Comments	Operable Unit Crosswalk	Related EUs
CP-LS-7	Legacy Source	200 Area HLW Transfer Pipeline	High-level waste (HLW) pipelines outside of tank farm EUs. Includes 200 East-West transfer lines, IMUSTS, catch tanks, diversion boxes, etc.	200-IS-1	CP-TF-1 through -9
CP-LS-8	Legacy Source	B plant Cribs and Trenches	Liquid waste sites on the west side of 200 E (associated with B Plant operations)	200-EA-1, 200-DV-1, 200-OA-1	CP-DD-2, CP-GW-1
CP-LS-9	Legacy Source	PUREX Cribs and Trenches (inside 200 E)	Liquid waste sites on the east side of 200 E (associated with PUREX (Plutonium Uranium Extraction Plant) operations and immediately surrounding PUREX)	200-EA-1, 200-PW-3	CP-DD-1, CP-GW-1
CP-LS-10	Legacy Source	PUREX and Tank Farm Cribs and Trenches (outside 200 E)	Liquid waste sites on the east side of 200 E (associated with PUREX and tank farm operations, but outside the 200 E Area fence)	200-EA-1	CP-GW-1
CP-LS-11	Legacy Source	B Pond	B Pond and associated ditches, where liquid wastes were discharged in the northern and western part of 200 E and outside the fence of 200 E	200-EA-1, 200-CW-1, 200-OA-1, 200-IS-1	CP-LS-7, CP-GW-1
CP-LS-12	Legacy Source	200 West Burial Grounds	Past practice radioactive waste burial grounds, including retrievable stored transuranic (TRU) trenches	200-SW-2	
CP-LS-13	Legacy Source	200 West Miscel-laneous Waste Sites	Waste sites, buildings, and structures associated with maintenance operations, laundry, and coal power plant in the west/central portion of 200 W	200-QA-1, 200-WA-1, 200-IS-1	CP-LS-7
CP-LS-14	Legacy Source	200 East Burial Grounds	Past practice radioactive waste burial grounds	200-SW-2	
CP-LS-15	Legacy Source	200-East Miscel-laneous Waste Sites	Waste sites, buildings, and structures associated with maintenance operations and coal power plant in the southern portion of 200 E	200-OA-1, 200-EA-1	
CP-LS-16	Legacy Source	Grout Vaults	Grout vaults located west of the Hanford Waste Treatment and Immobilization Plant (WTP)	NA	

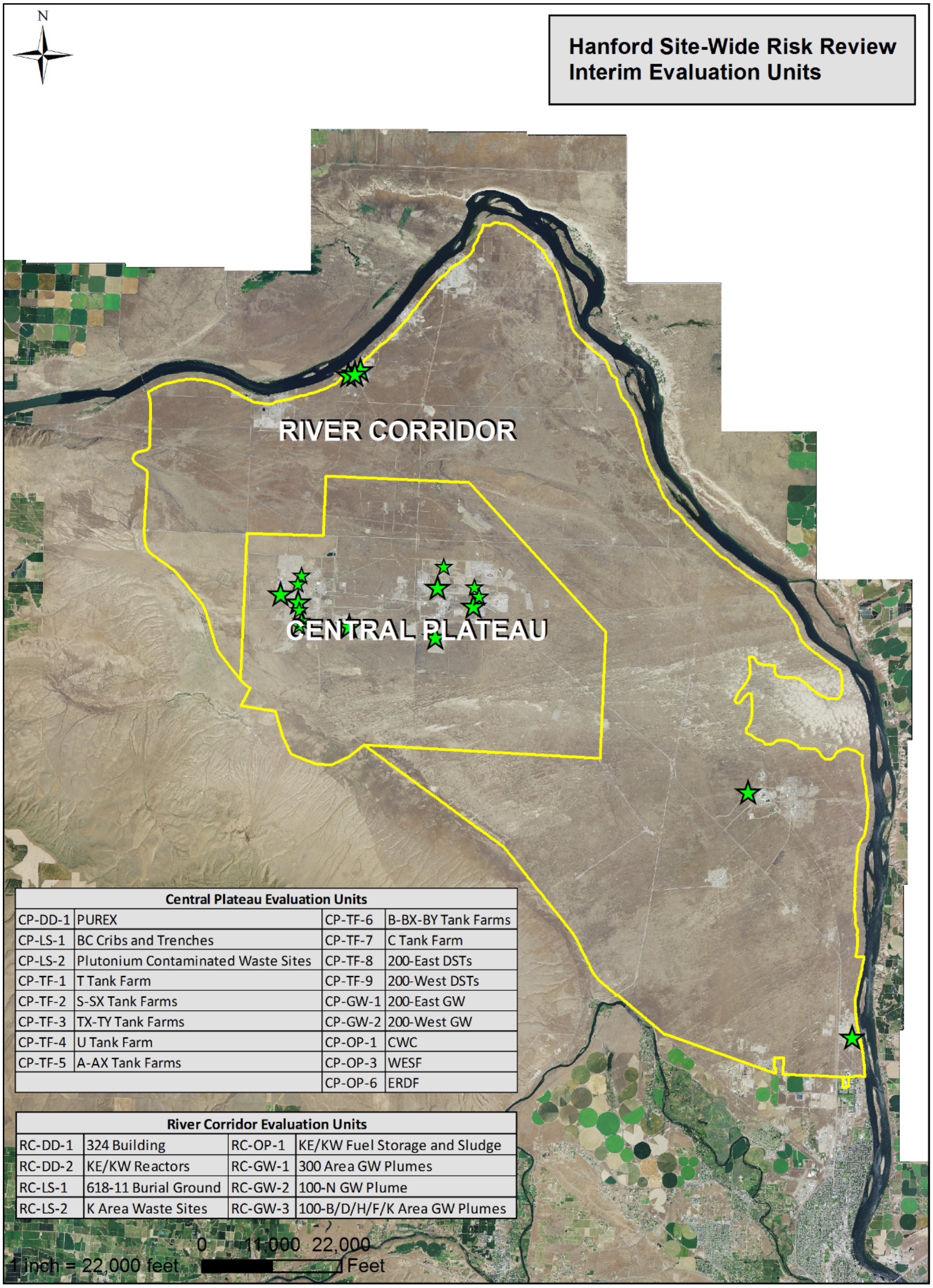
EU ID	Group	EU Name	Description & Comments	Operable Unit Crosswalk	Related EUs
CP-LS-17	Legacy Source	BC Control Zone	Surface contamination area to the south of 200 E (excluding the BC Cribs and Trenches)	200-OA-1	CP-LS-1
CP-LS-18	Legacy Source	Outer Area Sites	Outer area solid waste disposal sites (e.g., NRDWL, SWL, etc.) and other outer area waste sites, miscellaneous buildings, and structures	200-CW-1, 200-CW-3, 200-OA-1, 200-SW-1	
RC-LS-4	Legacy Source	618-10 Burial Ground	618-10 Burial Ground	300-FF-2	
Tank Farms					
CP-TF-1	TF	T Tank Farm	T tank farm, ancillary structures, associated liquid waste sites, and soils contamination	200-DV-1, WMA T, 200-WA-1	CP-LS-7, CP-GW-2
CP-TF-2	TF	S-SX Tank Farms	S-SX tank farms, ancillary structures, associated liquid waste sites, and soils contamination. Includes 242-S Evaporator	WMA S/SX, 200-DV-1, 200-WA-1	CP-LS-7, CP-TF-9, CP-GW-2
CP-TF-3	TF	TX-TY Tank Farms	TX-TY tank farms, ancillary structures, associated liquid waste sites, and soils contamination. Includes 242-T Evaporator	WMA TX/TY, 200-DV-1, 200-WA-1	CP-LS-7, CP-GW-2
CP-TF-4	TF	U Tank Farm	U tank farm, ancillary structures, associated liquid waste sites, and soils contamination	WMA U, 200-WA-1	CP-LS-7, CP-GW-2
CP-TF-5	TF	A-AX Tank Farms	A-AX tank farms, ancillary structures, associated liquid waste sites, and soils contamination	WMA A/AX, 200-EA-1, 200-PW-3	CP-LS-7, CP-TF-8, CP-GW-1
CP-TF-6	TF	B-BX-BY Tank Farms	B-BX-BY tank farms, ancillary structures, associated liquid waste sites, and soils contamination	WMA B/BX/BY, 200-DV-1, 200-EA-1	CP-LS-7, CP-GW-1
CP-TF-7	TF	C Tank Farms	C tank farm, ancillary structures, associated liquid waste sites, and soils contamination	WMA C	CP-LS-7, CP-GW-1
CP-TF-8	TF	200 East Double-Shell Tanks (DSTs)	AN, AP, AW, AY, AZ tank farms, ancillary structures, associated liquid waste sites, and soils contamination	NA	CP-LS-7, CP-TF-5
CP-TF-9	TF	200 West DSTs	SY tank farm, ancillary structures, associated liquid waste sites, and soils contamination	WMA S/SX	CP-LS-7, CP-TF-2

EU ID	Group	EU Name	Description & Comments	Operable Unit Crosswalk	Related EUs
		Groundwater			
RC-GW-1	GW	300 Area Ground-water (GW) Plumes	300 Area uranium and associated contaminant plumes	300-FF-5	RC-DD-1
RC-GW-2	GW	100-N GW Plume	100-N strontium and associated contaminant plumes	100-NR-2	
RC-GW-3	GW	100-B/D/H/F/K Area GW Plumes	100-B/D/H/F/K Area chromium and associated contaminant plumes, includes pump and treat systems	100-BC-5, 100-KR-4, 100-HR-3, 100-FR-3	
CP-GW-1	GW	200 East Ground-water	Existing groundwater plumes emanating from 200 E Area	200-BP-5, 200-PO-1	CP-LS-1, -8, -9, -10, -11, CP-TF-5, -6, -7
CP-GW-2	GW	200 West Ground-water	Existing groundwater plumes emanating from 200 W Area, includes pump and treatment systems	200-ZP-1, 200-UP-1	CP-LS-2 through -6, CP-TF-1 through -4
		Deactivation (Decontamination) and Decommissioning (D&D)			
RC-DD-1	D&D	324 Building	324 Building and associated soil contamination under the building	300-FF-2	RC-GW-1
RC-DD-2	D&D	KE/KW Reactors	KE/KW Reactors, basin, ancillary buildings, sludge, associated soil contamination	TBD, 100-KR-1, 100-KR-2	RC-LS-2, RC-GW-3
RC-DD-3	D&D	Final Reactor Disposition	C, D, DR, F, H, KE, KW, and N Reactors	TBD	
RC-DD-4	D&D	FFTF	Fast Flux Test Facility and ancillary buildings and structures	NA	
CP-DD-1	D&D	PUREX	PUREX Canyon, tunnels, ancillary buildings, structures, and associated near-surface contaminated soils	200-CP-1	CP-LS-9
CP-DD-2	D&D	B Plant	B Plant Canyon, ancillary buildings (e.g., 224-B), structures, and associated near-surface contaminated soils, includes the D&D of the Waste Encapsulation Storage Facility (WESF) after the capsules are moved into dry storage	200-CB-1	CP-LS-8

EU ID	Group	EU Name	Description & Comments	Operable Unit Crosswalk	Related EUs
CP-DD-3	D&D	U Plant	U Plant Canyon, ancillary buildings, structures, and associated near-surface contaminated soils	200-CU-1	CP-LS-3
CP-DD-4	D&D	REDOX	REDOX Canyon (S Plant), ancillary buildings, except 222-S laboratory, structures, and associated near-surface contaminated soils	200-CR-1	CP-LS-4
CP-DD-5	D&D	PFP	PFP ancillary buildings, structures, and associated near-surface contaminated soils	200-WA-1	CP-LS-2
Operating Facilities					
RC-OP-1	Ops	KW Basin Sludge	KW sludge, basin, and ancillary buildings	100-KR-1, 100-KR-2	RC-DD-2, RC-LS-2
RC-OP-2	Ops	Retained Facilities	Retained Office of Science facilities including the 318, 320, 325, 331, and 350 buildings	300-FF-2	RC-GW-1
CP-OP-1	Ops	CWC	Central Waste Complex (CWC) operations, closure, and D&D	NA	
CP-OP-2	Ops	T Plant	T Plant Canyon, ancillary buildings, structures. Evaluate through operations, then will be preserved as a historical site or undergo D&D	NA	
CP-OP-3	Ops	WESF (only Cs/Sr capsules)	WESF – Evaluate for the storage and removal of Cs/Sr Capsules. D&D included with B Plant EU	NA	CP-DD-2
CP-OP-4	Ops	WRAP	Waste Repackaging and Processing (WRAP) facility operations, closure, and D&D	NA	
CP-OP-5	Ops	CSB	Canister Storage Building (CSB) operations and closure (including adjacent spent fuel dry storage pad)	NA	
CP-OP-6	Ops	ERDF	Environmental Restoration Disposal Facility (ERDF) operations and closure	NA	
CP-OP-7	Ops	IDF	Integrated Disposal Facility (IDF) operations and closure	NA	
CP-OP-8	Ops	Mixed Waste Trenches	Mixed waste trenches (Trenches 31 and 34, next to WRAP) operations and closure	200-SW-2	CP-LS-14
CP-OP-9	Ops	Naval Reactors Trench	Naval reactors disposal trench operations and closure	200-SW-2	CP-LS-14
CP-OP-10	Ops	242-A Evaporator	Operations and D&D of the 242-A Evaporator	NA	CP-TF-5

EU ID	Group	EU Name	Description & Comments	Operable Unit Crosswalk	Related EUs
CP-OP-11	Ops	LERF	Operations and closure of the Liquid Effluent Retention Facility (LERF)	NA	
CP-OP-12	Ops	TEDF	Operations and closure of the Treated Effluent Disposal Facility (TEDF)	NA	
CP-OP-13	Ops	SALDS	Operations and closure of the State Approved Land Disposal Sites (SALDS)	NA	
CP-OP-14	Ops	WTP	WTP operations and D&D. Includes new tanks (if needed), preconditioning, four major facilities, and interim storage elements	NA	
CP-OP-15	Ops	222-S Laboratory	Operations and D&D of the 222-S Laboratory	NA	
CP-OP-16	Ops	ETF	Effluent Treatment Facility	NA	CP-OP-11 CP-OP-12 CP-OP-13
CP-DD-17	Ops	WSCF	Waste Sampling and Characterization Facility and ancillary buildings and structures	200-ZP-1	CP-GW-2

Notes for River Corridor: Includes Energy Northwest, PNNL, HAMMER, and LIGO as a comparator – but not as an EU. Includes infrastructure discussion as context, but not as an EU. Source remediation and D&D (RTD) being completed in FY15 are not included.
Notes for Central Plateau: Includes U.S. Ecology as a comparator – but not an EU. Includes infrastructure discussion as context, but not as an EU. T Plant is an operating facility and an historic site that is eligible for inclusion in the Manhattan Project National Historical Park Act that establishes the park at Hanford Site (S.1847, section 3039 (2014)).



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 2-2. General location evaluation units included in this interim report except groundwater EUs.

RADIONUCLIDES AND OTHER CONTAMINANTS CONSIDERED

The Risk Review Project focuses on radionuclides and contaminants that have been of large, site-wide significance and public concern or are the major contributors to receptor risks at specific EUs (i.e., risk drivers). Collectively, the set of radionuclides and contaminants being considered may differ for specific EUs (because of either presence or absence of specific radionuclides and contaminants and different risk and impact drivers), but are collectively referred to as primary contaminants.[30] In most cases, the list of primary contaminants for each EU will be more limited than the regulatory list of contaminants of potential concern. The radionuclides and other contaminants that are considered to have site-wide significance and are of large public concern at the Hanford Site for the interim report are:

- Radionuclides – cesium-137 (Cs-137); iodine-129 (I-129); isotopes of plutonium (Pu) including Pu-238, Pu-239, Pu-240, Pu-241, Pu-242; strontium-90 (Sr-90); technetium-99 (Tc-99); tritium (H-3 or ^3H_2O); and americium-241 (Am-241)
- Other contaminants – carbon tetrachloride (CT or CCl_4), trichloroethylene (TCE), hexavalent chromium [Cr(VI)], total chromium [Cr(total)], total uranium [U(total)][31], and nitrate (NO_3)

Examples of additional primary contaminants at specific or limited EUs are cyanide (CN), which is present in the B-Complex groundwater plume within the Central Plateau, diesel as total petroleum hydrocarbons (TPH-diesel), lead (Pb), and tributyl phosphate (TBP). Examples of radionuclides include carbon-14 (C-14), which is present in 100 K Area groundwater plume, chlorine-36 (Cl-36), and selected isotopes of nickel and europium. Additional details are provided in the methodology Report (CRESP 2015).

Mercury is considered in inventory estimates and potential impacts through groundwater. However, vapor exposure and impact pathways have not been considered in this report, but will be included for the final report.

DURABILITY OF INSTITUTIONAL CONTROLS

Institutional controls are assumed to be effective for the duration of federal control of designated land areas and the EUs contained therein. Furthermore, institutional controls are assumed only to be effective for 100 years after the transfer of land areas from federal to non-federal control. Some areas of the Hanford Site are currently planned to be under federal control for very long periods (e.g., greater than 300 years for permitted disposal areas in the Central Plateau). Periods of planned federal control may change over time in response to changes in public policy or other decisions. Changes in assumptions of institutional controls may necessitate changes in the end-states of an EU (i.e., changes in final barriers or physical-chemical forms or amounts of remaining contaminants) and cannot be predicted.

EVALUATION PERIODS

Three evaluation periods are considered for each EU in this Risk Review Project:

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[30] The terminology of "primary contaminants" is specific to the Hanford Risk Review Project, with the specific radionuclides and contaminants included based on Hanford history, prior evaluations, and with input from the Core Team.

[31] In the Risk Review Project, the chemical toxicity of uranium tends to drive the risk from this element. The various major uranium isotopes are also tracked for completeness. These include U-232, U-233, U-234, U-235, U-236, and U-238.

- Active cleanup (50 years or until 2064), including the current status and during cleanup actions
- Near-term post-cleanup (2064 to 2164)
- Long-term post-cleanup (2164 to 3064)

The rationale and description for each of these evaluation periods are provided below.

Active Cleanup

The active cleanup period for Hanford is defined as 50 years (i.e., until the year 2064). During this timeframe, all currently planned cleanup is assumed to be completed, except groundwater cleanup, natural attenuation processes when selected as a remedy (for vadose zone and groundwater), and final disposition of entombed reactors and facilities along the Columbia River Corridor. The current designated actions for the entombed reactors are to evaluate the final timeline and removal of these facilities to the Central Plateau in the future with ca. 75 years for reactor entombment to allow for radioactive decay and therefore increased safety associated with future actions.[32] Final onsite disposal units may require very long-term monitoring.

The goal of the Risk Review Project is to help inform decisions by DOE and regulators concerning future sequencing of cleanup activities, including which areas should be focused on earlier for additional characterization and analysis. Thus, the Risk Review Project does not assume a fixed sub-interval in time for cleanup of any specific EU or EU component. Rather, each EU and selected components are evaluated as if cleanup were not to occur for 50 years to provide insights into the risks that may be incurred through delay to help inform sequencing of cleanup actions. However, this is not to infer that delay of cleanup for 50 years is recommended.

Cleanup activities at Hanford are ongoing and are not static. Since the Risk Review Project is being completed in a short timeframe, this means that (1) risks to receptors may change as a result of changing contamination distributions, (2) risk to receptors may change as a result of nearby cleanup activities, and (3) currently undetermined cleanup methods or timing may affect risk in EUs or adjacent EUs.

Although characterization of each EU will include the risks posed by the current and projected contamination, the risk profile for each EU's sources may change significantly during, or as a result of, cleanup activities. Possible changes in the risk profile include increases in risks to workers, accidental or consequential dispersion of contaminants, disruption of biota and ecosystems, disruptions to or exposure of cultural resources, and impacts to nearby operating facilities. The final approach and timing selected for cleanup of each source area where there has not been a regulatory decision is typically, and by definition, not known at this time. Therefore, for EUs where regulatory determinations have not been made, a range of cleanup approaches is examined for each generic type of source when considering risks and impacts from cleanup.

The primary distinctions among different cleanup approaches are the amount of contaminant inventory remaining, barriers that prevent dispersion of residual contamination, and the types of activities required to achieve cleanup (potentially impacting worker safety and surrounding ecology and cultural resources). The range of possible cleanup approaches for any EU will emerge from information on the sources and risks/impacts at specific EUs. Hence, any list of probable cleanup approaches reflects how

[32] The EIS (DOE/EIS-0119D 1989) and its Addendum (DOE/EIS-0222-F 1992) for the disposition of eight surplus Hanford reactors.

the sources might be addressed. The list below provides several examples of the types of different remedial options for the major contaminant sources:

Legacy Source Sites

- Removal (excavation), transport, and onsite disposal
- In situ immobilization (e.g., grouting or injections to form low-solubility minerals)
- In situ treatment resulting in contaminant removal (e.g., in situ biodegradation or natural attenuation)
- In situ phytoremediation (e.g., use of plants to remove contaminants)
- Capping and restoration

Tank Waste and Farms

- Retrieval of waste
- Grouting of tanks and ancillary equipment

Groundwater and Deep Vadose Contamination

- Natural attenuation (e.g., by radioactive decay or biodegradation processes)
- In situ immobilization (e.g., grouting, desiccation, or injections to form low-solubility minerals)
- Capping (i.e., to limit infiltration and recharge)
- Groundwater recovery with or without active flushing (“pump and treat”)

D4 of Inactive Facilities

- Decommissioning and demolition, including in situ D&D
- Full or partial permanent entombment
- Interim entombment followed by further D&D (i.e., allowance for radioactive decay to reduce worker risks and potential impacts)

In addition, disposition of materials and wastes to an offsite federal or commercial disposal site or a national geologic repository is the disposition pathway for several sources of contamination (e.g., TRU, HLW).

For those sources where the cleanup plan has been determined by a final remedial action record of decision (ROD) (EPA 2013), such as for the 300 Area (EPA 2013), or evaluated in an EIS (e.g., DOE/EIS-0391 2012), such as for the tank farms, the selected remedy will be considered the baseline cleanup scenario in the Risk Review Project risk ratings. For sources where there has not been a final remedial decision, the DOE planning basis assumed for each EU is considered as a baseline reference for the range of potential cleanup approaches for each EU and is summarized in Appendix C.

The current status, potential initiating events, and pathways that cause or exacerbate risks are diverse because the EUs contain multiple sources and types of hazards, contaminant inventories, and existing environmental contamination. Initiating events can cause contaminants to move or migrate. Conceptual site models (CSMs) are provided for each EU category to help explain the potential initiating events and pathways to relevant receptors (Chapter 3). Nuclear safety analysis, which is embodied in the DSA process, including hazards analysis (HA), preliminary DSA, and final DSA, provides a detailed evaluation of external and operational initiating events and scenarios that can result in risks to human health from existing hazards. In addition to episodic events evaluated as part of nuclear safety analysis, prevailing conditions, including infiltration and subsurface contaminant transport with groundwater flow, are considered as mechanisms for dispersion of existing environmental contamination and for potential impacts to receptors.

Near-Term Post-Cleanup

The near-term post-cleanup period is for 100 years after cleanup is completed (until the year 2164). This period was selected because it is the interval over which institutional controls are assumed to be in effect for land areas no longer maintained under federal control. During this period, maintenance activities also are assumed to occur as necessary to maintain the integrity of the remaining engineered systems (landfill caps, liners, entombment, etc.), along with active monitoring to detect any new releases and confirm the efficacy of remaining remedial activities (natural attenuation, groundwater containment, etc.). Periodic regulatory reviews are also required by federal law to be continued as long as institutional controls are in place (e.g., CERCLA 5-year reviews).

Post-cleanup does not mean that all contamination has been removed from an EU or the Hanford Site. Thus, there will be a diversity of end-states that constitute "completion" at the EUs. The following are examples that illustrate the range of end-states for "sources" to be achieved at the completion of active cleanup:

- Legacy Source Sites: Cleanup to unrestricted use; cleanup to industrial use standards, or cleanup consistent with other land use designations
- Tank Waste and Farms: Removal of up to 99% of the waste contained in tanks, followed by grouting of tanks and ancillary equipment and capping of the tank farm[33]
- Groundwater and Deep Vadose Zone Contamination: Natural attenuation (e.g., by radioactive decay or biodegradation processes); removal or immobilization of a certain percent of the initial inventory; capping (i.e., to limit infiltration and recharge)
- D4 of Inactive Facilities: Decommissioning and demolition completed; final permanent entombment achieved

The presence of residual contaminants in remediated areas and engineered disposal facilities typically is evaluated through performance assessments under DOE Order 435.1.

Long-Term Post-Cleanup

The long-term post-cleanup period is assumed to extend for 900 years after the near-term post-cleanup period (until the year 3064) for a total post-closure assessment period of 1000 years. This interval was selected to be consistent with current DOE Order 435.1 for performance assessments, evolving Nuclear Regulatory Commission (NRC) recommendations for evaluation of closure of near-surface LAW disposal (ACRS Letter 2014), and the basis of prior contaminant transport modeling information. The same end-states associated with the end of the active cleanup period are assumed to apply until the year 3064, where reasonable. Associated uncertainties, uncertainty ranges, and impacts that may occur beyond this time frame will be clearly identified, where possible.

For many remaining sources, the only reasonable characterization for EUs will be (1) the remaining contaminant inventory along with the physical state and location; (2) the degradation, prevailing natural

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[33] According to the Tri-Party Agreement (Ecology, EPA, and DOE, 1998), retrieval limits for residual wastes are 360 ft^3 and 30 ft^3 for 100-Series and 200-Series tanks, respectively, corresponding to the 99% waste retrieval goal as defined in TPA Milestone M-45-00.

processes (contaminant transport and dispersion associated with recharge and groundwater flow, etc.), or failure modes that can result in dispersal or migration of contaminants from the remaining engineered systems or subsurface contamination; and (3) the probability of significant initiating events. The assumed set of infiltration and recharge rates for the long-term post-cleanup period will be the same as for the near-term, post-cleanup period because they bracket very low to very high infiltration rates that may be possible under a range of land cover and climate conditions.

LAND-USE AND GROUNDWATER USE

For the purposes of the Risk Review Project, it is assumed that all reasonably available land uses at the Hanford Site will have been realized when the near-term post-cleanup period begins or by 2064. This means that land use will be a factor to be considered as part of the evaluation for each EU for two periods: near-term post-cleanup (until 2164) and long-term post-cleanup (until 3064). However, while future land use is an important consideration for determining the extent of cleanup, it is not a direct factor in the urgency or sequencing of cleanup activities from a risk perspective (although it may be for other factors including community preferences). Additionally, in this Risk Review Project, the human health risks associated with land use have been separated between (1) surface (i.e., facilities, soils and waste disposal sites) and near-surface exposures associated with the land use scenario, and (2) use of groundwater. This separate consideration is important because (1) cleanup of facilities and surface and near-surface contamination is most frequently a separate effort from groundwater remediation; (2) treatment or alternate forms of water supply can be provided to facilitate desired land use when the groundwater within the unit being evaluated is not suitable; and (3) groundwater remediation timeframes may be much longer than required to achieve near-surface remediation and alternative land uses.

Direction for the Risk Review Project states, "The review should place Hanford environmental and nuclear safety hazards and risks in context with currently designated future uses of the Hanford site and nearby land uses and activities that have a potential to impact risks, natural resources and cultural resources." (Appendix A). The DOE NEPA determination for future land use at the Hanford Site is defined in the preferred land use alternative under the Comprehensive Land Use Plan EIS and ROD (DOE/EIS-0222-F 1999, DOE/EIS-0222 1999). See Figure 2-3 and Table 2-2 for more specific information on each designation. However, specific exposure scenarios that correspond with the EIS and ROD land use categories have not been developed through past Tri-Party[34] efforts and therefore are not currently available for evaluating risks under those future land use designations.

The State of Washington currently recognizes only "unrestricted use"[35] and "industrial use" as standard land use designations with established exposure scenarios (WAC 173-340-200, 2007). The EPA has recognized the following land uses as available following completion of remedial actions: any combination of unrestricted uses, restricted uses, and use for long-term waste management (OSWER Directive No.9355.7-04, p. 2).

The Core Team has requested that the Risk Review Project consider "unrestricted use," which also has been referred to as "residential land use" to serve as a second basis for assessment along with the primary designation from the land use EIS whenever the primary future land use designation would

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[34] Tri-Party refers to The State of Washington, DOE and EPA.

[35] "...has determined that residential land use is generally the site use requiring the most protective cleanup levels and that exposure to hazardous substances under residential land use conditions represents the reasonable maximum exposure scenario." WAC 173-340-740(1)(a)

conflict with the "unrestricted use" designation or is not designated for industrial use. The alternative land use designation or "unrestricted use" does not apply to EUs located within the Central Plateau.[36]

The Risk Review Project is using "unrestricted use" and "industrial use" scenarios and cleanup levels to understand the risks when land is cleaned up to a less restrictive standard but then failure of institutional controls leads to land usage consistent with a more restrictive exposure scenario (e.g., areas cleaned up to industrial land use and then used in a manner consistent with the residential use scenario). This assessment will be part of the final report.

Results from a limited set of additional alternative land use exposure scenarios also are being used for comparison.

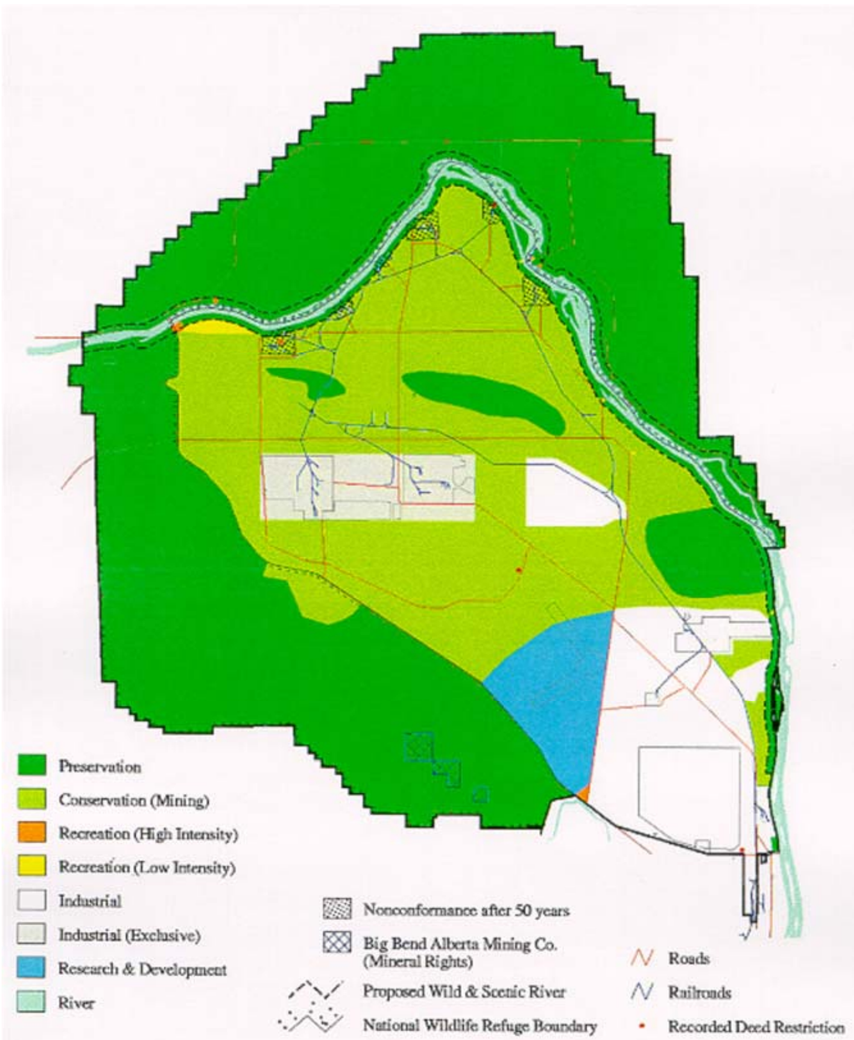


Figure 2-3. Future land use designations from the CLUP (DOE/EIS-0222-F, Figure 3.3).

[36] However, it should be noted that the T Plant (221-T Process Building) has been specifically identified as one of the buildings eligible to be protected under the legislation that establishes a Manhattan Project National Historical Park (see Chapter 8). This designation may require additional considerations with respect to cleanup requirements.

Table 2-2. Definitions of land use designations in the land use EIS and ROD (DOE/EIS-0222-F 1999, DOE/EIS-0222 1999).

Industrial Exclusive	An area suitable and desirable for treatment, storage, and disposal of hazardous, dangerous, radioactive, and nonradioactive wastes. Includes related activities consistent with Industrial-Exclusive uses.
Industrial	An area suitable and desirable for activities, such as reactor operations, rail, barge transport facilities, mining, manufacturing, food processing, assembly, warehouse, and distribution operations. Includes related activities consistent with Industrial uses.
Research and Development	An area designated for conducting basic or applied research that requires the use of a large-scale or isolated facility, or smaller scale time-limited research conducted in the field or within facilities that consume limited resources. Includes scientific, engineering, technology development, technology transfer, and technology deployment activities to meet regional and national needs. Includes related activities consistent with Research and Development.
High-Intensity Recreation	An area allocated for high-intensity, visitor-serving activities and facilities (commercial and governmental), such as golf courses, recreational vehicle parks, boat launching facilities, Tribal fishing facilities, destination resorts, cultural centers, and museums. Includes related activities consistent with High-Intensity Recreation.
Low-Intensity Recreation	An area allocated for low-intensity, visitor-serving activities and facilities, such as improved recreational trails, primitive boat launching facilities, and permitted campgrounds. Includes related activities consistent with Low-Intensity Recreation.
Conservation (Mining)	An area reserved for the management and protection of archeological, cultural, ecological, and natural resources. Limited and managed mining (e.g., quarrying for sand, gravel, basalt, and topsoil for governmental purposes) could occur as a special use (i.e., a permit would be required) within appropriate areas. Limited public access would be consistent with resource conservation. Includes activities related to Conservation (Mining), consistent with the protection of archeological, cultural, ecological, and natural resources.
Preservation	An area managed for the preservation of archeological, cultural, ecological, and natural resources. No new consumptive uses (i.e., mining or extraction of non-renewable resources) would be allowed within this area. Limited public access would be consistent with resource preservation. Includes activities related to Preservation uses.

EVALUATION TEMPLATE

Each Evaluation Template provides a consistent, cohesive, and useful portrayal of the multiple source types within each EU considered. Completed templates for each of the 25 units evaluated for this report may found in Appendices D through H. (See Appendix B of the methodology (CRESP 2015) for a copy of the Evaluation Template.) The Evaluation Template contains the following sections:

- Part I – Executive Summary provides an overview of the EU and its risk evaluations.
- Part II – Administrative Information allows cross-walking of EUs used in this Risk Review Project with regulatory operable units (OUs).
- Part III – Summary Description includes location and layout maps, primary EU components, and land use information.
- Part IV – Unit Description and History includes former and current uses, current extent of environmental contamination, ecological resources setting, and cultural resources setting.
- Part V – Waste and Contamination Inventory summarizes the inventory and physical-chemical form of contaminants present
- Part VI – Potential Risk Pathways and Events summarizes the current conceptual model, cleanup approaches, initiating events, and pathways that can result in risks to receptors over the three evaluation periods.
- Part VII – Supplemental Information and Considerations may include co-location of facilities, sequencing considerations, linkages to other required facilities or unique skills, loss of facility integrity, etc.

External Review

It is important that a broad spectrum of stakeholders, the public, Tribes, and government agencies have an opportunity to comment on documents prepared for the Risk Review Project.

In early September 2014, a draft methodology was posted on a CRESP web page (www.cresp.org/hanford), which is dedicated to the Risk Review Project, and was made available for written comment. In addition, CRESP team members met with the Hanford Advisory Board (public invited), Tribal Nation representatives, affected government agencies, and local elected officials to explain the methodology and encourage feedback. Finally, Core Team members and their staff reviewed the draft methodology, as did a peer-review group of experts. All written input received on the draft document was acknowledged and considered, and provided important input for improving the Risk Review Project methodology. A list of the comments received and an overview of revisions reflected in the methodology report (CRESP 2015) are available as a separate summary document.

Written comment will be solicited from a broad spectrum of stakeholders, the public, Native American Tribes, and government entities after release of the interim progress report (concurrent with the release of the methodology (CRESP 2015)) and after release of the draft final report prepared for the Risk Review Project.

2.2. A PRESUMPTIVE SET OF POTENTIAL PATHWAYS FROM CONTAMINANT RELEASE TO RECEPTORS

Despite the diversity of sources and receptors, there is a limited set of potential contaminant release mechanisms and pathways from source areas to receptors that constitute the focus of the Risk Review Project. The list below identifies the relevant contaminant release and impact pathways of primary importance for each source type. Hence, the following may be considered a "checklist" for evaluating sources within each EU.

Pathways

- Risks from Contaminated Near-Surface Soils – the primary pathways are (1) direct human exposure through land use; (2) transport to the subsurface and groundwater through infiltration; (3) contaminant transport through erosion, biotic processes, or atmospheric dispersion; (4) biota exposure and biotic transport; and (5) exposure to cultural resources.
- Risks from Vadose Zone Contamination – infiltration-induced transport through the subsurface to groundwater and the Columbia River.
- Risks from Engineered Waste Management Facilities (either currently operational or inactive) – initiating events (external or operational) that cause loss of waste/contaminant containment followed by either (1) direct human exposure, (2) atmospheric dispersion, (3) near-surface soil contamination, (4) impaired or precluded use of other resources and facilities, (5) damage to biota or ecosystems, or (6) damage to or destruction of cultural resources.
- Risks from D4 Facility Activities – occur primarily from unanticipated facility conditions and accidents during cleanup and maintenance activities. Accidents or other initiating events prior to completion of decommissioning may cause loss of waste/contaminant containment followed by combinations of (1) direct human exposure; (2) atmospheric dispersion; (3 near-surface soil contamination; (4) impaired or precluded use of other resources and facilities; or (5) damage to biota, ecosystems, or cultural resources.
- Risks from Groundwater Contamination – only may occur when there is active or projected use and/or consumption of contaminated groundwater, or as a consequence of contaminant discharge to the Columbia River. However, groundwater is a protected resource under Washington State and federal regulations, so risks or impacts to groundwater itself are also considered.

Receptors

- Worker Health Risks – occur primarily from unanticipated circumstances and accidents during cleanup and maintenance activities. Occupational health exposures and traumas may occur as a consequence of existing conditions, maintenance, monitoring, or cleanup activities.
- Public Health Risks – occur from exposures to contaminants in air, water, or near-surface soils or consumption of food grown in or harvested from contaminated soils. Potential exposure due to routine excavation or other activities is considered to a depth of 5 m. Groundwater contamination is evaluated separately from other pathways because groundwater use can be (and often is) managed separately from land use.
- Risks to Groundwater – either from waste currently in engineered facilities, near-surface contaminated soils, vadose zone contamination, or through the movement, diffusion, and dispersion of contaminants already present in groundwater. Sources currently in engineered facilities require an initiating event (e.g., cover or liner failure, corrosion or other induced leakage, infrastructure failure causing large water release, large precipitation event, earthquake, accident) to release contaminants to the soil surface or subsurface. Contaminants in near-surface soils and the vadose zone are transported to the groundwater as a function of prior moisture conditions and infiltration rate (location and surface condition dependent), individual contaminant sorption/transport characteristics (subsurface stratigraphy and contaminant dependent), and the distance to groundwater (location dependent). Further spreading of

contaminants in the groundwater depends on contaminant concentration, groundwater flow rate and dispersion, and the individual contaminant sorption/transport characteristics.

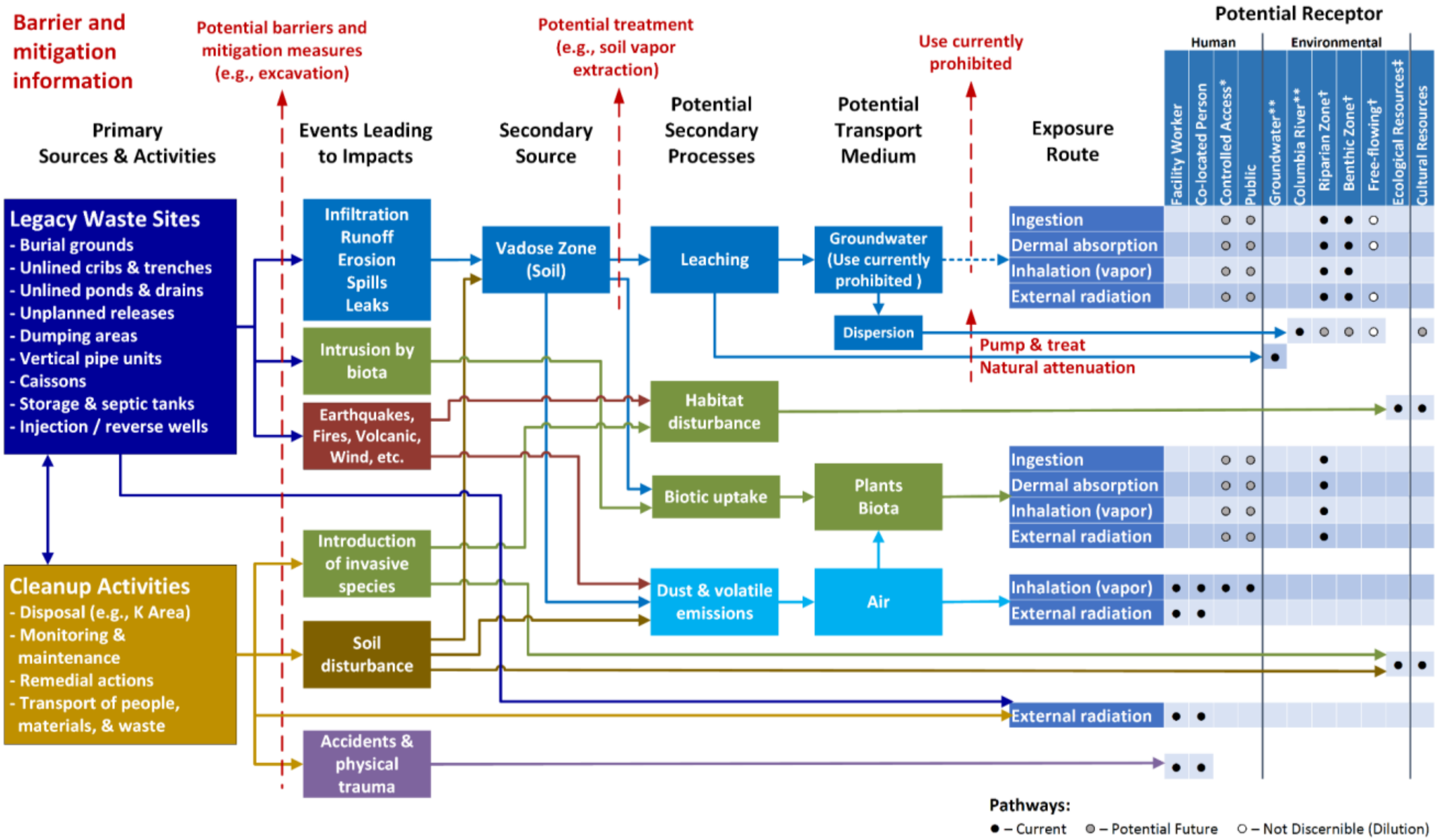
- Risks to the Columbia River – either from current or projected contaminated groundwater discharge through the riverbed or seepage, direct waste discharges, or overland flow and erosion that discharges to surface water. Risks of contaminant exposure in the riparian zone (through seeps) and benthic zone (through groundwater upwellings) originating from the Hanford Site are considered. Human health risks associated from potential surface water contamination originating from the Hanford Site are considered in the context of Columbia River use.
- Risks to Biota and Ecosystems – from physical disruption of an ecosystem, contaminant dispersion and uptake, fragmentation of habitats, or introduction of invasive species resulting from contaminant releases or cleanup activities (either near sensitive ecosystems or as a result of transit pathways to/from remediation activities). Physical disruptions, such as soil compaction, introduction of barriers (e.g., roads), and soil removal, have major impacts on species distribution and ecosystems.
- Risks to Cultural Resources – from physical disruption, destruction, exposure, impaired access, or precluded access resulting from contaminant releases or cleanup activities. Indirect impacts from impairment of view sheds are also considered. Risks to cultural resources will be described but not rated.

There are also potential risks to economic assets as a consequence of cleanup activities, but they are limited to EUs where either the presence of contamination or cleanup activities may directly impact other DOE or non-DOE facilities. Thus, the consideration of economic assets will be constrained to (1) the intersection of specific EUs with specific facilities, and (2) a description of the general economic context of the Hanford Site.

Many EUs may have multiple sources that are aggregated to provide a clearer picture of the risks associated with a geographic area. Evaluations of risks to certain receptors then lend themselves to consideration in the context of individual EUs. These include risks to human health, impacts to groundwater, and risks to the Columbia River. In addition, some receptors require consideration from broader perspectives: (1) a site-wide perspective and (2) the potential risk or impact based on the geographic location of the EU and surrounding areas. These broadly geographically defined receptors include sensitive biota and ecosystems, cultural resources (notably indirect impacts), and economic assets.

Furthermore, cumulative risk assessments are often performed to evaluate the combined fate and effects of multiple contaminants from multiple sources through multiple exposure pathways (MacDonell et al. 2013). However, the risk assessment for this review is very different from that of a baseline risk assessment or performance assessment. First, it is already assumed that there are unacceptable risks associated with contamination on the Hanford Site that must be addressed. Second, isolating single contaminants for EUs through a single exposure pathway (e.g., groundwater) allows the most urgent risks to be identified and helps inform sequencing of remedial actions across the Hanford Site.

A convenient representation of how sources are linked to potential receptors is a CSM (ASTM 1995; Brown 2008). For an environmental system, a CSM represents (often in block form) the biological, physical, and chemical processes that determine contaminant transport from sources through environmental media to potential receptors. Examples of CSMs for each of the five EU types were developed (Figure 2-4 through Figure 2-8) to help elucidate the sources, pathways, and receptors considered in this review. For example, legacy sources (and associated cleanup activities) are common to three of the five EU types, including the Tank waste and farms and inactive facilities (D4) EUs. And, as shown in Figure 2-4, legacy sources typically include sources such as burial grounds, unlined cribs and trenches, unplanned releases, events such as infiltration leading to further contamination of the vadose zone, and other pathways leading to exposure via ingestion and other routes of both human and ecological receptors. Impacts from cleanup activities are also included. The groundwater EU CSM (Figure 2-7) only considers contaminants already in the saturated zone (and potential impacts to groundwater, the Columbia River, and related receptors). The operating facilities EU CSM (Figure 2-6) only considers facilities that do not include legacy sources although many of the pathways and receptors are common to all EU types. The detailed approaches, including assumptions regarding sources, pathways, and receptors, used in the Risk Review Project evaluations are provided in the methodology document (CRESP 2015).



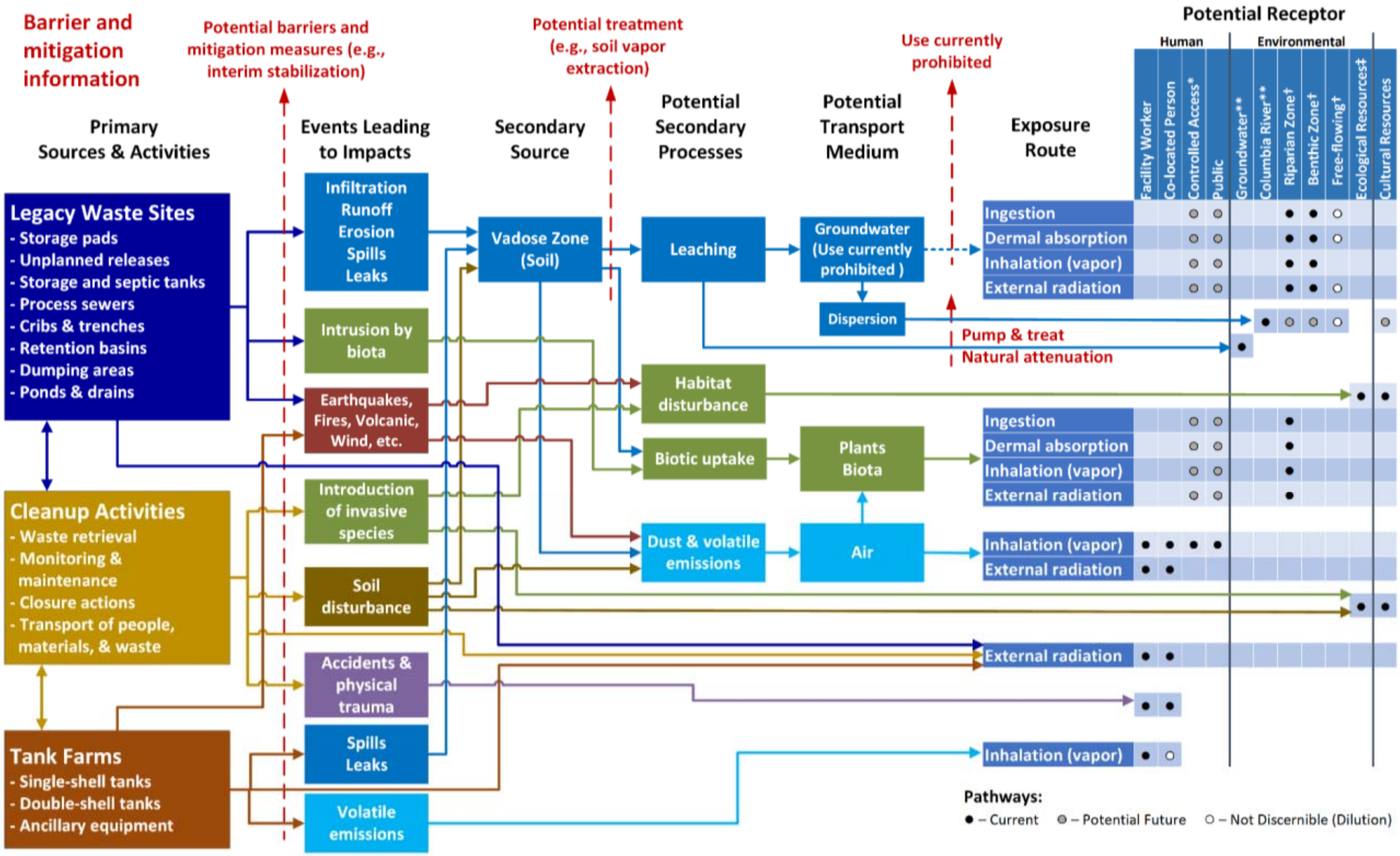
* Activities by members of Tribal Nations are considered a Controlled Access group within human health, recognizing the potential for different exposures as a result of specific cultural practices.

** These are evaluated as protected resources, independent of use.

† Threats to the Columbia River specifically include potential contaminant impacts to the ecology of the Riparian Zone, Benthic Zone, and Free-Flowing River component.

‡ Threats indicated within Ecological Resources focus on habitant disruption and potential impacts to endangered and sensitive species.

Figure 2-4. Legacy source evaluation unit conceptual site model.



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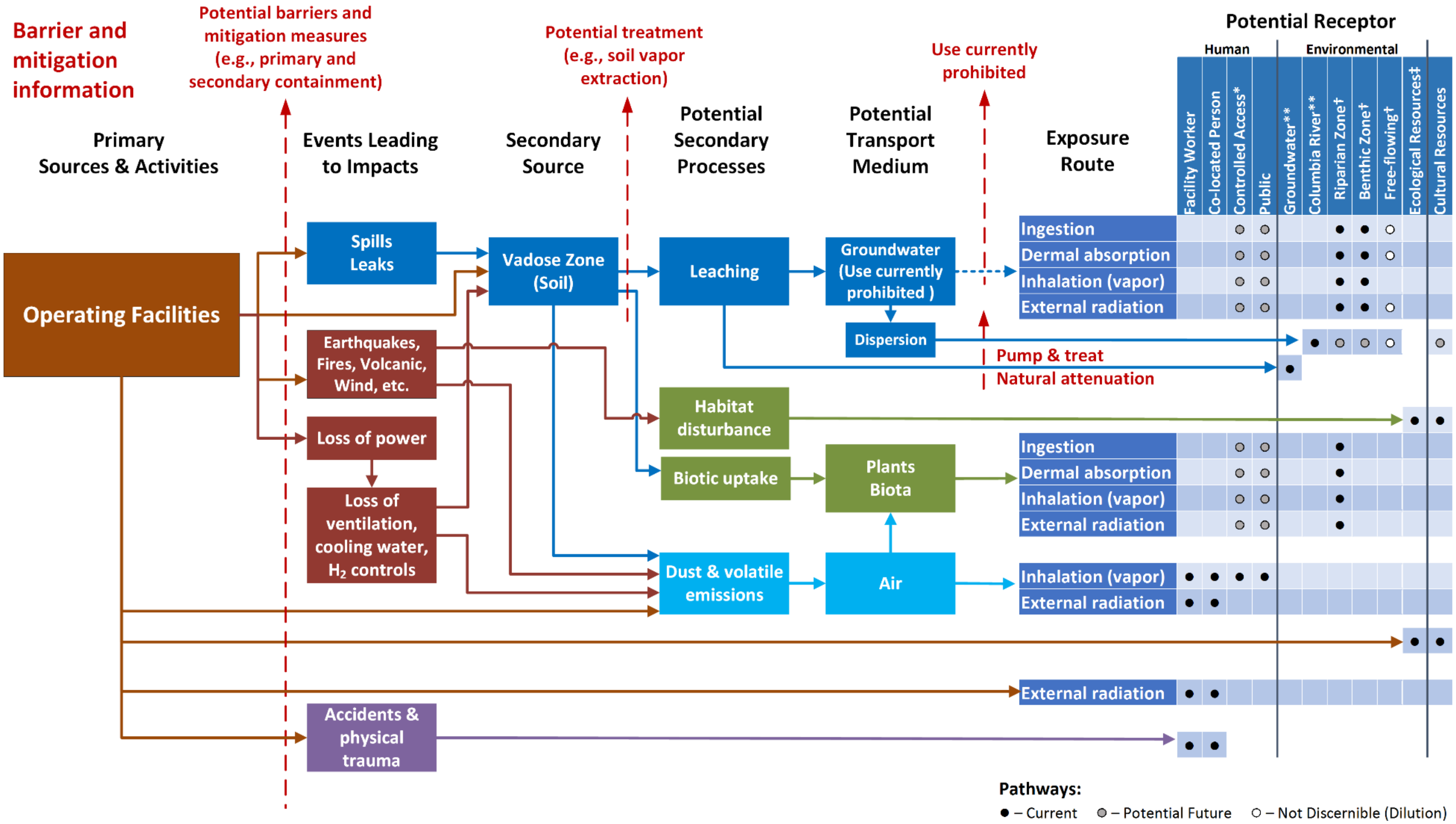
** These are evaluated as protected resources, independent of use.

† Threats to the Columbia River specifically include potential contaminant impacts to the ecology of the Riparian Zone, Benthic Zone, and Free-Flowing River component.

‡ Threats indicated within Ecological Resources focus on habitant disruption and potential impacts to endangered and sensitive species.

Figure 2-5. Tank waste and farms evaluation unit conceptual site model.



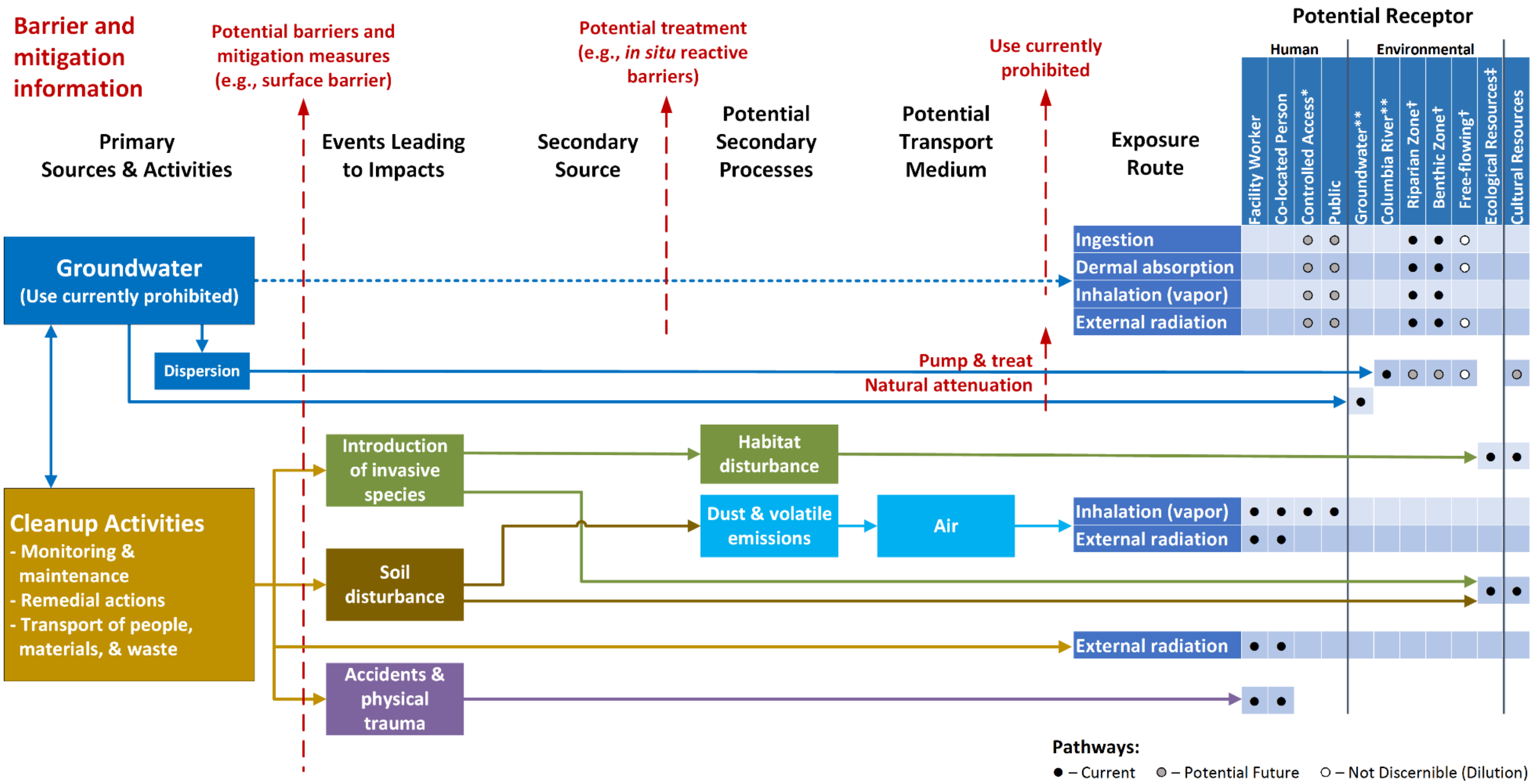
* Activities by members of Tribal Nations are considered a Controlled Access group within human health, recognizing the potential for different exposures as a result of specific cultural practices.

** These are evaluated as protected resources, independent of use.

† Threats to the Columbia River specifically include potential contaminant impacts to the ecology of the Riparian Zone, Benthic Zone, and Free-Flowing River component.

‡ Threats indicated within Ecological Resources focus on habitant disruption and potential impacts to endangered and sensitive species.

Figure 2-6. Operating facilities evaluation unit conceptual site model.



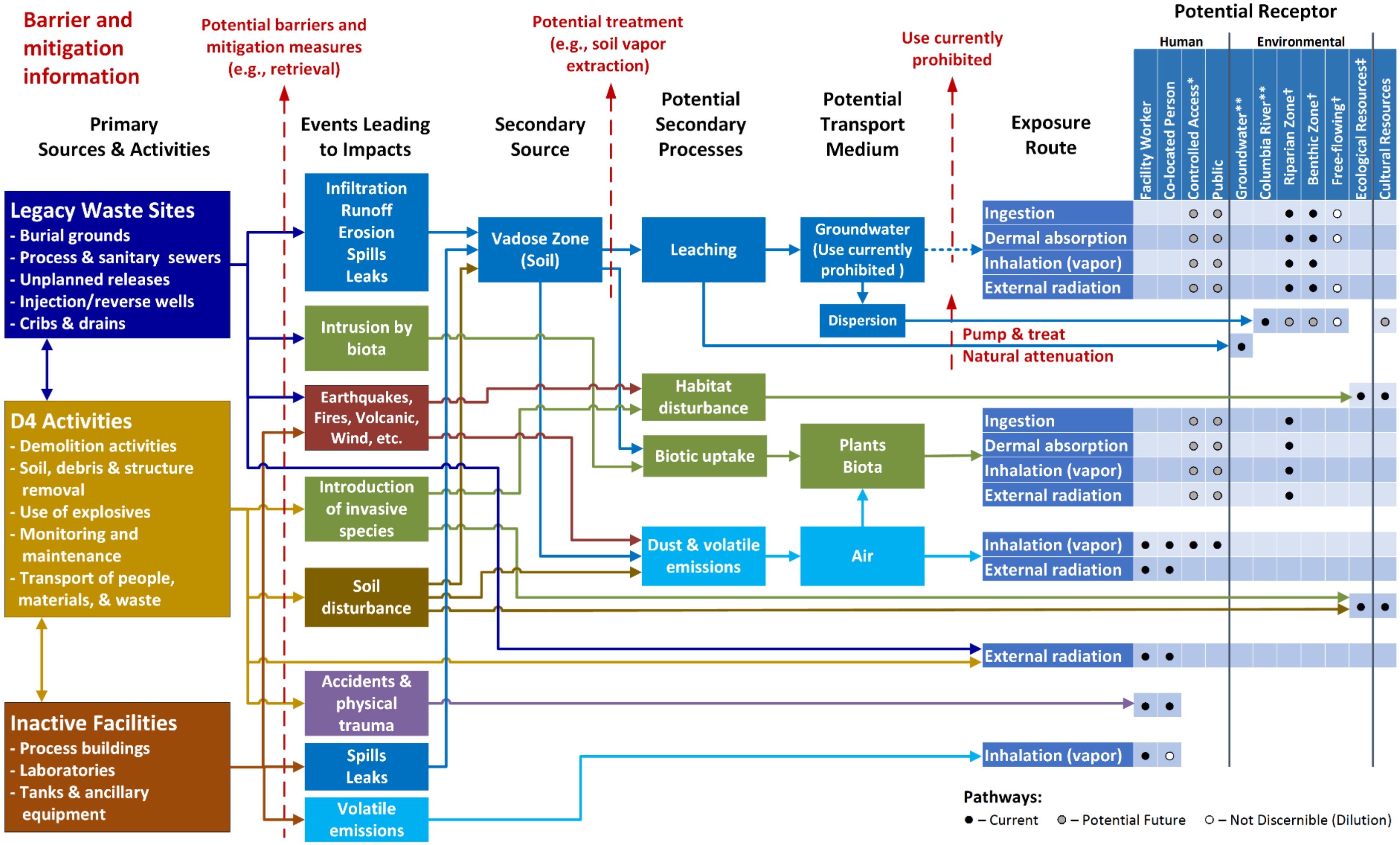
* Activities by members of Tribal Nations are considered a Controlled Access group within human health, recognizing the potential for different exposures as a result of specific cultural practices.

** These are evaluated as protected resources, independent of use.

† Threats to the Columbia River specifically include potential contaminant impacts to the ecology of the Riparian Zone, Benthic Zone, and Free-Flowing River component.

‡ Threats indicated within Ecological Resources focus on habitant disruption and potential impacts to endangered and sensitive species.

Figure 2-7. Groundwater evaluation unit conceptual site model.



* Activities by members of Tribal Nations are considered a Controlled Access group within human health, recognizing the potential for different exposures as a result of specific cultural practices.

** These are evaluated as protected resources, independent of use.

† Threats to the Columbia River specifically include potential contaminant impacts to the ecology of the Riparian Zone, Benthic Zone, and Free-Flowing River component.

‡ Threats indicated within Ecological Resources focus on habitant disruption and potential impacts to endangered and sensitive species.

Figure 2-8. Inactive facilities (D4) evaluation unit conceptual site model.

2.3. EVALUATION APPROACHES FOR SPECIFIC RECEPTORS

USE OF METRICS AND ASSIGNMENT OF RISK RATINGS

A system for categorizing the magnitude and likelihood of risks to each receptor forms the basis for assigning risk ratings to receptors for each EU, within each evaluation period. The risk rating assumes that nuclear safety hazards are assessed based on unmitigated dose estimates because the unmitigated dose integrates across the radionuclide inventory as a *relative* risk metric, and acknowledges that some mitigation measures may be subject to failure, while the Risk Review Project recognizes that typical DOE/contractor mitigation actions substantially reduce most risks, typically to Low or ND.

Specific metrics for each receptor type that provide the basis for the risk ratings are identified in Chapters 5 through 8 of the methodology document (CRESP 2015). Risks and potential impacts are categorized into 5 ratings: Not-discernible (ND), Low, Medium, High, or Very High, where Very High is used only for exceptional cases. Further, for many receptors, the risk rating for an equivalent impact during the active cleanup period is higher than in the near-term post-cleanup period. This rating reduction is considered appropriate for most cases because of the additional response time available before preventative action would be required, and therefore addressing the risk or potential impact is less urgent. In addition, within similar types of EUs, the risk ratings are expected to differ. Risks that are rated higher, therefore, should suggest that remediation should proceed more quickly.

As discussed earlier, the final report for the Risk Review Project will provide a final list the risk ratings for each receptor group, except cultural resources. For example, a final set of tables will provide the risk ratings by receptor for all EUs. There is no scientifically accepted method of normalizing ratings between and among receptors. That is, high risk may mean different things for human health, ecological resources, and groundwater. The final risk ratings will explain the meaning of the risk rating designation with respect to each receptor.

Also, as noted, risks to receptors will not be integrated across different receptor types. The balancing and relative importance of risks to different receptors are driven by individual and collective values, which vary considerably and therefore make integration across different receptor types the domain of DOE and its regulators with input from their constituencies. However, the final report for the Risk Review Project will provide examples that illustrate ways to carry out difficult grouping or binning that integrates the ratings across receptor categories (e.g., integrated risk binning that combines risks to human health with risks to ecology and groundwater).

The methodologies for evaluating risk to receptors are summarized in Section 2.3 of this report and are detailed in separate chapters of the methodology document (CRESP 2015). Descriptions or characterization of the receptors vary somewhat depending on the receptor. For example, ecological receptors are examined in terms of both species and ecosystems of value, cultural receptors include several key periods (Native American (10,000 years ago to present), pre-Hanford Era (1805-1943), and the Manhattan Project/Cold War Era (1945-1990)), and the Columbia River is described with groundwater because it is the groundwater that has the potential to discharge radionuclides and other contaminants to the river. The characterization of resources at risk forms an important basis for developing the methodology for each resource, as well as the basis for determining the risk rating.

The methodology for evaluating each receptor varies because the nature of the receptor varies (e.g., groundwater vs. facility workers). For example, workers and the public include only people, while ecological receptors include thousands of species and many different kinds of ecosystems, and cultural receptors includes many kinds of resources (e.g., artifacts, traditional cultural places, and historic buildings). Further, the Risk Review Project recognizes that risk to any individual is important, while for ecosystems the important consideration is the population of a given species (except in the case of federally or state-listed species).

Initiating Events

The initiating event methodology provides a basis for assigning the likelihood of loss or degradation of barriers and guidance, which is used to assign impacts (consequences) due to the loss of barrier based on the event being considered. For EUs for which there is a DSA, HA, or other document that provides initiating event likelihoods and consequence estimates, these documents are used.

Initiating events are typically episodic events that may occur over short time frames (less than a day) and are considered in addition to natural prevailing processes (i.e., groundwater flow) that may result either by themselves or in combination with initiating events, in risks to receptors from contaminants already in environmental media (e.g., soils, vadose zone, groundwater).

The consideration of initiating events includes those directly attributed to human initiators and natural phenomena. Human-initiated events include human errors or omission or commission leading to accidents, loss of institutional controls, failure of engineered systems, and external events from anthropogenic (man-made) sources (e.g., nearby transportation accidents, aircraft impacts, events at other EUs). Natural events include natural phenomena hazards (e.g., earthquake, high winds, volcanic ashfall, and wildfires) and processes such as structural decay of barriers and facilities exposed to the environs, changes in water table, and drought/climate change that may occur over time. Severe natural phenomena hazards (e.g., seismic events, 1000 year flooding, large geomagnetic disturbances) can result in site-wide or regional impacts leading to additional releases and limit the availability and capability to respond to the event.

Initiating events are qualitatively binned within the following likelihood ranges, which is consistent with DOE and Hanford contractor guidance (e.g., DOE-STD-3009, HNF-8739, TFC-ENG-DESIGN-C-47) for the development of safety analysis:

- Anticipated (A) – events expected to occur $>10^{-2}$/yr
- Unlikely (U) – events expected to occur within the range of 10^{-2} - 10^{-4}/yr
- Extremely Unlikely (EU) – events expected to occur within the range of 10^{-4} - 10^{-6}/yr
- Beyond Extremely Unlikely (BEU) – events expected to occur $<10^{-6}$/yr

The initiating event methodology also provides guidance related to the damage to a barrier the event is expected to cause. Note: The consequence determinations within HAs and DSAs and the hazardous material exposures are usually limited to short durations (e.g., less than 8 hours) and do not include food or water pathways. For the Risk Review Project, longer-term consequences and the additional receptor pathways are also considered. Event consequences are categorized as having the following impacts:

- (Low) Localized Impacts – events associated with damage to individual barriers, which may result in release of material and immediately impact the nearby worker but which are not expected to have impacts outside the facility/area boundary. Environmental impacts are expected to be limited and able to be mitigated and remediated. From a radiological inventory standpoint, these are events associated with less than Hazard Category 3 (DOE-STD-1027, CN1) quantities of material. Within a Documented Safety Analysis or Hazards Analysis, these events are typically identified as having High or Significant consequences to the Facility Worker and

Low or Negligible consequences to a Co-located Person (e.g., < 25-100 rem, < Protective Action Criteria (PAC)-2/3) and to the Public (e.g., < 1-5 rem, <PAC-1/2).

- (Moderate) Facility Impacts – events associated with damage to many barriers or entire facility/systems, which may result in release of material and have an immediate impact on receptors outside the EU site or facility/area boundary but not the overall Hanford Site boundary. Environmental impacts would be expected to be limited to the Hanford Site boundary but could include potential impacts to groundwater. Within a DSA or hazards analysis, these events are typically identified as having High or Significant consequences to the facility worker, Moderate to High consequences (e.g., >25 rem, >PAC-3) to a co-located person and Low or Negligible and consequences to the public.
- (High) Offsite Impacts – Events associated with damage to multiple facilities/systems, which may result in release of material and have an immediate impact on receptors outside the Hanford Site boundary. Environmental impacts would be expected to be seen offsite and could include potential impacts to groundwater and surface water. Within the DSA or hazards analysis, these events are typically identified as having High or Significant consequences to the facility worker and co-located person and Moderate to High (e.g.,>1-5 rem, >PAC-2) consequences to the public.

HUMAN HEALTH

The following categories of potentially exposed persons or populations are defined for evaluation purposes: (1) facility worker, (2) co-located person, (3) controlled access persons, and (4) public. Assumptions and methodology are described in detail in the methodology report (CRESP 2015) for relative rating of each category of potentially exposed persons during (1) the active cleanup period (or until 2064), including the current status of the EU prior to cleanup, where applicable, and during active cleanup (or until 2064); and (2) the near-term post-cleanup (until 2164, or assuming a 100-year duration for institutional controls associated with areas transferred from federal control).

Hanford can be considered as multiple entities: large areas of uncontaminated or minimally contaminated landscape and a mosaic of former industrial lands and disposal areas subject to cleanup. In addition, some areas have near-surface contamination from non-DOE uses (e.g., former orchard lands contaminated from agricultural use of lead arsenic pesticide). Public occupancy is currently prohibited at the Hanford Site, current non-worker exposure is minimal, and access is highly controlled (however, substantial resources are needed annually to maintain this condition).

The mosaic of planned future land uses depends in part on existing contamination, cleanup objectives, and potential future exposure pathways. In the post-cleanup period, some land (e.g., the Central Plateau) may be owned and controlled by DOE or another federal agency, and may have controlled access. Many of the EUs evaluated will likely be remediated in place or have some residual contamination inventory. For this interim report, these are primarily EUs considered part of the "industrial-exclusive" or core zone of the Central Plateau, and are anticipated to remain under federal control. Other parts of the Hanford site after cleanup may be transferred from federal control for other uses (e.g., recreational, industrial, other forms of development or preservation). Future risk assessments may be needed to address uncertainties in current modelling (Scott et al. 2005) or additional cleanup actions may be needed if land use changes.

For the purposes of the Risk Review Project, near-surface contamination is defined as being within the uppermost 5 m of soil or the depth of the constructed facility if it is deeper than 5 m. Groundwater is evaluated separately from land use because (1) groundwater use can be, and often is, managed separately from land use; (2) groundwater is considered a protected resource by the State of Washington, with a goal of restoration to the highest potential use; and (3) there is short-term potential for provision of alternate or treated water supply commensurate with the anticipated uses, until groundwater quality can meet relevant water quality standards (WQSs).

The Risk Review Project considers potential exposures (and their associated risks/impacts) prior to remediation, during remediation, and after completion of remediation. Following cleanup of specific areas, land associated with some EUs may be released for designated land uses with or without associated institutional controls. Other areas (e.g., ERDF and portions of or the entire 200 Area) will probably be maintained by the federal government in perpetuity with controlled access consistent with residual contamination and hazards, intended uses, and mitigation measures to protect human health.

The Risk Review Project is not performing an independent risk assessment, but rather an order-of-magnitude rating or binning of potential risks to human health based on hazards, accident or exposure scenarios, and consequences to different categories of people who may be present on or adjacent to the Hanford Site.

Categories of People Used for Evaluation

The following are definitions for different categories of people used in the Risk Review Project:

- **Facility Worker** – any worker or individual within the facility or activity geographic boundary as established for DSA and located less than 100 m from the potential contaminant release point. This definition is consistent with the DOE definition of a facility worker under the DOE-STD-3009-2014and the Safety Analysis and Risk Assessment Handbook (SARAH) (HNF-8739, 2012).
- **Co-located Person** – a hypothetical onsite individual located at the distance (not less than 100 m or at the boundary of the facility *or activity boundary*) from the point of potential contaminant release at which the maximum dose occurs. If the release is elevated, the person is assumed to be at the location of greatest dose, which is typically where the plume touches down. This definition is consistent with the DOE definition of a co-located worker, but also is expanded to represent any person at the postulated location, independent of that person's activity or employer.
- **Controlled Access Person** – an individual who is granted limited access to the site, within the current site controlled access boundary, for a specific purpose or set of activities. The general location of the site controlled access boundary is indicated in Figure 2-9 and is generally demarcated as the area between Highways 240 and 24 and the towns of Richland and West Richland on the south and west and the south bank of the Columbia River on the north and east. Individuals or groups of people are assumed to be granted access within these boundaries with restrictions. These include risk mitigation measures to provide adequate protection of human health such that resultant health risks would be *Non-discernible* to *Low*.

  Depending on the nature of the access purpose or activities, the restrictions may include any of the following: location, age, or health restrictions; activity restrictions (flora or fauna collection or consumptive practices, excavation, etc.); training; personal protection equipment; and communications and/or notification requirements. This definition has been developed for the purpose of the Risk Review Project. Specific controlled access groups may include (1) people granted access for work-related visits, (2) people granted access for educational activities (e.g., site tours or visiting the B Reactor), and (3) people granted access for recreational activities. Site access for practicing Tribal cultural activities represents a unique controlled access group that will require a clear definition of safety and mitigation measures that may include biomonitoring of collected flora and fauna and should consider unique Tribal use and consumptive practices.

Some groups of controlled access persons will have risks similar to the general onsite workforce (e.g., onsite office workers) if a postulated upset event or scenario occurs based on the controlled access person's location and restrictions (e.g., if children are allowed, risks may be greater). In other cases, groups of controlled access persons will have different risks (e.g., less) than the general onsite workforce because of greater restrictions on where they can be located on site and when they are permitted on site (e.g., restricting access while higher risk activities are occurring). However, the actual risks to controlled access persons under non-work-related activities are not well established at this time because the specific exposure scenarios and mitigation measures are not part of the currently analyzed cases under DOE HAs and DSAs or environmental risk assessments. Thus, further risk analysis most likely will be required, along with evaluation of specific risk mitigation strategies considered as part of granting access to parts of the Hanford Site for non-work-related activities.

Recommending specific controls and mitigation measures for any of the controlled access groups, including for Tribal cultural activities, is beyond the scope of the Risk Review Project.

- **Public** – people present for any purpose outside the Hanford Site controlled access boundary (see Figure 2-9), where access to the surface soil to a depth of 5 m is not restricted.

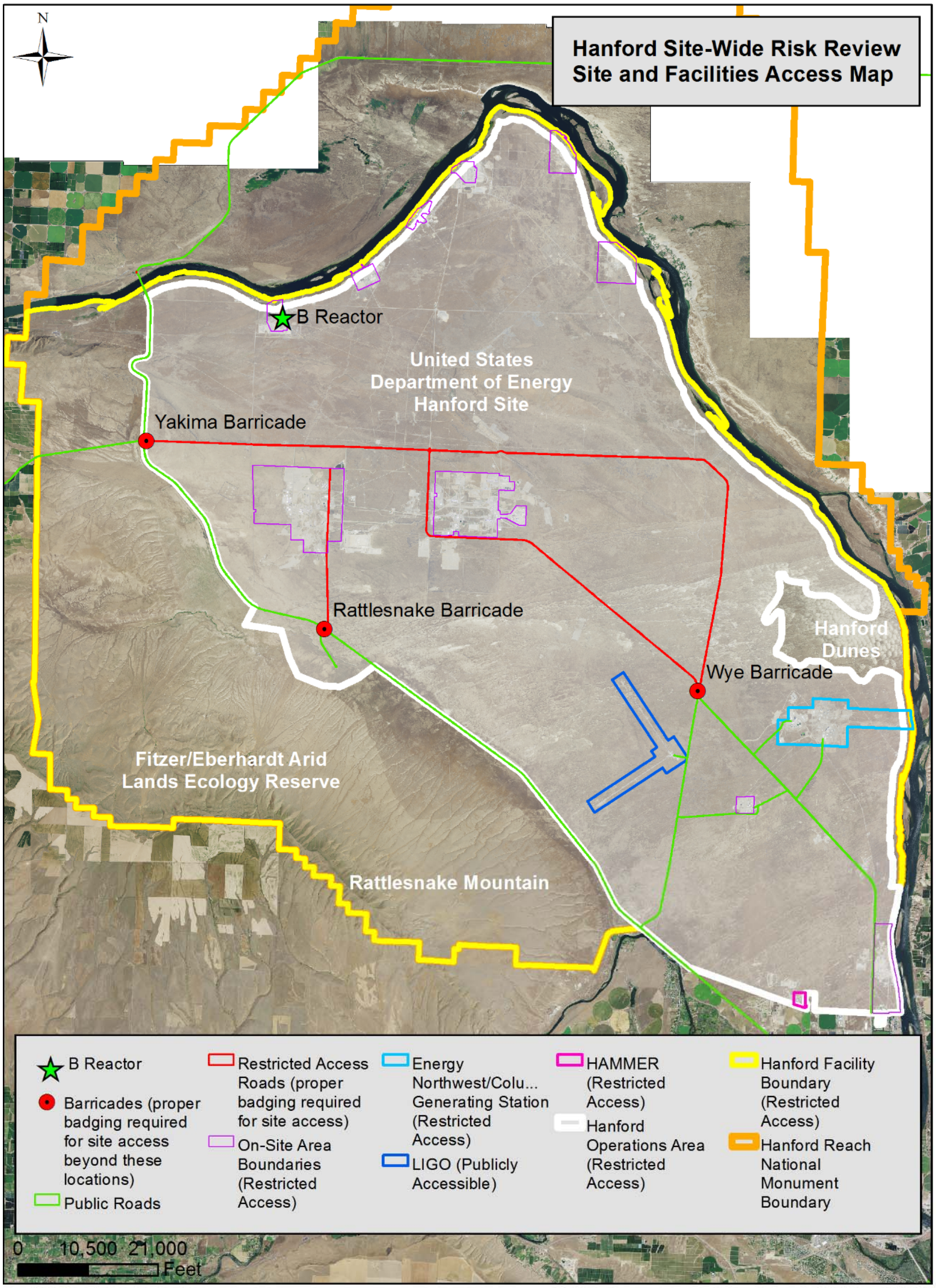


Figure 2-9. Hanford Site boundaries, public roads, and access control points. The shaded area between the river and the highways indicates the controlled access portion of the site. People outside of the lighter gray shaded area would be considered "public."

Health Risk Ratings

A basic assumption is that worker risk only exists when work is actually occurring. Some facilities are intrinsically hazardous due to the inventory and condition of the site. Some tasks are intrinsically hazardous due both to the inventory and to the activities that must be conducted.

The Risk Review Project considers three types of facility worker risk:

- **Type 1** – acute events or upset conditions (i.e., from explosions, fires, earthquakes, structural failures) resulting in blast injuries, fires, collapses, and sudden radiation and chemical releases. These are low probability, high consequence events that may result in death, injury, or exposure of individual or large numbers of facility workers, co-located persons, controlled access persons, or potentially the public. These events or scenarios range greatly in probability and are captured in hazard assessments or DSAs, which should be available (at least in draft) for most of the EUs. The initiating events may be natural disasters or anthropogenic.
- **Type 2** – potential threats associated with occupational hazards from subacute or chronic exposure (hours to days) to site-specific radioactive or chemical hazards (intermediate probability and consequence). Worker safety programs strive to prevent these exposures under "normal" operating conditions. Specific types of hazards in addition to radiation and chemical hazards are known to exist in many Hanford facilities (e.g., asbestos, beryllium, polychlorinated biphenyls (PCBs)) and are considered as part of analyses.
- **Type 3** – industrial accidents and injuries, including, for example, transportation accidents, falls, struck by objects, crush injuries, machinery injuries, and heat stress. These are relatively frequent events, particularly in construction activities, that may result in death or injury, but usually to one or a few individuals, and can be considered higher probability and lower consequence events compared to Type 1 (above).

The three types of worker risk are considered individually to develop a risk rating, since the risks are not additive. Type 2 and Type 3 risks are the domain of industrial safety and are part of the safety culture emphasized in DOE's Integrated Safety Management. As a result, fatalities have been rare in DOE's environmental management program, and lost-time injuries (per job hour) occur at a rate about one-third that of comparable outside work. Thus, mitigated Type 2 and Type 3 risks are *Low* or *ND* for most EUs. An overview of unmitigated hazards to workers, related to the five types of EUs considered in the risk-rating is provided in the methodology report (CRESP 2015).

The hazard assessments and DSAs develop worst-case assessments of unmitigated risks, varying in probability and consequence. These documents also address measures used to prevent (reduce the probability of an event) or mitigate the consequences. Nuclear safety engineering plays a primary role in anticipating, evaluating, preventing, and mitigating the Type 1 hazards. As a result, the mitigated risks are usually *Low* or even *ND*. For each EU, the scenarios that result in the highest unmitigated dose (including the dose estimate) and the primary mitigation measures are summarized in the EU template.

For remediation projects and/or operating facilities that have hazards assessments or DSAs, the rating for Type 1 risks relies on the unmitigated dose estimates to the co-located person as the primary differentiating characteristic. This is because dose estimates usually are not directly calculated for facility workers, and the unmitigated dose to the co-located person considers all significant radiological and chemical hazards present in a facility. *The scenarios that result in significant unmitigated dose are the result of initiating events that may occur with a high uncertainty with respect to probability of occurrence, and therefore the consequence rating is assumed to be the risk rating.* Scenarios with the greatest unmitigated dose to the co-located worker (including the dose estimates) and the mitigation measures are summarized in the EU template.

Radiation Dose Considerations and Risk Review Project Ratings

Table 2-3 summarizes various dose limits, standards, guidelines, benchmarks, and recommendations regarding human exposure to radiation. The discussion that follows only refers to whole body doses. The exposures being considered in the Risk Review Project are from Type I events, with ***theoretical scenarios constructed for safety analysis causing postulated exposures*** lasting hours or days. The dose limits and standards provided in the following table refer most frequently to the dose delivered over a year—referred to as the annual dose. The doses are expressed as “total effective dose”. This consists of summing the dose from all external exposures and adding it to the dose commitment due to oral or respiratory intakes during the year. This distinction is made between internal and external radiation exposure because internally deposited radionuclides deliver their dose over time following the intake. An estimate of the dose that will be received from the annual external exposure and intake is calculated, and then assigned in the year of exposure. This is the standard method of accounting for radiation dose that will be received by the individual as a consequence of the long-term decay and elimination of the radioactive material from their body.

Doses from natural background, therapeutic and diagnostic medical radiation, and participation as a subject in medical research programs are not included in dose records or in the assessment of compliance with the occupational dose limits.

The values in Table 2-3 include the regulatory levels such as dose limits set by DOE (DOE 10 CFR 835) and the NRC (NRC 10 CFR 20) and standards set by the U.S. Occupational Safety and Health (OSHA). Two advisory bodies, the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP) make recommendations regarding allowable or excessive exposure for consideration by regulatory authorities. Some of their recommendations are noted.

These doses are (or would be if an event occurred) superimposed on a background signal of radiation from cosmic rays, terrestrial sources (primarily radon), and internal radionuclides. The average U.S. background radiation (excluding medical uses) was estimated at 360 mrem/yr (BEIR 1990). More recent estimates place the average at 310 mrem/yr (NRC 2014). Background radiation in radon-rich areas can exceed 1000 mrem/yr.

The primary applicable DOE document for controlling radiation exposure of workers at DOE installations is *Occupational Radiation Protection* (10 CFR 835), which defines the radiation protection standard “applicable to DOE, its contractors, and persons conducting DOE activities” and includes equivalent dose limits. In addition to radiation protection limits, DOE establishes “administrative control levels.” These are below the dose limits and are intended to ensure that the DOE limits and control levels are not exceeded. They also help reduce the collective dose to individuals and the worker population. The DOE dose limits take into account information provided by the ICRP, NCRP, and EPA. The whole body dose limit is 5 rem/yr (5 rem=5000 mrem=0.05 Sv = 50 mSv). The DOE administrative level is 2 rem/yr. DOE also has a dose limit applicable to the public of 0.1 rem (100 mrem) per year.

The NRC has similar standards that limit maximum radiation exposure to individual members of the public to 100 mrem (1mSv) per year above background, and limit occupational radiation exposure to adults working with radioactive material to 5 m (50 mSv) per year (NRC 10 CFR 20). The OSHA worker standard is also 5 rem/yr.

Table 2-3. Criteria, standards, guidelines, benchmarks, and recommendations from various U.S. and international agencies for human exposure to radiation (1 mSV = 100 millirem).

Estimated Total Effective Dose (TED[e])	DOSE Limits, Standards, Guidelines, Benchmarks, and Recommendations
0.012 rem (12 mrem or 0.12 mSv)	EPA recommends a 12 mrem/yr dose (effective dose equivalent), corresponding to an estimated 3 x 10^{-4} excess lifetime cancer risk (incidence) for 30 yr residential land use at CERCLA sites.[a]
0.025 rem (25 mrem or 0.25 mSv)	NRC's License Termination Rule (LTR) specifies 25 mrem/yr dose (TED) for unrestricted use from all exposure pathways combined to an average member of the critical group. (http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/full-text.html#part020-1402
0.1 rem (100 mrem or 1mSv)	Expressed as an annual dose limit for public. (DOE 10 CFR 835.207) It is set at 0.1 rem (100 mrem or 1 mSv) per year above background. Other federal agencies (OSHA, NRC 10 CFR 20) use the same limit for public exposures.
0.3 rem (300 mrem[a] or 3 mSv)	Average annual U.S. background radiation from natural sources is about 0.3 rem per year (NRC 2014) NOT including medical uses.[b] An individual's dose depends on many factors including location, altitude, geology, and lifestyle.
2 rem (or 2,000 mrem or 20 mSv)	Occupational dose as recommended by the ICRP[b] is 2 rem (or 0.02 Sv or 20 mSv) per year. DOE establishes an Administrative Control at an occupational dose of 2 rem/yr.
5 rem (or 5,000 mrem or 50 mSv)	Annual occupational dose limit as set by the DOE (10 CFR 835, DOE *Occupational Radiation Protection)* rule for radiation workers specifies a dose limit of 5 rem (or 5,000 mrem or 50 mSv) per year. This is equivalent to both the NRC and the OSHA occupational radiation exposure standard of 5 rem/yr for non-DOE workplaces.
25 rem (or 25,000 mrem or 250 mSv)	If from ***a single short-term event***, the 25 rem DOE dose limit applies to a worker who is protecting large populations or critical infrastructure or performing life-saving efforts in emergency circumstances. This one-time qualified worker dose requires DOE prior authorization to proceed.
100 rem (or 100,000 mrem or 1000 mSv)	A 100 rem dose, occurring from a single short-term event, may cause acute symptoms (nausea and vomiting with 4 h) in 5% to 30%of the exposed population. The risk of fatal cancer is increased by up to 8% (the lifetime risk of fatal cancer without radiation exposure is approximately 24% (NCRP 2005)). A 100 rem dose, accumulated over a working lifetime yields the ICRP[c] recommended maximum lifetime dose for a radiation worker: 1 Sv (or 100 rem). This dose, accumulated over a long period, will not cause acute symptoms in the exposed population. Because the dose is spread out over time, the estimated risk of cancer is cut in half to approximately 4% (In contrast, the NCRP[d] recommends a maximum permissible dose of 0.65 Sv (or 65 rem, which is 10 mSv × age).

a="Although radiation may cause cancers at high doses and high dose rates, currently there are no data to establish unequivocally the occurrence of cancer following exposure to low doses and dose rates – below about 10,000 mrem (100 mSv)". From the USNRC, http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/bio-effects-radiation.html

b=Average background varies with elevation up to about 500 mrem

c=ICRP= International Council on Radiation Protection=consensus body with no regulatory authority

d=NCRP=National Council on Radiation Protection

e= The term TED, which is replacing the earlier TEDE, reflects current international, industry and federal standards and reflects DOE STD 3009-14. Some of the documents cited in this report specify doses using TEDE. For most circumstances, the differences in are not substantial.

Table 2-4 presents the Risk Review Project ratings for facility workers and co-located persons that are based on *unmitigated* dose estimates from DSA or hazard assessments using the estimated unmitigated dose to the co-located worker as the metric for Risk Review Project rating. Similarly, Table 2-5 presents the Risk Review Project ratings for the public. Rating categories for the public are more stringent than for facility workers and co-located persons because of increased training and informed consent associated with worker and onsite activities. Note that rating definitions used by the Risk Review Project are different from DOE-STD-3009 risk rating assignments. These differences were to facilitate more effective risk communication with a general audience in context with information provided in Table 2-3.

Table 2-4. DOE-STD-3009-2014 and Risk Review Project "worker" and "co-located person" risk rating basis for unmitigated Type 1 design basis events (single event unmitigated dose estimates).

Unmitigated Estimated TED[b]	**DOE-STD-3009-2014 Rating (corresponding to DSA or HA ratings)**	**Risk Review Project Rating**
≤0.1 rem		ND[a]
>0.1 rem to ≤5 rem	Low	Low
>5 rem to ≤25 rem	Low	Medium
>25 rem	Medium	High
>100 rem	High	

a. "ND" or "Not Discernible" does not exist in the DOE nuclear safety risk or consequence levels (DOE-STD-3009-2014 or SARAH). This rating is added for binning purposes.

b. The term TED, which is replacing the earlier TEDE, reflects current international, industry and federal standards and reflects DOE STD 3009-14. Some of the documents cited in this report specify doses using TEDE. For most circumstances, the differences in are not substantial.

Table 2-5. DOE-STD-3009-2014 and Risk Review Project "public" risk rating basis for unmitigated Type 1 design basis events (single event unmitigated dose estimates).

Unmitigated Estimated TED[b]	**DOE-STD-3009-2014 Rating** (corresponding to DSA or HA ratings)	**Risk Review Project Rating**
≤0.1 rem		ND[a]
>0.1 rem to ≤1 rem	Low	Low
1 to ≤5 rem	Medium	Medium
>5 rem	Medium	High
>25 rem	High	

a. "ND" or "Not Discernible" does not exist in the DOE nuclear safety risk or consequence levels (DOE-STD-3009-2014 or SARAH). This rating is added for binning purposes.

b. The term TED, which is replacing the earlier TEDE, reflects current international, industry and federal standards and reflects DOE STD 3009-14. Some of the documents cited in this report specify doses using TEDE. For most circumstances, the differences in are not substantial.

GROUNDWATER AND THE COLUMBIA RIVER

Many of the EUs being considered involve discharges of contaminants into the environment that either have 1) resulted in current groundwater contamination, or 2) may in the future impact groundwater, or 3) the groundwater may serve as a contaminant transport pathway for threats to the Columbia River. Threats to groundwater evaluated are:

1. Groundwater currently contaminated and the potential for increased extent of contaminated groundwater from the spread of contaminants already in groundwater;
2. The potential for existing environmental contamination present in the near surface or vadose zone to increase the extent of contaminated groundwater; and,
3. The potential for contaminants currently in engineered facilities (i.e., tank wastes) to increase the extent of contaminated groundwater.

Threats considered to the Columbia River from discharges of contaminated groundwater through springs and upwellings are as follows:

1. Threats to the riparian zone ecology;
2. Threats to the Columbia River benthic zone ecology; and,
3. Threats to the free stream ecology.

The approach used was developed in the context of the highly variable degrees of uncertainty and information gaps in contaminant distributions and subsurface contaminant transport at the many contamination sources within the Hanford Site. Thus, the methodology focuses on groundwater evaluation metrics that may lead to rough-order of magnitude (ROM) differences and thereby allow relative binning of potential impacts and risks from EUs (CRESP 2015). This focus is in contrast to the information needed for a performance assessment or a baseline risk assessment, or the basis for remedial process selection and design.

The primary contaminant groups used in this review that relate to the EUs evaluated in this interim report

[37] are described in Table 2-6, which categorizes them according to their mobility and persistence in the Hanford environment. The categorization was done on a relative basis among the primary contaminants that pertain to the 25 interim report EUs. Mobility relates to the primary contaminant's relative ability to be transported in the subsurface environment (as represented by the contaminant transport retardation factor, R) and is mainly a function of the contaminant's chemistry and sorption with the Hanford subsurface geology. For the radioactive contaminants, the persistence category is based on the radionuclide's half-life. The persistence category of the organic and inorganic contaminants is based on their chemical degradation and biodegradation potential. Chromium, being non-degrading and not radioactive, is classified as having a high persistence in the subsurface.

For the purposes of this site-wide review, the primary contaminants were divided into four groups based on their persistence and mobility. Group A contains technetium-99, iodine-129, carbon-14, hexavalent chromium, and carbon tetrachloride. Group B contains strontium-90, TCE, PCE, uranium, total chromium, and cyanide. Group C contains tritium, nitrate, and TPH-diesel. Group D contains cesium-137 and plutonium. Additional contaminants may be added to the groupings based on review of the full set of EUs. The groups are ranked relative to one another with respect to potential for threats water

[37] Additional contaminants will likely be added to the current group of contaminants indicated here when the remaining EUs are evaluated.

resources, with Group A being the highest (highly mobile and highly persistent) and Group D being the lowest (low mobility and highly persistent) for the purpose of this study.

Table 2-6. Primary contaminant groups used in this risk review project.

		Mobility*		
		Low (R>500)	Medium (5<R<500)	High (R<5)
Persistence	Low		TPH-diesel	$^{3}H_2O$, NO_3
	Medium	Cs-137, Am-241	Sr-90	Cyanide, TCE
	High	Pu, Eu, Ni (all isotopes)	$U^{(total)}$, $Cr^{(total)}$	Tc-99, I-129, C-14, Cl-36, Cr^{6+}, Carbon Tetrachloride

Group A Primary Contaminants
Group B Primary Contaminants
Group C Primary Contaminants
Group D Primary Contaminants

* Assume most mobile form of contaminant
R = retardation factor

The major steps of the evaluation process are (1) identifying EUs that either are impacting or may impact groundwater; (2) compiling relevant information concerning the source, vadose zone, and saturated zone for each EU; (3) calculating the evaluation metrics for each EU; and (4) comparing the evaluation metrics. Information gaps, uncertainties, and data gaps will be described for each EU. The methodology considers the three evaluation time frames defined for the Risk Review Project: active cleanup (50 years, to 2064), near-term post-cleanup (100 years post cleanup, to 2164), and long-term post-cleanup (1000 years post-cleanup, to 3064 or beyond where indicated) (CRESP 2015). Three possible recharge rates (i.e., surface barrier (0.5 mm/yr), undisturbed plant communities (5 mm/yr), and disturbed soil (50 mm/yr)) are considered to reflect uncertainties and a range of potential local surface conditions over the indicated time frames as a result of ground cover, closure covers, climate variation, and localized surface hydrologic effects.[38]

The evaluation metrics for risks to groundwater from current groundwater plumes and near-surface or vadose zone sources are as follows:

1. The estimated time interval until groundwater would be *impacted* by a primary contaminant where a current plume does not exist over the three evaluation periods. Groundwater is considered *impacted* when a primary contaminant concentration exceeds a threshold value, e.g., a drinking water standard or maximum contaminant level.

[38] A value of 100 mm/yr is used when needed to reflect specific conditions (e.g., gravel cover).

2. The estimated amount of groundwater (e.g., areal extent) currently *impacted* by the primary contaminants with existing plumes.
3. The *groundwater threat metric (GTM)*, defined as the volume of groundwater potentially contaminated at the reference threshold concentration (e.g., drinking water standard) based on the estimated contaminant inventory over the three evaluation periods.

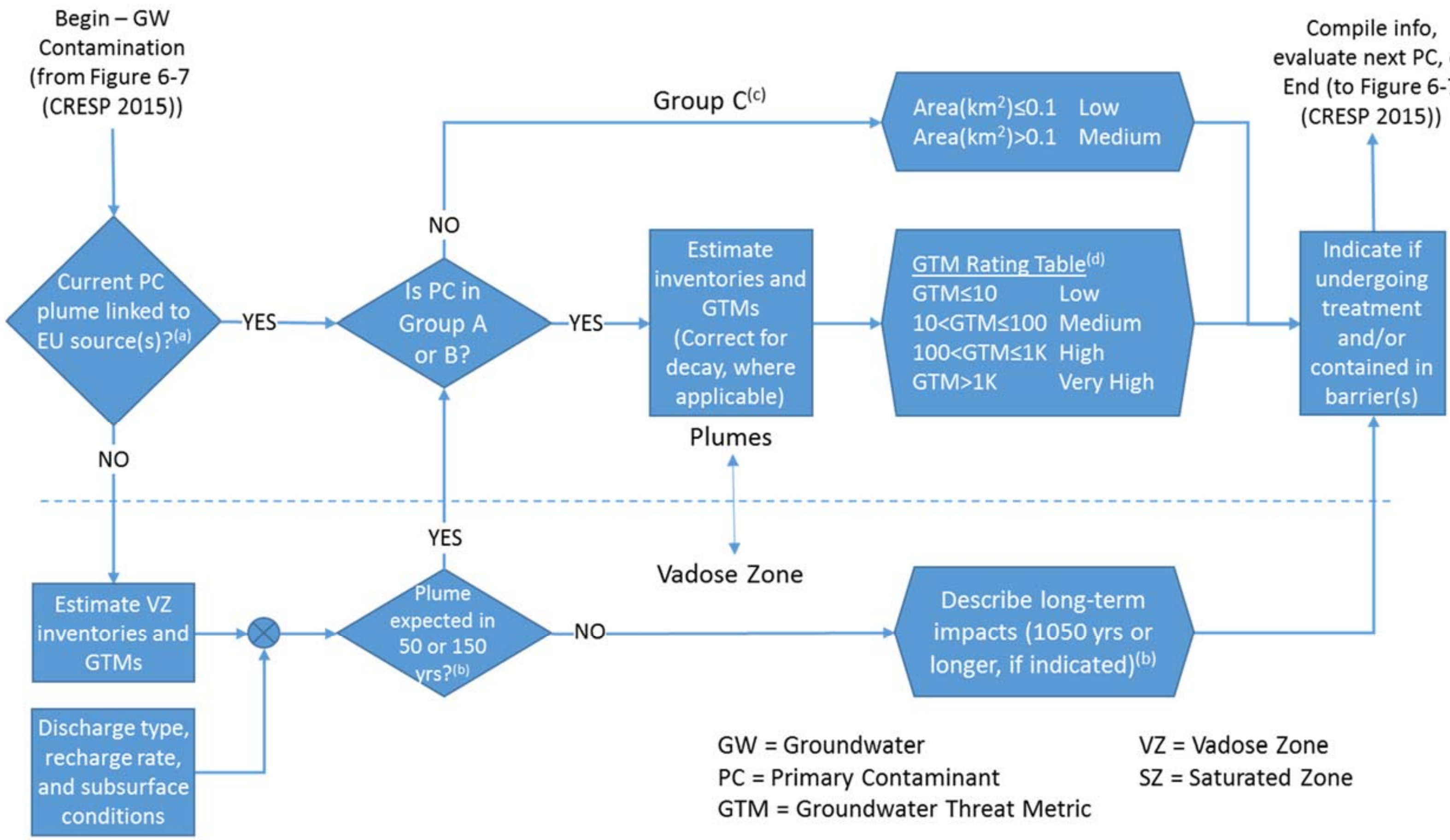
The decision logic for assigning Risk Review Project ratings for existing groundwater contamination and contaminants in the vadose zone and engineering systems is provided in Figure 2-10.

The selected evaluation metrics for risks to the Columbia River from near surface, vadose zone, and groundwater contamination sources are as follows:

1. The estimated time interval until the Columbia River is *impacted* over the three evaluation periods. The Columbia River is considered *impacted* when a primary contaminant concentration exceeds a benthic or free-flowing threshold value.
2. The ratio (R1) of the maximum primary contaminant concentration within the plume to the reference threshold screening value (e.g., Biota Concentration Guide (BCG) for radionuclides or ambient water quality criterion (AWQC) for chemicals).
3. The ratio (R2) of the upper 95th percentile upper confidence limit (UCL) on the log-mean plume concentration to the reference threshold screening value.
4. For benthic impacts, the length of river shoreline estimated to be impacted by the plume above a reference threshold.[39]
5. For riparian zone impacts, the area of the riparian zone estimated to be impacted by the plume above a reference threshold.

The decision logic for assigning Risk Review Project ratings for threats to the Columbia River is provided in Figure 2-11. The tables for assigning ratings for Group A and Group B primary contaminants for riparian zone and benthic zone threats are provided in Table 2-7 and Table 2-8, respectively.

[39] The impact area of the Columbia River for the benthic ecology is inherently more uncertain than the length of river reach because the specific area of the groundwater discharge into the river is unknown for most cases. Rather, the length of the river reach can be estimated based on the plume intersection with the river edge. Furthermore, the impacted river length and impacted area are highly correlated based on limited available data (CRESP 2015).



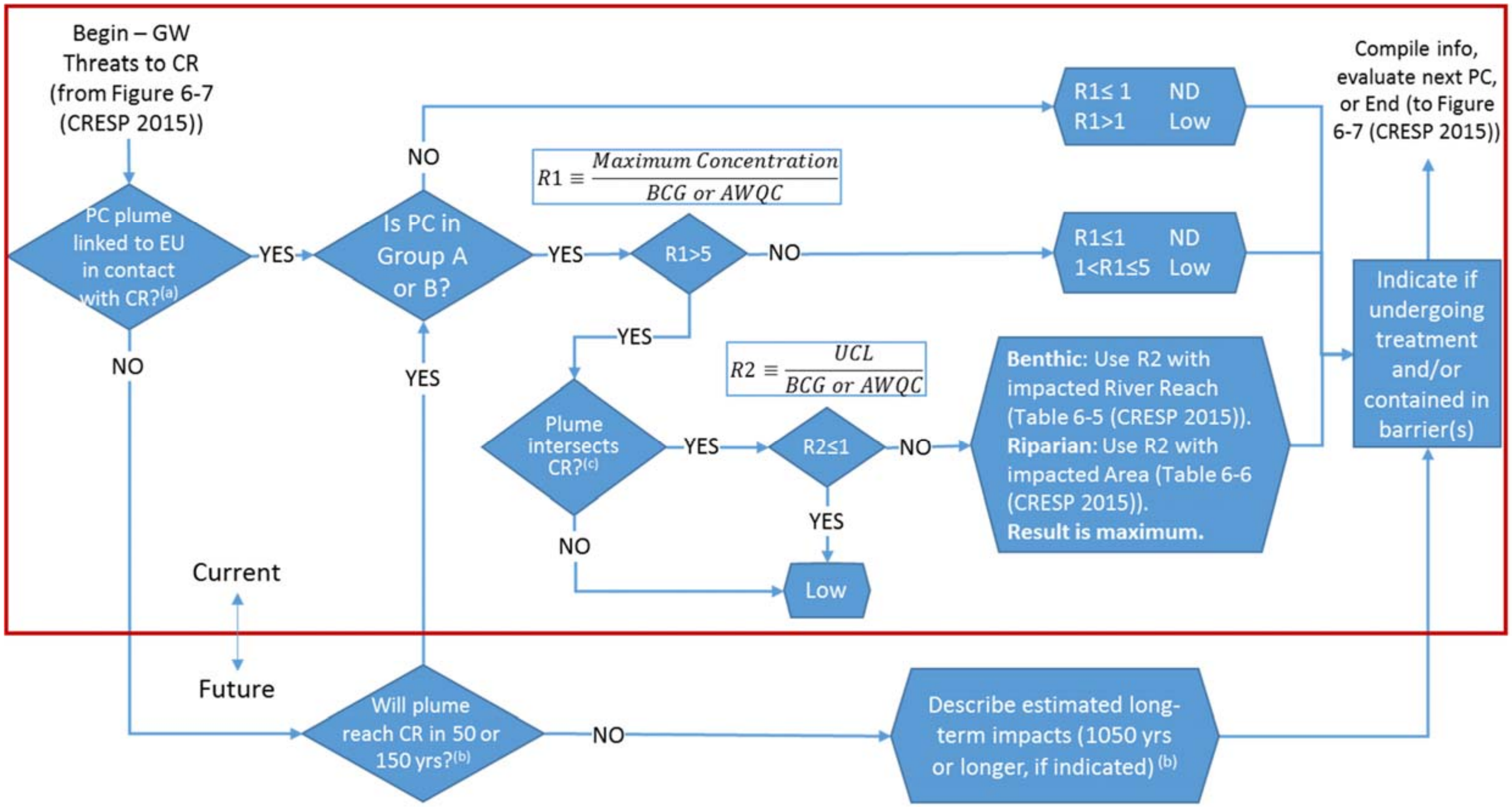
a. Based on plume area above a threshold (e.g., Water Quality Standard (WQS) from 2013 Annual GW Monitoring Report (DOE/RL-2014-32 Rev. 0)). Note plume areas and corresponding estimated plume volumes are (highly) positively correlated.

b. Use available information (e.g., environmental impact statements, risk assessments) to evaluate.

c. Note, no Group D contaminants have been identified as groundwater threats.

d. GTM Rating Table for Group A and B PCs (Table 6-3 (CRESP 2015)).

Figure 2-10. Decision logic for characterizing threats to groundwater as a protected resource with respect to existing groundwater contamination and vadose zone contamination. Note: No Group D contaminants have been identified as groundwater threats.



PC = Primary Contaminant
GTM = Groundwater Threat Metric
UCL = Upper 95% confidence limit (log-mean)
VZ = Vadose Zone
CR = Columbia River
AWQC = Ambient Water Quality Criterion (chemicals)
BCG = Biota Concentration Guide (radionuclides)
ND = Not discernible

a. Based on plume area above a threshold (e.g., Water Quality Standard (WQS) from 2013 Annual GW Monitoring Report (DOE/RL-2014-32 Rev. 0)). Note plume areas and corresponding estimated plume volumes are (highly) positively correlated.
b. Use available information (e.g., environmental impact statements, risk assessments) to evaluate.
c. Based on either aquifer tube data or contours exceeding the threshold (e.g., from PHOENIX at http://phoenix.pnnl.gov/).

Figure 2-11. Decision logic for rating threats to the Columbia River from groundwater contaminants (where steps in red box are for current impacts and those below are for potential future impacts to the river).

Table 2-7. Riparian zone ratings for contaminants based on the area of the potentially impacted riparian zone and the ratio R2 (i.e., (log-mean concentration, 95th UCL)/AWQS)).

	(Log-Mean Concentration, 95th UCL)/(AWQS)			
Area (hectacres)	< 1	1 to < 5	5 to < 10	> 10
<0.5	ND	Low	Medium	Medium
0.5 to < 5	ND	Medium	Medium	High
5 to < 15	ND	Medium	High	High
> 15	ND	Medium	High	Very High

ND = Not discernible
BCG = biota concentration guide for radionuclides
AWQC = ambient water quality criterion for chemicals

Table 2-8. Benthic zone ratings for contaminants based on the estimated length of potentially impacted river reach and the ratio R2 (i.e., (log-mean concentration, 95th UCL)/BCG or AWQC)).

	(Log-Mean Concentration, 95th UCL)/(BCG or AWQC)			
River Reach (m)	< 1	1 to < 5	5 to < 10	> 10
<50	ND	Low	Medium	Medium
50 to < 500	ND	Medium	Medium	High
500 to < 1500	ND	Medium	High	High
> 1500	ND	Medium	High	Very High

ND = Not discernible
BCG = biota concentration guide for radionuclides
AWQC = ambient water quality criterion for chemicals

ECOLOGICAL RESOURCES

The Risk Review Project methodology for evaluating ecological resources on the Hanford Site is an independent evaluation that encompasses evaluations of site resources in comparison to the Columbia Basin ecoregion; evaluations by DOE, the State of Washington, the State of Oregon, Nature Conservancy, and Tribes (where available); and onsite field evaluations in 2014-2015 (CRESP 2015). It uses the level of resource values designed by DOE (DOE/RL-96-32 2013) in conjunction with information from the State of Washington, Tribes, and others. The resource values are modified by field work evaluations of current resource levels and landscape features (patch size, patch shape, connectivity), and exotic/alien species, and considerations of contamination (potential exposure during active cleanup or in the 100 years thereafter). A major contribution of the ecological risk evaluation is the acquisition of new field data on resource level values for the EUs and the surrounding buffer areas.

The risk that the ecological resources experience is a function of contaminants that are present, as well as ecological accessibility, remediation types, functional remediation parameters (e.g., number of people, cars, trucks, heavy equipment, capping, excavation), and scales (temporal, spatial). Ecological resources are at risk not only from contaminants and onsite activities, but from the activities on adjacent habitat. That is, people, cars, and trucks moving through a non-target site to reach the target remediation site can affect adjacent, not-target sites (defined as buffer areas). These effects can be direct (e.g., traffic and habitat disruption, exposure to contaminants) or indirect (e.g., disturbance to animals, dispersal of seeds). Laydown areas can have an important effect, and must be selected carefully to minimize disruption to both EUs and the buffer zone. Post-cleanup risks to ecological receptors include contamination left in place.

This methodology is designed to use available, Geographic Information System (GIS)-based information on ecological resources on the Hanford Site, in addition to field data gathered in 2014 and 2015 (CRESP 2015). The information relates to individual species (which are at risk), species groups (e.g., native grasses and shrubs), and key unique habitats or ecosystems that could be at risk. The methodology was developed so that it could be applied to different EUs, and could be applied by personnel with basic ecological knowledge. While landscape features can be determined from maps, they must be checked in the field, and other necessary field work includes determining the percent of alien/exotic species present on the site, as well as the occurrence of endangered/threated/species of special concern.

The rating scale of Low to Very High used for ecological resources is described briefly below, and is based on the resource levels defined by DOE (DOE/RL-96-32 2013):

- Low = Little probability to disrupt or impact level 3-5 ecological resources.
- Medium = Potential to disrupt or impair level 3-5 ecological resources.
- High = Likely to disrupt and impair level 3-5 ecological resources of high value or resources that have restoration potential, and may cause permanent disruption.
- Very High = High probability of impairing (or destroying) ecological resources of high value (levels 3-5) that have typical (and healthy) shrub-steppe species, low percent of exotic species, and may have federally listed species. Likely to cause permanent degradation or disruption.

CULTURAL RESOURCES

The methodology for evaluating cultural resources at risk at Hanford Site during the active cleanup and near-term post-cleanup periods is an independent analysis that encompasses a thorough review of existing documentation for each unit being evaluated (and buffer area) (Chapter 8 of methodology report (CRESP 2015)). The definition of the term “cultural resources” is identical to the definition used in the Hanford Cultural and Historic Resources Management Plan, which states:

> *Cultural resources is a collective term applicable to: 1)prehistoric-and historic-archaeological sites and artifacts designating past Native American utilization of the Hanford Site; 2) historic-archaeological sites and artifacts indicating post Euro-American activities relating to the pre-Hanford period; 3)Hanford Site Manhattan Project and Cold War era buildings, structures, and artifacts; 4) landscapes, sites, and plants and animals of cultural value to the Native American community; and 5) landscapes, sites, and materials of traditional cultural value to non-Native Americans (DOE/EIS/RL-98-10, Rev 0 Appendix A 2003).*

An overall risk or impact rating or binning for cultural resources is not provided for any of the evaluation periods. This is because cultural resources risks cannot be estimated in the same way that risks, for example, to groundwater can be characterized. Additionally, federal law requires that a cultural resources review be completed before any project activity may begin, including those associated with remediation, regardless of any rating that may be provided (National Historic Preservation Act and Section 106 reviews, 16 U.S.C. 470 et. seq.; 36 CFR Part 800 (2004)). A similar mandate is not imposed for other receptors being evaluated.

At the Hanford Site, this required cultural resources review is carried out for each project activity consistent with federal statutory and regulatory requirements. Requirements include identification, evaluation, and assessment of the potential effects of remediation on cultural resources. And, if adverse impacts to cultural resources are anticipated from the activity, the regulatory process calls for an agreement to be negotiated that outlines mitigation measures intended to minimize and/or avoid any adverse impacts, including those resources located subsurface. The process also mandates procedures for consultation with Washington Department of Archaeology and Historic Preservation, State Historic Preservation Officer (SHPO), Native American Tribes (Tribes), and interested parties or stakeholders.

While the analysis does not include an overall impact rating of Not Discernible, Low, Medium, High, or Very High, the cultural resources impacts (both direct and indirect) during current operations, active cleanup (until 2064), and near-term post-cleanup are made and expressed as known, unknown, or none to cultural resources within the unit being evaluated (and the buffer area). These assignations are based on existing cultural resources documentation from DOE and Washington State records for the unit being evaluated (and immediate surrounding area) or other information made available by Tribes and/or historical societies to establish whether cultural resources are or have been present within that EU. Such a determination is made for each of the three overlapping landscapes that comprise the cultural resource setting at Hanford Site (i.e., Native American (10,000 years ago to present), Pre-Hanford Era (1805-1943), and Manhattan Project and Cold War Era (1943-1990)). Additionally, as noted, direct and indirect impacts are provided. 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.

The purpose of the cultural resources documentation review is to provide guidance to DOE and regulatory agencies as remediation options for the EU are considered. And, if the remediation option has already been determined, the purpose is to provide additional insights to DOE, regulatory agencies, SHPO, Tribes, and other interested parties or stakeholders on the extent to which remediation activities may adversely affect cultural resources. Finally, the analysis of cultural resource-related documentation is intended to provide insights into the residual effects that may remain after completion of cleanup.

The third period, long-term post-cleanup (until 3064), is not being evaluated for risks to cultural resources. This is because it is difficult to predict the presence of cultural resources for a period so remote as no tools exist to determine which of the resources considered significant today and in the near future will have the same level of significance hundreds of years from now.

2.4. CONSIDERATION OF UNCERTAINTY IN THE HANFORD RISK REVIEW

The Hanford Risk Review is not a regulatory risk assessment; however, the Review has many elements in common with regulatory risk assessment especially in terms of the uncertainties in the information used, including that from prior assessments. For example, each step in the risk assessment process incurs several types of uncertainties, and these uncertainties encumber discussions of risk and communication of risk. Uncertainty is inherent in the process even when using the most accurate data and the most sophisticated models (EPA 2005). Sources of uncertainty include 1) intrinsic variability in the processes or variables being studied or analyzed, 2) model variability (parameter estimates), 3) decision-rule variability (choices of processes or variables for inclusion and standards for comparison), and 4) residual variability due to random errors, systematic errors, and inadequate sampling or data. In some cases uncertainties can be estimated or bounded, while in other cases they are unknown. Some information is unknown, and some is unknowable, although more data points can reduce these uncertainties (EPA 2005).

For the Risk Review Project, a central uncertainty results from the unevenness in terms of extent and detail, and frequently very limited or incomplete (and in some cases inconsistent), information available for individual EUs. Identifying key data gaps is also an important part of characterizing risk. The variability in available data is a direct result of the long time period and step-wise process being taken for cleanup of the Hanford Site and that different EUs are at different stages of investigation and cleanup. There are also uncertainties in the natural chemical, hydrologic, and biological systems themselves, as well as the waste characterization and distribution of current environmental contamination. The Risk Review Project has used consistent sources of information wherever possible and has selected a rough order-of-magnitude (ROM) basis for comparing risks (i.e., ratings for different receptors[40]) as a way of managing the large uncertainties and differing states of information as described below. The major contaminated sites were grouped into 60 EUs to make the Risk Review Project and its results tractable. There is an inherent trade-off between grouping contaminated areas into EUs (with the concomitant loss of information, specificity, and variability due to aggregation of source information) and the ability to complete the Review and provide sufficient information to support decision making in a timely and efficient manner. Contaminated areas were grouped in a way to minimize the loss of information and to not mask major risk factors (considering the ROM basis used for comparison). Where found necessary, evaluations were focused on a much finer gradation, including consideration of individual Operable Units for potential groundwater impacts and individual Tank Farms (and individual waste tanks and constituents) for evaluating impacts from Hanford tanks.

Additional information on key uncertainties and the approaches used in the Risk Review Project evaluations is provided in the Methodology, section 2.14.

[40] For example, ratings of Not Discernible to Very High for impacts to groundwater as a protect resource *or* ecological impacts are intended to represent the same comparative ratings; however, ratings are not intended to represent the same results across impacts (e.g., a Low rating for potential impacts to groundwater as a protected resources does not have the same meaning as a Low rating for ecological impacts).

CHAPTER 3. RESULTS FROM REVIEW FOR EACH CATEGORY OF EVALUATION UNITS

3.1. LEGACY SOURCE EVALUATION UNITS

The Hanford legacy EUs represent sites containing contaminant releases to the ground surface or subsurface resulting from prior actions, including waste disposal actions that are no longer being carried out at a particular location and are potentially subject to cleanup. They include past practice liquid waste disposal sites (e.g., cribs, ponds, and ditches), buried solid waste sites (including retrievably stored TRU waste sites), unplanned releases, and associated underground piping and infrastructure. Legacy EUs may affect human health and environmental resources primarily either through near-surface soil-borne contamination or through potential impacts to groundwater.

Evaluations have been completed on the current condition and cleanup alternatives for four of the approximate 24 legacy source EUs: (1) BC Cribs and Trenches, (2) 618-11 Burial Ground, (3) K Reactor Area Waste Sites, and (4) the Plutonium-Contaminated Waste Sites. A comparison of findings is provided below. Figure 3-1 is a map of the Hanford Site showing the location of each of these EUs, with green stars identifying the four EUs included in this interim report and red stars identifying the EUs remaining to be evaluated as part of the final report.

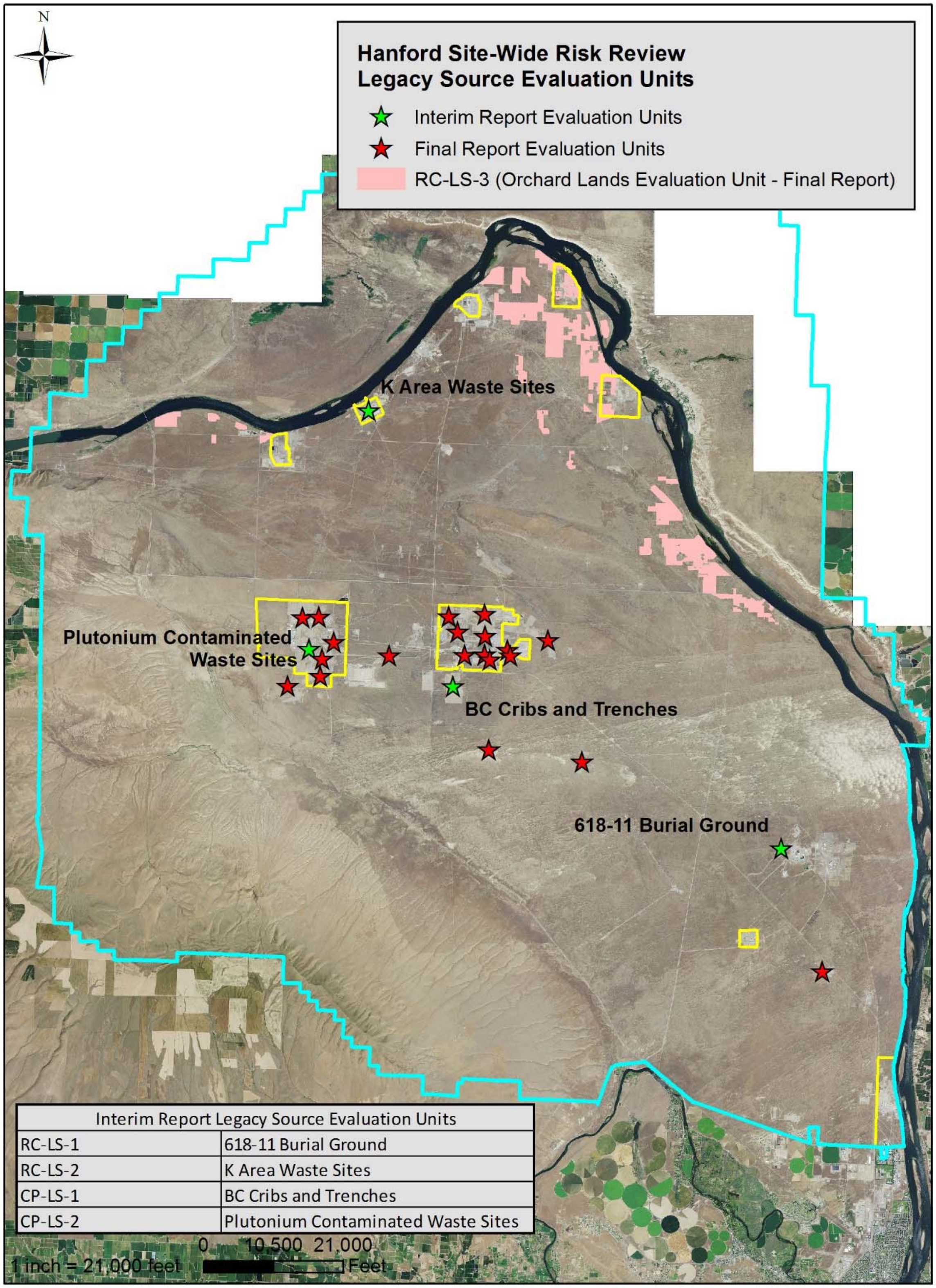


Figure 3-1. Map of legacy evaluation unit locations.

Description of Legacy Evaluation Units

The following are short overview summaries of the Hanford legacy group of EUs considered in this report:

- 618-11 Burial Ground (RC-LS-1)
- BC Cribs and Trenches (CP-LS-1)
- K Reactor Area Waste Sites (RC-LS-2)
- Plutonium Contaminated Waste Sites (CP-LS-2)

618-11 Burial Grounds (RC-LS-1)

The 618-11 Burial Ground (Figure 3-2) received TRU and mixed fission waste from March 1962 until December 1967 from all of the 300 Area radioactive material handling facilities. The burial ground consists of three trenches, approximately 900 ft long, 25 ft deep and 50 ft wide, laid out in an east-west direction. The trenches comprise 75% of the site area. There are 50 vertical pipe units (storage units) that consist of five 55-gallon steel drums welded together and placed vertically in the soil. These are buried in three rows in the northeast corner of the site. There are also approximately five 8-foot-diameter caissons situated at the west end of the center row of the vertical pipe units (Figure 3-3).

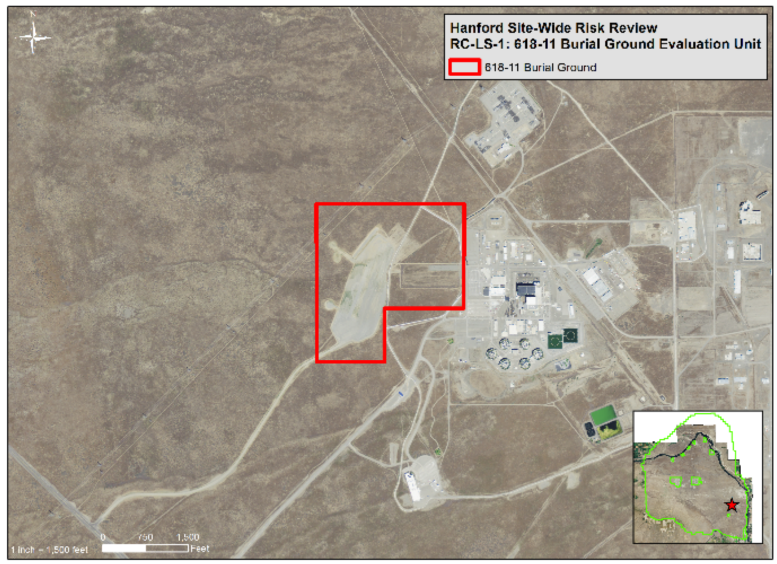


Figure 3-2. Aerial view of 618-11 Site.

Current Status: The 618-11 Burial Ground is closed, covered with soil, and vegetated. It is currently embedded with unconsolidated sands and gravels of the Hanford formation and covered with eolian silts characteristic of this region that have been vegetated with crested wheatgrass. The vegetated silt acts as hydraulic barrier that limits percolation of meteoric water into the waste to minute amounts (1 to 3 mm/yr). However, there is gravel cover over the vertical pipe units and caissons that facilitates elevated levels of infiltration and may drive future contaminant release to the groundwater.

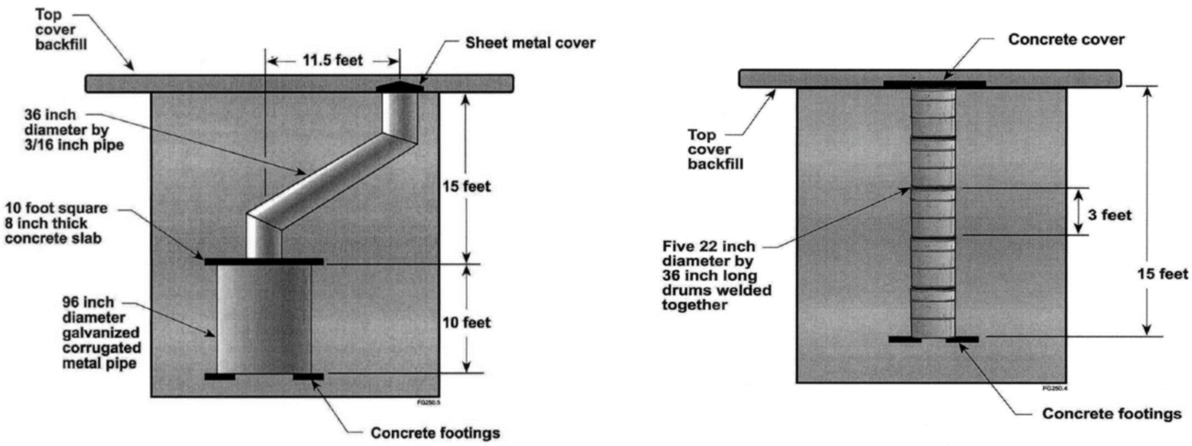


Figure 3-3. Illustration of caissons and vertical pipe units in the ground at 618-11 site (DOE CP-14592, 2003).

A plume containing tritium and nitrate is beneath the site. Concentrations are diminishing due to natural dilution, dispersion, and decay such that the tritium concentration is not expected to exceed drinking water standards when the plume reaches the Columbia River. That is, natural attenuation processes are managing the plume effectively. Additional releases of tritium may occur in the future as a result of leakage from disposed containers.

Primary Contaminants: The waste material was generated during laboratory examinations and studies, including analyses of fuel reactor samples, characterization of the chemical and physical properties of immobilized forms of plutonium, and analysis of ruptured reactor fuel (Table 3-1) (Dunham 2012). Specific waste items may include wipes, towels, protective clothing, cardboard, metal cans, high efficiency particulate air (HEPA) filters, stainless steel tubing, plastic pipe, lead (bricks and sheeting), polyethylene bottles, failed machinery, used lab ware (beakers, pipettes, vials, and tubing), gloves, lab equipment (balances, drying ovens, heating mantles, pumps, and reaction vessels), thermometers, concrete, soil, plumbing fixtures, and tools (screw drivers, wrenches, and shears). Some drums disposed in trenches contain oil. Also included are sample residues from fuel pellets, ruptured fuel elements, ceramics, and grouted plutonium in cans.

Table 3-1. 618-11 Burial Ground (RC-LS-1) radionuclide inventory (Dunham 2012).

Radionuclides	Group	Curies (Ci)
Americium-241	D	230
Carbon-14	A	NP[(a)]
Chlorine-36	A	NP
Cobalt-60	C	NP
Cesium-137	D	5,300
Europium-152	D	NP
Europium-154	D	NP
Tritium	C	Inventory information not available
Iodine-129	A	NP
Nickel-59	D	NP
Nickel-63	D	NP
Plutonium-Total Rad[(b)]	D	770
Strontium-90	B	4,200
Technetium-99	A	NP
Uranium- Total Rad[(c)]	B	NP

a. Not present at significant quantities for the indicated EU
b. Sum of plutonium isotopes 238, 239, 240, 241, and 242
c. Sum of uranium isotopes 232, 233, 234, 235, 236, and 238

Table 3-2. 618-11 Burial Ground (RC-LS-1) chemical inventory (Dunham 2012).

Chemical	Group	kg
Beryllium	---	330
Carbon Tetrachloride	A	NP
Cyanide	B	NP
Chromium	B	NP
Chromium-VI	A	NP
Mercury	D	NP
Nitrate	C	NP
Lead	D	NP
TBP	---	NP
Trichloroethene	B	NP
Uranium	B	NP

Surficial contamination was noted in 1980 after the site was initially closed and covered with soil. The entire site was subsequently regraded, backfilled with an additional 2 ft of soil, and seeded with crested wheat grass. The seed was irrigated for 6 weeks to establish the vegetation. The current barriers to release include an intact soil cover over the waste site. The depth varies based on what is covered (trench, caisson, vertical pipe units), but the cover is at least 2 m of clean soil. In addition, specific waste disposal units such as the vertical pipe units and caissons contain the higher activity wastes. Boxes containing low-level wastes that were disposed in the trenches probably have degraded.

Primary Risks: The primary risks associated with 618-11 arise from sampling, characterization, and removal operations because of the poorly characterized, high activity and pyrophoric wastes that were disposed. A primary concern is that an upset event during cleanup activities may disrupt operations at the Energy Northwest Columbia Generating Station, which borders 618-11.

Cleanup and Disposition: Remediation of this site is currently slated for completion by 2018, with industrial exposure criteria set as the cleanup level. Buried wastes and associated hard infrastructure (caissons, vertical pipe units) will be removed and disposed in ERDF. During remediation, the primary pathways are likely to be air releases from energetic events and/or accidental fires (the site has a mixture of potentially explosive and or pyrophoric constituents). This pathway probably would have effects to a limited distance from the area, and potentially may be further reduced through secondary containment (work area enclosures) during removal operations.

BC Cribs and Trenches (CP-LS-1)

The BC Cribs and Trenches (Figure 3-4) site lies within the 200-BC-1 OU, south of the 200 East Area. The 200-BC-1 OU consists of 28 waste sites, including 26 cribs and trenches, one siphon tank, and one pipeline. These waste sites were used in the 1950s to dispose of more than 140 million L (38 million gal) of tank waste supernatant from the B, BX, BY, and C Tank Farms. Four trenches received smaller quantities of liquid waste that were generated in the 300 Area and transferred by tanker truck to the 200 Area. The largest volume of waste at these sites was disposed of in six cribs and 16 trenches and was conveyed by an underground pipeline from the B, BX, BY, and C Tank Farms.

Current Status: The BC Cribs and Trenches waste sites are separated into the following four distinct groups based on waste site configuration, primary waste source, and relative volume of waste received: (1) high-volume scavenged waste cribs and trenches; (2) specific retention scavenged waste trenches; (3) specific retention 300 Area waste trenches; and (4) one underground storage tank (200-E-14). An additional contaminant source is derived from the contaminated vadose zone underneath the cribs and trenches. The area is currently covered with clean soil backfill.

Primary Contaminants: The primary contaminants present at the BC Cribs and Trenches include nitrate (NO3-), chromium, Tc-99, Sr-90, Cs-137, U-238 and Pu (Table 3-1 and Table 3-2). According to Ward et al. (2004), the BC Cribs and Trenches are believed to have received approximately 30 Mgal of scavenged tank waste containing an estimated 400 Ci of 99Tc as well as large quantities of NO3- and 238U.

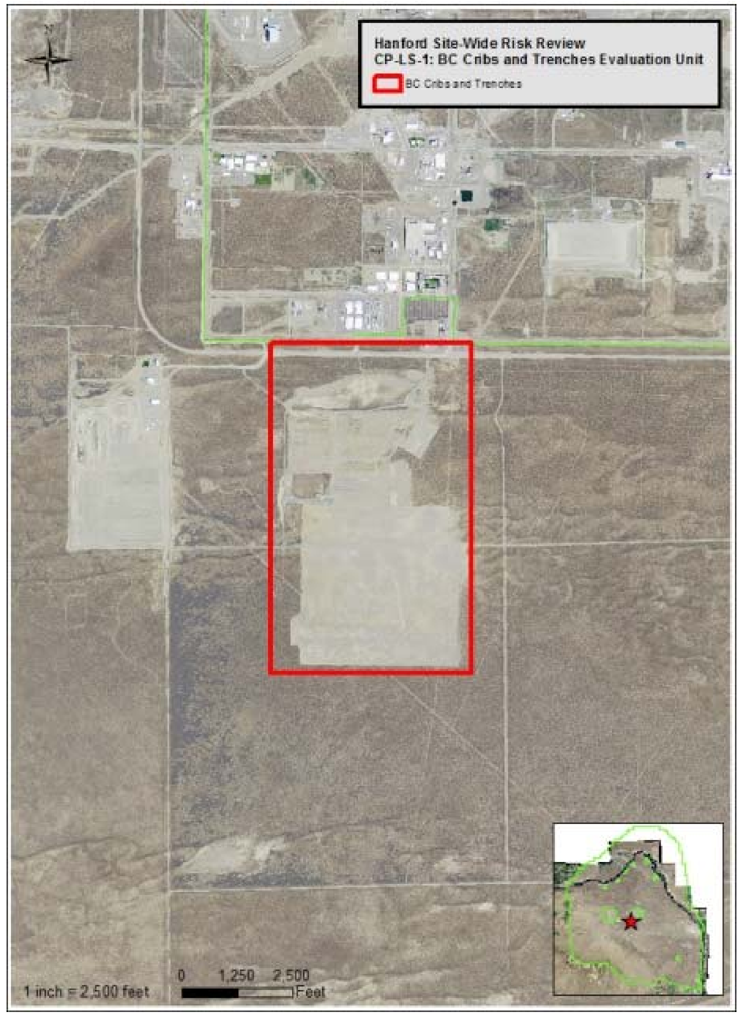


Figure 3-4. Aerial view of BC Cribs and Trenches.

The physical states of the primary contaminants are adsorbed in the contaminated soil and present in crib and trench debris, and the depth of contamination varies by waste site and contaminant. Serne et al. (2009, pp. 9.2 – 9.3) indicate that there is an approximately 15 ft thick layer of sandy silt and fine silty sand at a depth of approximately 120 to 130 ft below ground surface that contains "elevated technetium-99 and EC (electrical conductivity)," and that "the most elevated nitrate concentrations are found from 28 to 245 ft bgs". According to Ward et al. (2004, p. 1.1), "^{99}Tc at concentrations over 75,000 pCi/L were recently reported for a monitoring well near SX-115" although the exact source is unknown. In contrast, some 3.686 x 10^6 L (9.737 × 10^6 gal) of supernatant fluid containing 128 Ci of ^{99}Tc were discharged to seven trenches over a period of about 1.5 years in the BC Cribs and Trenches area, yet there is no evidence of groundwater contamination from the cribs or trenches. The current distribution of ^{99}Tc in the vadose zone beneath 216-B-26 is therefore not easy to explain using current conceptual models. Recent sampling at the 216-B-26 Trench shows a zone of ^{99}Tc contamination between 18 and 53 m. The peak soil concentration exceeds 100 pCi/g, while the pore water concentration is approximately 1.4·x 10^6 pCi/L, both at a depth of about 30 m."

Primary Risks: The primary risk to human health would be through direct contact with the waste, particularly cesium-137 and strontium-90, because high concentrations of cesium-137 and strontium-90 are at relatively shallow depths in the cribs and trenches. However, casual contact with the waste is prevented by site access controls and the layer of clean soil over the buried wastes. The primary vadose zone risks to groundwater (rated as High) are Tc-99, I-129, Cr(total) and Cr(VI). A significant quantity of Sr-90 is present but not anticipated to contaminate groundwater within the 150 year evaluation period.

Table 3-3. BC Cribs and Trenches (CP-LS-1) radionuclide inventory.

Radionuclides	Group	Curies (Ci)
Americium-241	D	190
Carbon-14	A	28
Chlorine-36	A	NP
Cobalt-60	C	27
Cesium-137	D	5,000
Europium-152	D	1.7
Europium-154	D	130
Tritium	C	740
Iodine-129	A	0.65
Nickel-59	D	1.1
Nickel-63	D	95
Plutonium-Total Rad[(a)]	D	170
Strontium-90	B	4,400
Technetium-99	A	410
Uranium- Total Rad[(b)]	B	2.9

a. Sum of plutonium isotopes 238, 239, 240, 241, and 242
b. Sum of uranium isotopes 232, 233, 234, 235, 236, and 238

Table 3-4. BC Cribs and Trenches (CP-LS-1) chemical inventory.

Chemical	Group	kg
Carbon Tetrachloride	A	NP
Cyanide	B	NP
Chromium	B	23,000
Chromium-VI	A	23,000
Mercury	D	35
Nitrate	C	22,000,000
Lead	D	61
TBP	---	NP
Trichloroethene	B	NP
Uranium	B	3,700

Cleanup and Disposition: The designated future land use is Industrial Exclusive. For the BC Cribs and Trenches Area waste sites, five remedial alternatives were identified for detailed and comparative analyses: (1) no action; (2) maintain existing soil cover, institutional controls, and monitored natural attenuation; (3) removal, treatment, and disposal; (4) capping; and (5) partial removal, treatment, and disposal with capping.

K-Area Waste Sites (RC-LS-2)

The K-Area Waste Sites (Figure 3-5) consist of a variety of sites within the fence at the 100 K Area associated with the original plant facilities constructed to support K Reactor operation. Included within the EU are 4 burial grounds, (includes pits, dumping areas, burial grounds), 33 cribs (subsurface liquid disposal, includes French drains, cribs, sumps), 2 infrastructure buildings, 10 pipelines and associated valves, 1 pond/ditch, 6 process buildings, 10 septic systems, 19 storage pads, 11 underground storage tanks, and 9 unplanned release sites. Many of the sites have no contamination, but need to be removed as part of larger K Reactor area remediation efforts.

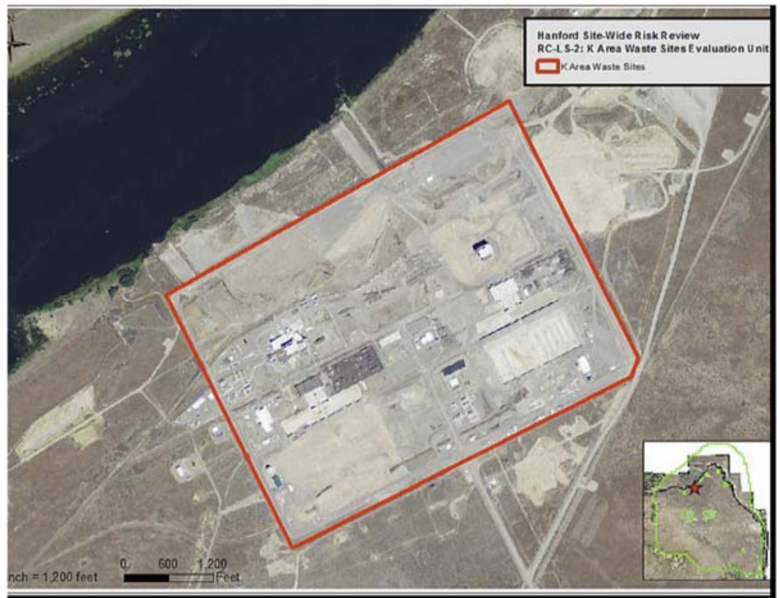


Figure 3-5. Aerial view of K-Area Waste Site.

Current Status: Most of the waste sites around the K-East Reactor Building have been remediated, those around the K-West Reactor Building must wait for removal of the sludge in the K-West fuel basin and demolition of the basin and remaining ancillary buildings.

Primary Contaminants: Table 3-5 and Table 3-6 list the primary radionuclide and chemical contaminants present and estimated quantities in the K Area waste sites**.** Most of the contamination resides in the soil and is sorbed onto sediments and soils.

Primary Risks: Many of the sites, such as underground pipelines, were never used with radioactive materials and so remediation is not likely to expose radioactive contamination. Other sites are considered to have minimal contamination. An HA identified 18 potential scenarios. The postulated unmitigated hazardous conditions result in Low consequences to the onsite and offsite receptors and no significant impact to the facility worker. Several scenarios were identified as presenting a standard industrial hazard to the facility worker, which are consistent with the nature of the activities.

Cleanup and Disposition: This waste site remediation needs to be coordinated with the K-West Sludge removal project and cocooning of the K-East and K-West Reactor Buildings. Many of the waste sites identified with this EU will be remediated through the process of "confirmatory sampling, no action," also known as CNSA. Others will be remediated through the process of remove-treat-dispose (RTD). For these sites, excavation, coupled with removal of underground structures such as piping, will take place, samples will confirm that cleanup criteria are met, and the site will be backfilled with clean and compacted soil. The contaminated soil will be disposed of at ERDF or elsewhere if it contains hazardous materials that exceed ERDF acceptance criteria. Where contamination must be left in place to maintain structural integrity, soils will be remediated to 15 ft below ground surface. To the extent practical, the current plan is for the soils to be cleaned such that unlimited future use is allowed. Where not practical, institutional controls and long-term monitoring will be required.

The known/likely presence of tribal cultural resources complicates remediation efforts.

Table 3-5. K Area Waste Sites (RC-LS-2) radionuclide inventory.

Radionuclides	Group	Curies (Ci)
Americium-241	D	NP
Carbon-14	A	110
Chlorine-36	A	NP
Cobalt-60	C	11
Cesium-137	D	0.67
Europium-152	D	0.0026
Europium-154	D	0.17
Tritium	C	82
Iodine-129	A	NP
Nickel-59	D	NP
Nickel-63	D	NP
Plutonium-Total Rad[(a)]	D	0.019
Strontium-90	B	2.1
Technetium-99	A	NP
Uranium- Total Rad[(b)]	B	0.0022

a. Sum of plutonium isotopes 238, 239, 240, 241, and 242
b. Sum of uranium isotopes 232, 233, 234, 235, 236, and 238

Table 3-6. K Area Waste Sites (RC-LS-2) chemical inventory.

Chemical	Group	kg
Carbon Tetrachloride	A	NP
Cyanide	B	NP
Chromium	B	NP
Chromium-VI	A	NP
Mercury	D	NP
Nitrate	C	NP
Lead	D	NP
TBP	---	NP
Trichloroethene	B	NP

Uranium	B	NP

Plutonium-Contaminated Waste Sites (CP-LS-2)

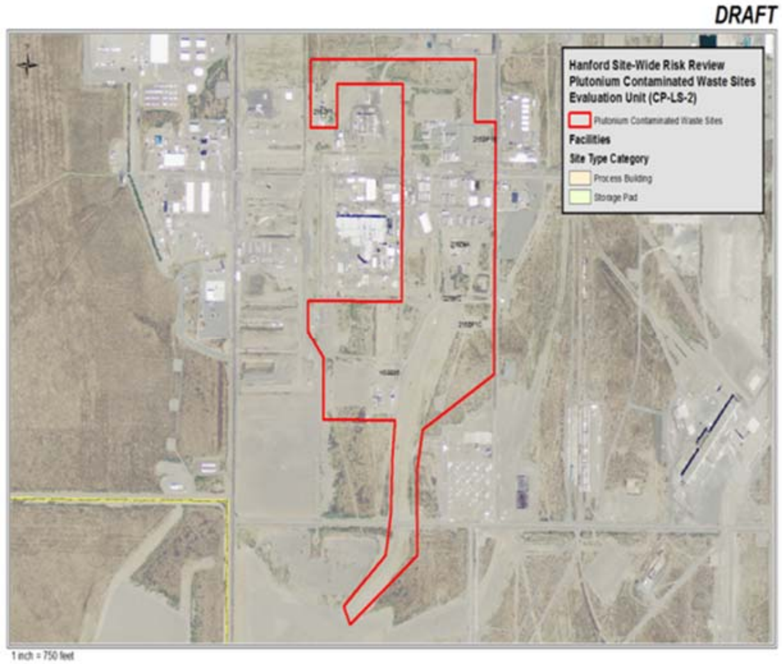


Figure 3-6. Aerial view of Pu-Contaminated Waste Site.

This EU consists of a variety of plutonium-contaminated cribs, trenches, piping, burn pits, and ancillary structures associated with PFP in the central part of the 200 West Area (Figure 3-6). CP-LS-2 is one of seven EUs situated in the 200 West Area of the Hanford Site. The 200 West Area is located is in the middle of the Central Plateau, which encompasses the region where chemical processing and waste management activities occurred. Pipes conveyed the liquid waste from nuclear processing facilities to the waste sites. At the cribs, tile field, and French drain, liquid waste was discharged into a layer of gravel that drained into the underlying soil and may have drained laterally as well as downward. As a consequence, the soils in, or underlying, these sites contain substantial amounts of radionuclides including plutonium and cesium, as well as large quantities of chemical constituents such as carbon tetrachloride, chromium, and nitrate.

Current Status: Most of the area is currently stabilized and covered with clean soil backfill, and many areas area are marked and posted as an underground radioactive material area. Soil vapor extraction was implemented as an interim action in 1992 to remove carbon tetrachloride from the vadose zone in 200-PW-1 overlying the 200-ZP-1 groundwater (DOE/RL-2014-32, Rev. 0). The system has removed 80,000 kg of carbon tetrachloride to date; however, the mass removed each year was decreasing and therefore shutdown. The system did not operate in 2013 (DOE/RL-2014-32, Rev. 0). The 200-West pump and treat system to remediate groundwater was started in 2012 and removed 3,600 kg of carbon tetrachloride, 91 kg of chromium, 0.00024 µCi of I-129, 244,000 kg of nitrate, 98 g (1.5 Ci) of Tc-99, and 15 kg of TCE, and 1.1 kg of U[41] by 2013 (DOE/RL-2014-32, Rev. 0).

Contaminants: The primary radionuclide and chemical contaminants and inventory estimates for this collection of sites are provided in Table 3-7. Compared to other EUs evaluated in this report, this EU contains a substantial amount of mercury and TBP.

Primary Risks: Many of the principal contaminants of concern (plutonium, cesium, strontium, and uranium) are relatively immobile in soils in the absence of significant amounts of water to mobilize them. However, other contaminants such as carbon tetrachloride may pose a long-term threat to

[41] Uranium is not a contaminant of concern for the 200-ZP-1 OU; it is including to track 200-UP-1 groundwater treated.

groundwater unless they are further reduced in concentration.[42] No hazard assessment or DSA has been found for these specific sites, but it is estimated that the principal hazard would be collapse of trenches with potential for small localized release of radioactive materials. The primary threat to groundwater is from carbon tetrachloride (rated Very High), although it has been treated by vapor extraction and is currently being treated by the 200 West pump and treat system. Chromium also is considered a threat to groundwater (rated Medium). A significant amount of Sr-90 is present in the vadose zone but is not anticipated to impact groundwater because of retention in the vadose zone and radioactive decay.

Table 3-7. Plutonium Contaminated Waste Sites (CP-LS-2) radionuclide inventory.

Radionuclides	Group	Curies (Ci)
Americium-241	D	27,000
Carbon-14	A	0.000015
Chlorine-36	A	NP
Cobalt-60	C	0.026
Cesium-137	D	160
Europium-152	D	0.000069
Europium-154	D	0.007
Tritium	C	0.0015
Iodine-129	A	0.0037
Nickel-59	D	0.00014
Nickel-63	D	0.013
Plutonium-Total Rad[a]	D	47,000
Strontium-90	B	160
Technetium-99	A	0.0036
Uranium- Total Rad[b]	B	1.7

a. Sum of plutonium isotopes 238, 239, 240, 241, and 242
b. Sum of uranium isotopes 232, 233, 234, 235, 236, and 238

[42] Approximately 910,000 kg of carbon tetrachloride was discharged to waste sites associated with the CP-LS-2 EU (Table 3-8). Treatment activities in the Central Plateau removed approximately 10% of the amount discharged, including pump and treat and soil vapor extraction operations through 2013 (DOE/RL-2014-32, Rev. 0).

Table 3-8. Plutonium Contaminated Waste Sites (CP-LS-2) chemical inventory.

Chemical	Group	kg
Beryllium	---	330
Carbon Tetrachloride	A	910,000
Cyanide	B	NP
Chromium	B	3,500
Chromium-VI	A	3,500
Mercury	D	760,000
Nitrate	C	7,900,000
Lead	D	480
TBP	---	110,000
Trichloroethene	B	NP
Uranium	B	220

Cleanup and Disposition: Because this EU contains multiple sites, a series of remedial actions have been identified based on their specific characteristics and inventories. Groundwater remediation is in-progress using the 200 West pump and treat system. Clean soil covers will be added back over sites to provide at least 5m (15 ft) of cover over cesium-contaminated soils. Institutional controls and long-term monitoring will be required for sites where contamination is left in place, and to assure that land use is consistent with the ROD. The large volume of waste associated with these sites and structures makes complete retrieval and disposal infeasible. Where possible, TRU waste will be recovered and disposed of at the Waste Isolation Pilot Plant (WIPP). Other contaminated soils will be disposed at the ERDF. However, there will be residual waste left in place that is not feasible to retrieve.

COMPARISON OF INVENTORIES AND PHYSICAL/CHEMICAL STATES OF WASTES AND CONTAMINANTS, BARRIERS

The 618-11 Burial Ground and BC Cribs and Trenches have similar inventories of cesium-137 and strontium-90, but differ in terms of total plutonium and technetium-99 (Table 3-9 and Table 3-10**Error! Reference source not found.**). The 618-11 site has substantially more plutonium (in curies) than the BC Cribs site, while BC Cribs and Trenches has technetium-99 and the 618-11 site reports no significant quantity of technetium-99. The Plutonium-Contaminated Waste Sites have significant inventories (in kg) of carbon tetrachloride, chromium (total and hexavalent), beryllium, mercury, tri-butyl phosphate and nitrate.

Many of the principal contaminants of concern (plutonium, cesium, strontium, mercury and uranium) are relatively immobile in soils in the absence of significant amounts of water to mobilize them. However, other contaminants such as Tc-99 and carbon tetrachloride will continue to pose a long-term further threat to groundwater until they are substantially reduced in concentration through continued use the 200 West pump and treat system.

No DSAs of radiological dose consequences for accidents or other initiating events have been prepared except for the 618-11 Burial Ground. Most of these legacy waste sites are stable and covered with clean soils, and thus represent Not Discernible to Low risks unless physically disturbed. Remediation of the 618-11 site is currently slated for completion by 2018 with industrial exposure criteria set as the cleanup level. Buried wastes and associated hard infrastructure (caissons, VPUs) will be removed and disposed in ERDF. During remediation, the primary pathways are likely to be air releases from energetic events and or accidental fires (the site has a mixture of potentially explosive and or pyrophoric constituents). This pathway probably would have limited distance from the area. Several activities related to characterization of the site (not remediation) have anticipated frequencies of occurrence in the 1 in 100 per year, maximum unmitigated facility worker risk from characterization is categorized as moderate (≥25 rem TEDE).

Table 3-9. Primary radiological inventories (curies).

Evaluation Unit	Cs^{137}	Sr^{90}	Pu (total)	Tc^{99}
618-11 Burial Ground	5,300	4,200	770	NP
K Area Waste Sites	0.67	2.1	0.019	NP
BC Cribs and Trenches	5,000	4,400	170	410
Pu-Contaminated Waste Sites	160	160	47,000	0.0036

Table 3-10. Primary chemical inventories (kg).

Evaluation Unit	CCl_4	Cr (total)	NO_3	Other
BC Cribs and Trenches	NP	23,500	22,000,000	NP
618-11 Burial Ground	NP	NP	NP	330[(a)]
K Area Waste Sites	NP	NP	NP	NP
Pu-Contaminated Waste Sites	911,000	3520	7,930,000	4400[(a)] 760,000[(b)] 110,000[(c)]

a. Beryllium
b. Mercury
c. TBP

CONSIDERATIONS FOR TIMING OF THE CLEANUP ACTIONS

Many of the principal contaminants of concern (plutonium, cesium, strontium, and uranium[43]) are relatively immobile in soils in the absence of significant amounts of water to mobilize them. Delay of cleanup for several decades will allow reduction in activity of the moderate lived radionuclides present at the site (e.g., ^{90}Sr and ^{137}Cs). At 618-11, careful consideration should be given to interim measures to reduce water infiltration over the vertical pipe units and caissons and delay excavation of the wastes until after the Energy Northwest Columbia Generating Station is closed. Carbon tetrachloride and other Group A and B contaminants in the vadose zone and groundwater will pose a long-term threat to further groundwater contamination unless they are further reduced in concentration through active mitigation

[43] Uranium has very complex environmental chemistry in some areas of the Hanford Site and is not well represented as a linear partitioning process, but in some cases is better represented as an ongoing secondary source, where the rate of release is controlled by other factors (oxidation, carbonate, etc.).

measures (e.g., groundwater recovery and treatment; removal, capping or immobilization). For example, soil vapor extraction (SVE) has been effective at treating the upper vadose zone (removing approximately 80,000 kg of carbon tetrachloride); however, there is a large groundwater plume that is currently being treated and apparently a secondary source of carbon tetrachloride in the deeper part of the vadose zone where the existing SVE treatment system coverage has not provided effective treatment[44]. For example, treatment processes have removed approximately 10% of the carbon tetrachloride discharged into the Central Plateau waste sites.[45]

If near-surface sites with relatively immobile contaminants (Group D) remain unremediated (e.g., by removal, immobilization or placement of durable caps) in the long term, erosion may compromise the surficial soils, allowing exposure of the waste and ingress of meteoric water. Inadvertent intruders could also access the waste site if it is not subject to institutional controls.

COMPARATIVE SUMMARY

Comparing differences between the four legacy waste sites necessitates consideration of failure of one or more passive or active safety controls, and thus the unmitigated radiological dose exposures to on- and off-site persons as represented by a hypothetical individual located 100 m from the EU boundary (co-located person) and another individual located at the Hanford Site controlled access boundary (public or maximally exposed offsite individual (MOI)). As revealed by the comparison of these four legacy sites, human health risks are driven by the following factors:

- Quantity of radionuclide (in Ci) and chemical inventory of the contaminants;
- Mobility of the contaminant (sorbed, presence in vadose zone or groundwater);
- Whether cleanup work is occurring or failure of safety systems could cause accidental dispersal of radionuclides or chemical contaminants; and
- For the public or MOI, the distance between the initiating event and the Hanford Site boundary

The 618-11 waste site is closed, with most of the site covered with soil and vegetated. The vegetated silt acts as hydraulic barrier that limits percolation of meteoric water into the waste to minute amounts, except in the area of the caissons and vertical pipe units, which are covered with gravel that facilitates increased percolation of precipitation and runoff. Beneath the site is a groundwater plume containing tritium and nitrate, whose concentrations are diminishing such that the tritium concentration is not expected to exceed drinking water standards when the plume reaches the Columbia River (Vermeul et al. 2005). The primary risk drivers for this site will derive from active remediation activities associated with air releases from energetic events and or accidental fires, with the potential to impact operations at the adjacent Energy Northwest Columbia Generating Station. The potential risks from waste retrievals may possibly be mitigated by temporary enclosing structures or delaying waste removals until after the nuclear generating station is no longer active. Except for reduction of the infiltration over the caissons and vertical pipe units, there is not a risk-based urgency to clean up the site.

The BC Cribs and Trenches waste sites are closed and are currently covered with clean soil backfill. The primary risk to human health derives from potential direct contact with the waste, particularly cesium-137 and strontium-90, because high concentrations of cesium-137 and strontium-90 are at relatively shallow depths in the cribs and trenches. The large depth of the vadose zone and limited surface water

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[44] Expansion of the SVE treatment system potentially may address carbon tetrachloride in the deeper vadose zone.
[45] The extent of evaporation of carbon tetrachloride after discharge is uncertain but has been estimated at between 21 and 38% (DOE/RL-2007-22 2007, p. 4-3)

infiltration reduces contaminant migration to very small rates. Active remediation of this site poses the greatest potential risk of human exposure for this EU.

The Plutonium-Contaminated Waste Site contains the largest radiological inventory, but the cesium-137 and plutonium very low mobility in the vadose zone, and thus contaminant migration of these constituents is expected to be minimal. Further, most of the area is currently stabilized and covered with clean soil backfill, and many areas are marked and posted as an Underground Radioactive Material area. Because this EU contains multiple sites, a series of remedial actions have been identified based on their specific characteristics and inventories. Clean soil covers will be added back over sites to provide at least 15 ft over cesium-contaminated soils. Institutional controls and long-term monitoring will be required for sites where contamination is left in place, and to ensure that land use is consistent with the ROD. The large volume of waste associated with these sites and structures makes complete retrieval and disposal infeasible.

Most of the waste sites around the K-East Reactor Building have been remediated; and those small amounts that remain are primarily immobile in the soils and sediments where "confirmatory sampling, no action" or limited removal actions are the anticipated outcomes for these limited waste sites. The contaminated soil will be disposed of at ERDF or elsewhere if it contains hazardous materials. Where contamination must be left in place to maintain structural integrity, soils will be remediated to 15 ft below ground surface. The primary risk drivers for this site will derive from active remediation activities associated with air releases during RTD and direct human contact during sampling and transport of contaminants to the ERDF.

3.2. TANK WASTE AND FARMS EVALUATION UNITS

DESCRIPTION OF TANK WASTE AND FARMS EVALUATION UNITS

Nine tank waste and farms EUs have been identified for inclusion in the interim progress report as indicated in Table 3-11. These EUs represent all 149 Hanford Site single-shell tanks (SSTs) and 28 double-shell tanks (DSTs) as well as ancillary equipment and geographically co-located legacy disposal sites. They are located in the Central Plateau within the 200 West and 200 East Areas. All current land-use activities in the 200 West and 200 East Areas are *industrial* in nature (Hanford 200 Area ROD[46]) and the land-use designations contained in the land use EIS and ROD indicate that the 200 West and 200 East Areas are denoted *Industrial-Exclusive* (DOE/EIS-0222-F). An industrial-exclusive area is "suitable and desirable for treatment, storage, and disposal of hazardous, dangerous, radioactive, and nonradioactive wastes" (DOE/EIS-0222-F).

[46] http://www.epa.gov/region10/pdf/sites/hanford/200/hanford_200_rod.pdf

Table 3-11. Tank waste and farms EUs and tank information included in the interim report (corresponding co-located legacy sites not listed). All Hanford single- and double-shell tank farms are included in the tank farm evaluation units.

Evaluation Unit	Tank Farm(s)	Waste Management Area(s) (WMAs)	Tank Type	Tanks	Location
CP-TF-1	241-T (T)	WMA T	Single-shell	16	200 West
CP-TF-2	241-S/SX (S-SX)	WMA S-SX	Single-shell	27	200 West
CP-TF-3	241-TX/TY (TX-TY)	WMA TX-TY	Single-shell	24	200 West
CP-TF-4	241-U (U)	WMA U	Single-shell	16	200 West
CP-TF-5	241-A/AX (A-AX)	WMA A-AX	Single-shell	10	200 East
CP-TF-6	241-B/BX/BY (B-BX-BY)	WMA B-BX-BY	Single-shell	40	200 East
CP-TF-7	241-C (C)	WMA C	Single-shell	16	200 East
CP-TF-8	241-AN/AP/AW/AY/AZ (AN-AP-AW-AY-AZ)	Not applicable	Double-shell	25	200 East
CP-TF-9	241-SY (SY)	Not applicable	Double-shell	3	200 West

Figure 3-7 shows the locations of the tank waste and farms EUs within the Central Plateau. The 177 underground waste storage tanks at the Hanford Site were constructed in groups of similarly designed structures called "tank farms." Eighteen tank farms are distributed between the 200 East and 200 West Areas and are connected by a cross-site transfer line that allows for waste transfers between the two areas. Over 50 million gallons of waste are stored in the tank farms. The tanks contain a mixture of liquid, sludge, and saltcake (precipitated solid salts) waste with both radioactive and chemically hazardous constituents. Liquids in the tanks exist as supernatant (liquid above solids) and interstitial liquid (liquid filling the voids between solids). Sludge consists primarily of solids (hydrous metal oxides) that were precipitated by the neutralization of acid wastes. Saltcake, when present, generally exists from evaporation of water from the waste. These waste types do not necessarily exist as distinct layers but may be intermingled at the interfaces between layers (RPP-13033).

Detailed maps and characteristics of the waste tanks, ancillary equipment, and legacy source units in each tank waste and farm EU are provided in the relevant EU description (see Appendices E-1 through E-10).

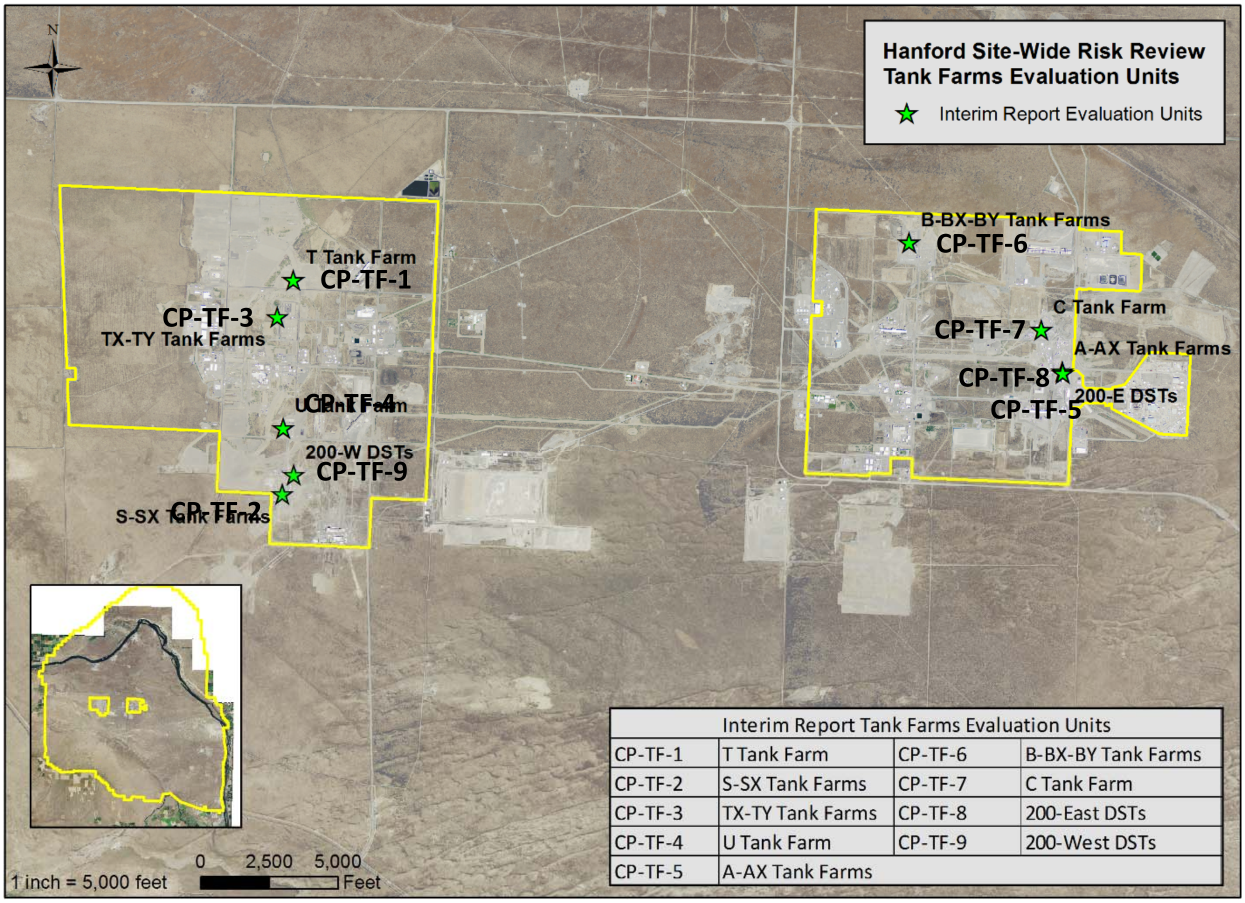

Figure 3-7. General location of the Hanford tank farm evaluation units (where CP-TF-5 and CP-TF-8 are both represented by the star in the southeastern part of 200 East). The location of the 200 East and 200 West Areas in relation to the Hanford Site boundary is shown in the inset.

Hanford Single-Shell Tanks

Of the 18 tank farms, 12 are SST farms that contain 149 of the 177 tanks. The SST farms, constructed between 1943 and 1964, are in groups of 4 to 18 tanks and are divided between the 200 East and 200 West Areas. The original SST design was a reinforced concrete shell and dome with an internal liner (structurally independent from the reinforced concrete tank) of mild carbon steel covering the bottom and sidewalls. The first SSTs were designed with operating volumes of 530,000 gallons. The succeeding generations of SSTs were built with operating volumes of 758,000 gallons and 1 million gallons. Included among the 149 SSTs are 16 smaller tanks that have the same design as the larger tanks, but have operating volumes of only 55,000 gallons. A typical SST configuration is shown in Figure 3-8 (RPP-13033). A congressional mandate prohibited waste additions to Hanford SSTs after January 1, 1981.[47]

[47] Berman presentation on July 29, 2009, titled "Hanford Single-Shell Tank Integrity Program." Available at www.em.doe.gov.

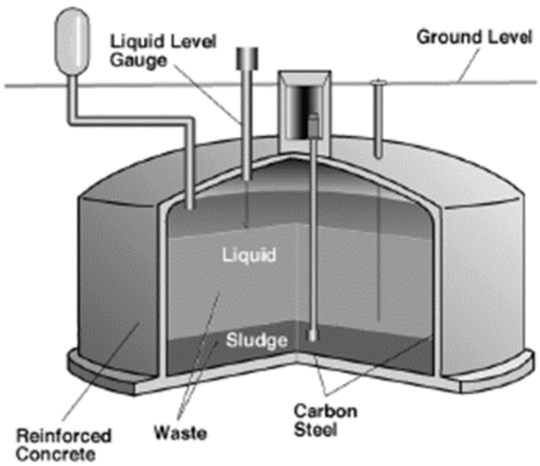

Figure 3-8. Typical Hanford single-shell tank design.

Hanford Double-Shell Tanks

To provide additional storage capacity, 28 DSTs were built in six tank farms between 1968 and 1986. Some SST waste has been transferred to the DSTs for subsequent treatment elsewhere on the Hanford Site starting after 2019. DSTs will also be used for future staging of SST wastes for treatment. Five of the DST farms are located in the 200 East Area, and one is located in the 200 West Area. All DSTs are similar in design and each has a storage capacity of approximately 1 million gallons. A typical DST configuration is shown in Figure 3-9 (RPP-13033).

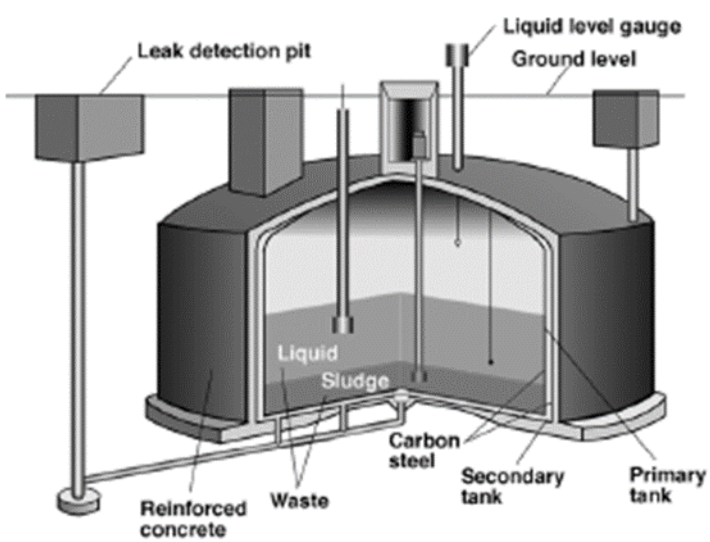

Figure 3-9. Typical Hanford double-shell tank design.

Each DST consists of a carbon-steel primary tank and a carbon-steel secondary tank within a protective reinforced concrete shell. The primary tank contains waste, is freestanding, and rests on an insulating concrete pad. The insulating pad rests on the secondary tank and was cast with air distribution and drain grids to provide for leak detection, maintain a uniform tank bottom temperature, facilitate heat removal, and eliminate pockets of water condensation. The secondary tank is 5 ft larger in diameter than the primary tank, providing an air space, or annulus, that separates the two steel tank walls. The secondary tank serves as a barrier to the environment in the event that the primary tank leaks. AY-102 has been observed to leak small waste quantities only through the primary tank (and not through the secondary tank). No DSTs are known to have leaked to the environment.

Tank Waste Retrieval and Tank Farm Closure

Between 1978 and 1996, 147 of the 149 SSTs[48] were interim stabilized (Weyns 2015), where pumpable liquids (both drainable interstitial liquid and supernatant) were removed to reduce the hydraulic pressure on the tanks and thereby reduce the potential for leakage.

The SSTs in WMA C (i.e., CP-TF-7 in 200 East as illustrated in Figure 3-7) were previously interim stabilized (i.e., liquid transferred to DSTs to <50 kgal drainable interstitial liquid and <5 kgal of supernatant) and waste retrieval initiated to remove waste from the tanks, thereby leading to final tank closure. Tank waste retrieval currently is in progress in the C tank farm (Weyns 2015):

- Retrieval has been completed in nine of the C tank farm tanks (C-103, C-104, C-106, C-110, C-112, and C-201 through C-204).
- Retrieval has been completed to various limits of technology in four tanks (C-101, C-107, C-108, and C-109).
- Retrieval is in progress in the remaining tanks (C-102, C-105, C-111).

Final retrievals have not yet begun at other SST farms.

The preferred tank closure alternative includes 99% retrieval of waste from the SSTs for staging in DSTs and treatment elsewhere onsite; operations and necessary maintenance, waste transfers and associated operations, and upgrades to existing tanks or construction of waste receipt facilities (DOE/EIS-0391 2012, Chapter 2, p. 2-321). SST closure operations include filling the tanks and ancillary equipment with grout to immobilize residual waste contaminants. Disposal of contaminated equipment and soil would occur on site. Decisions on the extent of soil removal and/or treatment would be made on a tank farm or WMA[49] basis through the RCRA closure permitting process. Under this process, the tanks would be stabilized by filling with grout, and an engineered modified RCRA Subtitle C barrier put in place followed by post-closure care.

Thus, workers and the public would be isolated from the residual contamination in the tanks by the tank structure, grout and soil cover. Tank waste contamination already in the vadose and saturated zones would experience reduced infiltrating water (the primary driver for the release and transport of contaminants) because of the surface barrier.

Legacy Disposal Sites and Unplanned Contaminant Releases Associated with Tank Waste and Farms EUs

Each EU associated with SST waste and farms also has geographically co-located legacy disposal sites as well as subsurface contamination from tank leaks and other unplanned releases. Furthermore, each of the SST farms is being regulated under RCRA as part of a corresponding WMA. In general the tank farm and tanks are within the WMA, which is within the EU (the EU also includes geographically co-located legacy sites and underlying vadose zone contamination, some of which may not be part of the WMA). A summary of past disposal practices and releases that have resulted in subsurface contamination within the boundary of the EU follows. There are no subsurface contamination inventories associated with the

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[48] Tank 241-C-106 went straight to retrieval and was not interim stabilized and Tank 241-S-102 was again considered interim stabilized in 2010 (Weyns 2015).

[49] A waste management area, or WMA, is a grouping of tanks and waste sites for regulatory purposes, which may not correspond with the EU groupings used in this report.

200-West DST waste and farm EU (from two unplanned release sites without known inventories) and a small source associated with the 200-East DST waste and farm EU (from one crib and some unplanned release sites); therefore, those two EUs are not described below. The small 200-East DST waste and farm EU sources and 200-West unplanned release sites are described in Appendix E.10, and E.9, respectively.

EU CP-TF-1: T Tank Farm, WMA T, and Associated Legacy Sites (200 West)

Historical liquid waste disposal practices as well as leaks and unplanned release have resulted in contamination near the T tank farm (Horton 2006, p. 2.2-2.3) and within the boundary of the T tank farm EU:

- 216-T-7 crib operated from 1948 to 1955 and received 110×10^6 L of second-cycle, T-Plant cell drainage waste, and plutonium concentrator waste.
- 216-T-32 crib operated from 1946 to 1952 and received 29×10^6 L of waste from the 224-T building by way of the 241-T-201 SST.
- 216-T-14 through 216-T-17 specific retention trenches each received 785,000 to 1×10^6 L of first-cycle waste in 1954.
- 216-T-36 crib southwest of the T tank farm received about 522,000 L of decontamination waste and condensate in 1967 and 1968.
- 216-T-5 crib, located just west of the T tank farm, received about 2.6×10^6 L of second cycle waste in 1955.
- Seven of the T tank farm SSTs are "assumed leakers" with leaks estimates ranging from <1,000 gallons (T-103, T-108, and T-109) to 115,000 gallons (T-106 in 1973) (Weyns 2015, pp. 18-22).
- Nine unplanned releases have been documented in or near WMA T that also fall within the T tank farm EU boundary.

EU CP-TF-2: S-SX Tank Farms, WMA S-SX, and Associated Legacy Sites (200 West)

Various cribs in the area around the S-SX tank farms (and within the S-SX tank farm EU boundary) received large volumes of slightly contaminated waste and other waste streams (Wood et al. 1999), where the largest include:

- 216-S-8 trench (east of WMA SX) received 2.6×10^6 gallons of REDOX waste (including unirradiated uranium) between 1951 and1952.
- 216-S-23 trench (northeast of S tank farm) received 76×10^6 gallons of evaporator condensate between 1973 and 1995.
- 216-S-1 crib (east of WMA SX) received 42×10^6 gallons of process condensate between 1952 and 1956.
- 216-S-3 crib (east of WMA SX) received 1.1×10^6 gallons of stream condensate between 1953 and 1956.
- 216-S-5 crib (southwest of WMA SX) received 1,100×10^6 gallons of stream condensate between 1954 and 1957.
- 216-S-6 crib (southwest of WMA SX) received 1,200×10^6 gallons condenser waste (REDOX) between 1954 and 1957.

- 216-S-7 crib (east of WMA SX) received 82×10^6 gallons of stream condensate between 1956 and 1965.
- 216-S-9 crib (east of S tank farm) received 13×10^6 gallons of redistilled process condensate between 1965 and 1975 (replacing 216-S-7 crib).
- 216-S-21 crib (west of S tank farm) received 23×10^6 gallons of stream condensate between 1954 and 1970.
- 216-S-25 crib (west of S tank farm) received 76×10^6 gallons of evaporator condensate between 1973 and 1995.
- Nine of the S-SX tank farm SSTs are declared “assumed leakers,” with leaks estimates ranging from <5,000 gallons (SX-114 and SX-107) to 50,000 gallons (SX-115 in 1965) (Weyns 2015, pp. 18-22).
- Twenty-five unplanned releases have been documented in or near WMA S-SX that also fall within the S-SX tank farm EU boundary.

It appears that tank wastes were not directly cascaded from the S-SX tank farm tanks to the cribs.

<u>EU CP-TF-3: TX-TY Tank Farms, WMA TX-TY, and Associated Legacy Sites (200 West)</u>

Past practices and unplanned disposals have resulted in legacy (vadose zone) contamination near the WMA TX-TY (Horton 2007, p. 2.3-2.6)[50] and that fall within the TX-TY tank farm EU boundary:

- 216-T-21 through T-24, specific retention trenches were used in 1954 and received a total of 5×10^6 L of first cycle supernatant waste from TX tank farm tanks.
- 216-T-25 trench was active during September 1954 and received 3×10^6 L of evaporator waste from the 242-T Evaporator.
- 216-T-28 crib was active from 1960 to 1966 and received 42.3×10^6 L of waste including steam condensate decontamination waste, miscellaneous waste from 221-T Building, and decontamination waste from the 2706-T Building and 300 Area laboratory waste.
- 216-T-19 crib and tile field, located south of the TX tank farm, operated from 1951 to 1980 and received 455×10^6 L of effluent from the 242-T Evaporator and T Plant operations.
- Thirteen of the TX-TY tank farm’s 24 SSTs are declared “assumed leakers” (Weyns 2015, p. 19), with leaks estimates ranging from <1,000 gallons (TY-101 in 1973) to 35,000 gallons (TY-105 in 1960).
- Eleven unplanned releases have been documented in or near WMA TX-TY that also fall within the TX-TY EU boundary.

<u>EU CP-TF-4: U Tank Farm, WMA U, and Associated Legacy Sites (200 West)</u>

Waste was cascaded among the U tank farm waste tanks; however, it appears none was released to cribs or ditches related to the U tank farm EU. The 216-U-3 french drain (located south of WMA U and within the U tank farm EU) received 7.9×10^6 L of liquid from steam condensers on waste tanks in the U tank farm and likely contains nitrate and minor amounts of fission products and actinides.

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[50] The wastes disposed to some of the cribs and trenches adjacent to WMA TX-TY were similar to the wastes stored in the SSTs, making it difficult to distinguish waste sources for existing groundwater contamination.

Four of the tanks in the U tank farm (U-101, U-104, U-110, and U-112) are "assumed leakers" (Weyns 2015, p. 20), ranging from 5000 to 8100 gallons (U-110 in 1975) to 55,000 gallons (U-104 in 1961). All four "assumed leakers" have been stabilized and contain little or no pumpable liquid.

Four unplanned releases have been documented associated with the U tank farm EU with unknown waste volumes. Three unplanned releases that may have significant impacts are beta contamination in diversion boxes east of the U tank farm, a "violent chemical reaction" in a vault (244-UR) that spread first-cycle metal waste contaminants over an unspecified area, and a ruptured waste line at tank U-103 (Hodges and Chou 2000, p. 2.3).

EU CP-TF-5: A-AX Tank Farms, WMA A-AX, and Associated Legacy Sites (200 East)

Various non-tank sources that received large volumes of slightly contaminated waste and other waste streams have resulted in extensive vadose zone and groundwater contamination in the areas around the WMA A-AX (Narbutovskih and Horton 2001, p. 3.4-3.5) that fall within the A-AX tank farm EU boundary:

- Surface spills associated with leaks from transfer lines, diversion boxes, catch tanks, and vaults.
- Liquid disposal facilities including cribs, trenches, and french drains were used to discharge from 1600 gallons to 304 Mgal of volume effluents, including condensate and condenser cooling water, depleted uranium waste, cell and stack drainage waste, and tributyl phosphate (TBP)-kerosene organic waste from PUREX.
- Two of the A-AX tank farm SSTs are declared "assumed leakers," with leak estimates ranging from 500 to 2500 gallons (from A-104 in 1975) to 10,000 to 270,000 gallons (from A-105 in 1963, which occurred when a steam explosion ruptured the tank bottom), not including leaks from transfer lines, other ancillary equipment, surface spills, or overflow amounts (Weyns 2015, pp. 18-21).

EU CP-TF-6: B-BX-BY Tank Farms, WMA B-BX-BY, and Associated Legacy Sites (200 East)

Various non-tank sources (e.g., cribs, trenches, tile fields, and reverse wells) that received large volumes (7.2 to 36.8 Mgal) of contaminated waste and other waste streams have resulted in extensive vadose zone and groundwater contamination in the areas around the WMA B-BX-BY (PNNL-13022) and fall within the B-BX-BY tank farm EU:

- Liquid wastes that vary from high-level metals waste to large quantities of ferrocyanide scavenged uranium recovery waste taken directly from tanks in the 241-BY tank farm
- Large volumes of tritium-rich tank condensate generated during the in-tank solidification program that began in 1965

EU CP-TF-7: C Tank Farm, WMA C, and Associated Legacy Sites (200 East)

Various non-tank sources that received large volumes of contaminated waste and other waste streams have resulted in vadose zone and groundwater contamination in the areas around the C tank farm EU, including 14 documented, unplanned releases (i.e., surface spills and leaks from transfer lines, diversion boxes, catch tanks, and vaults) (Horton and Narbutovskih 2001) that fall within the C tank farm EU.

INVENTORIES OF KEY WASTE CONSTITUENTS AND PRIMARY CONTAMINANTS

Operations at the Hanford Site included multiple processes for recovery of specific nuclear materials from irradiated fuel elements, and thus many different waste streams were delivered to the tank farms over several decades. Furthermore, additional processing was carried out on some wastes contained in tanks to recover specific constituents (uranium, Cs-137, Sr-90, etc.) and additional waste transfers were made between tanks (within and between tank farms) as part of tank farms management. For this review, several models have been used to estimate characteristics of the Hanford tank wastes as they exist today. These models were developed from historical information (Remund et al. 1995). For example, the Hanford Defined Wastes/Tank Layering Model (HDW/TLM) (Agnew 1994) was used to estimate tank contents for all 149 SSTs (Brevick et al. 1994). Tank wastes are categorized based on the major waste types (primary and secondary) that were deposited in each tank and based on process histories. A chemical composition is specified for each waste type, and tanks are identified by volume percentages of all possible waste types (derived from historical information). The chemical compositions are then volume averaged to obtain a final waste composition estimate for each SST. The tank wastes in the tank waste and farms EUs can be summarized (Remund et al. 1995) as:

- CP-TF-1 (T tank farm) in 200 West – first cycle decontamination from bismuth phosphate process, lanthanum fluoride finishing waste, and PUREX and REDOX cladding wastes
- CP-TF-2 (S-SX tank farms) in 200 West – redox wastes and salt and slurry cake from evaporator campaigns
- CP-TF-3 (TX-TY tank farms) in 200 West – salt cake from evaporator campaigns T1 and T2
- CP-TF-4 (U tank farms) in 200 West – aluminum cladding REDOX wastes, salt and slurry cake from evaporator campaigns
- CP-TF-5 (A-AX tank farms) in 200 East – salt cake and slurry from evaporator campaigns A1 and A2 and washed PUREX sludge
- CP-TF-6 (B-BX-BY tank farms) in 200 East – salt cake from evaporator campaigns B and BY, metal waste from bismuth phosphate process, first/second cycle decontamination from the bismuth phosphate process, and lanthanum fluoride finishing waste
- CP-TF-7 (C tank farm) in 200 East – First cycle decontamination from bismuth phosphate process, aluminum cladding PUREX wastes, metal waste from bismuth phosphate process, and ferrocyanide sludge

More recent, detailed compositional estimates of what is currently in the Hanford waste tanks are available in the Best Basis Inventory,[51] which also was used to specify inventories of specific constituents for the EUs.

The primary constituents evaluated for the tank waste and farms EUs include (1) radionuclides - tritium (H-3); Sr-90; Tc-99; I-129; Cs-137; the sum of U-233, U-234, U-235, U-236, and U-238 (for completeness although risk is driven by uranium toxicity); and the sum of Pu-238, Pu-239, Pu-240, Pu-241, and Pu-242; and (2) chemicals – Cr (total), Cr(VI), nitrate (NO_3), U (total), and TCE. Subsurface inventories of some contaminants (e.g., tritium, TCE, Cr) may have resulted from legacy disposal practices within the defined EU rather than from tank leaks or unplanned releases.

Figure 3-10 compares the relative amount of radionuclides (Ci) for tritium (H-3), Sr-90, Tc-99, I-129, Cs-137, the sum of U-233, 234, 235, 236, 238, and the sum of Pu-238-239-240-241-242 by tank farm. Sr-90 and Cs-137 dominate the overall amount of radionuclide inventory. However, since this comparison is based on individual radionuclide activity, this does not directly relate to the dose consequence, due to the very different dose conversion factors for the individual radionuclides listed.

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[51] Best Basis Inventory (BBI) Summary (March 24, 2014) provided in spreadsheet form by Mark Triplett (PNNL). The current version of the BBI is stored online and can be accessed using the Tank Waste Information Network System (TWINS) at: https://twinsweb.labworks.org/ (July 2015).

Figure 3-11 through Figure 3-20 represent a set of pie diagrams summarizing several of the primary constituents and the total activity estimated to be within each tank and waste farm EU. "Slices" of each pie diagram represent the relative amounts of an identified primary constituent (e.g., tritium) estimated to be within the specified tank farm tanks in the EU, as well as from leaks and legacy disposal practices for each EU. The area for each EU pie is scaled relative to the total amount of the constituent present across all nine tank farm EUs. The primary radioactive contaminants represent much of the total activity (Figure 3-17) in the waste tanks, with the notable exceptions of Y-90 (which is in secular equilibrium with Sr-90) and Ba-137m (which is in secular equilibrium with Cs-137). These two isotopes (Y-90 and Ba-137m) account for approximately 48% of the activity in the Hanford tanks (which is also approximately equal to that represented by Sr-90 and Cs-137). Other tanks have significant proportions of Sm-151 (a U-235 fission product), Pu-241 (formed by neutron capture), Am-241 (primarily from beta decay of Pu-241), and Ni-63 (an activation product). However, these other isotopes are not risk drivers in the evaluations used to support this review.

One message from these figures is that the identified constituents are unevenly distributed across the individual tanks within an EU as well as across the set of tank farm EUs. For example, the inventory of tritium is dominated by intentional discharges to cribs in EUs CP-TF-2 (S-SX), CP-TF-3 (TX-TY), and CP-TF-5 (A-AX), and relatively small quantities of tritium remain in the tanks compared to prior releases.

The vast majority of the radionuclide and chemical inventory shown in the figures is contained in the tanks with the following exceptions:

- I-129 and Tc-99 in the T (CP-TF-1), TX-TY (CP-TF-3), and B-BX-BY (CP-TF-6) tank farm EUs, where significant releases occurred either through leaks or discharges to cribs; however, the total inventory of Tc-99 and I-129 is relatively small compared to other EUs (Figure 3-14 and Figure 3-15)
- Cr(total) inventory in the T tank farm EU (CP-TF-1) is dominated (ca. 75%) by intentional discharges to cribs and trenches, and significant amounts have been intentionally discharged also at tank farm EUs S-SX, TX-TY, and B-BX-BY (Figure 3-18)
- Uranium in the A-AX tank farm EU (CP-TF-5), where disposal through trenches and cribs contribute more than half of the inventory within the EU, and B-BX-BY and TX-TY, where significant releases occurred through leaks and cribs (Figure 3-19);
- Nitrate in EUs T and B-BX-BY where greater than 50% of the inventory has been through intentional discharges, as well as a significant fraction in EUs S-SX and TX-TY (Figure 3-20)

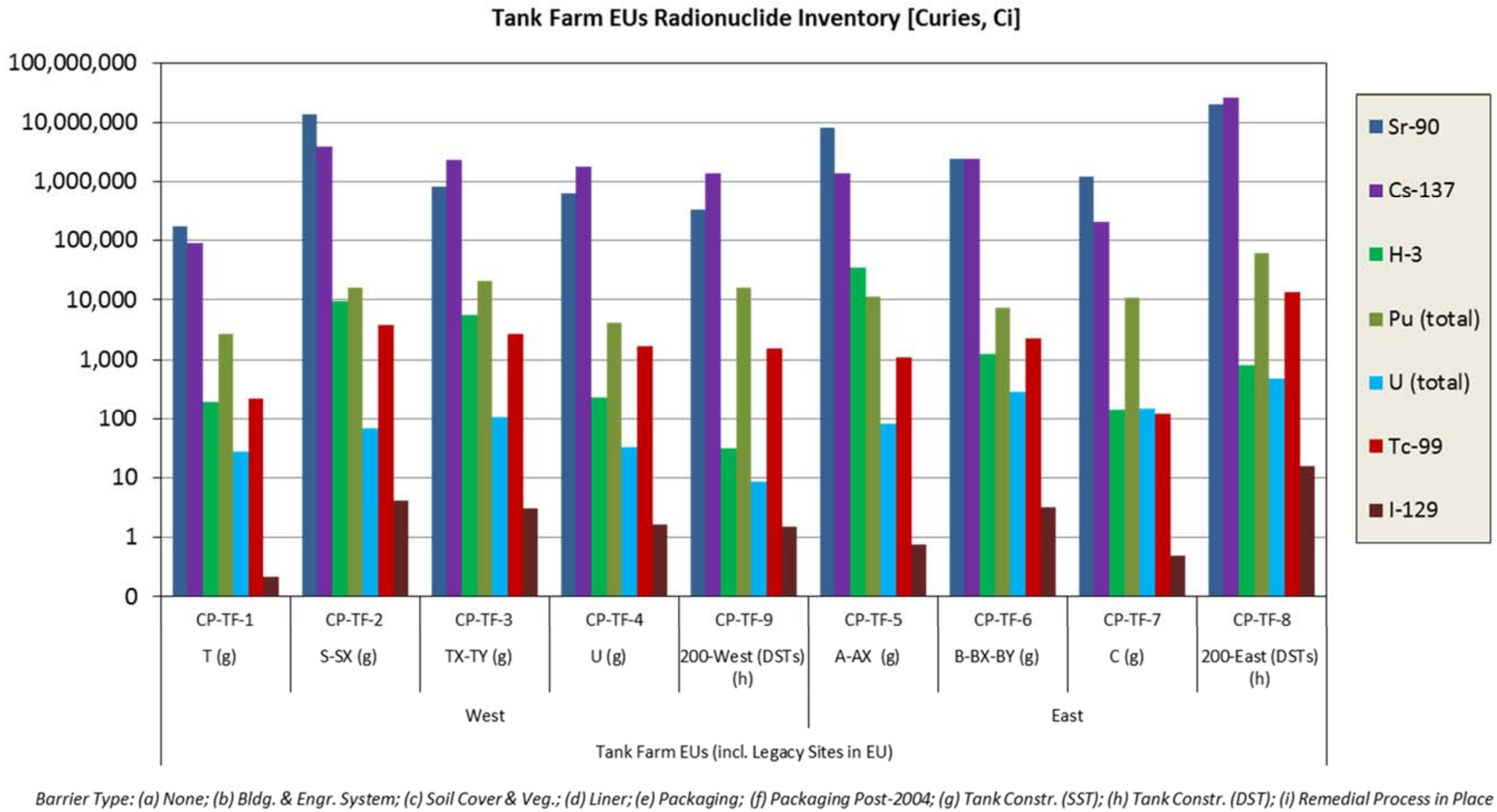

Figure 3-10. Radionuclide inventories by tank farm EUs.

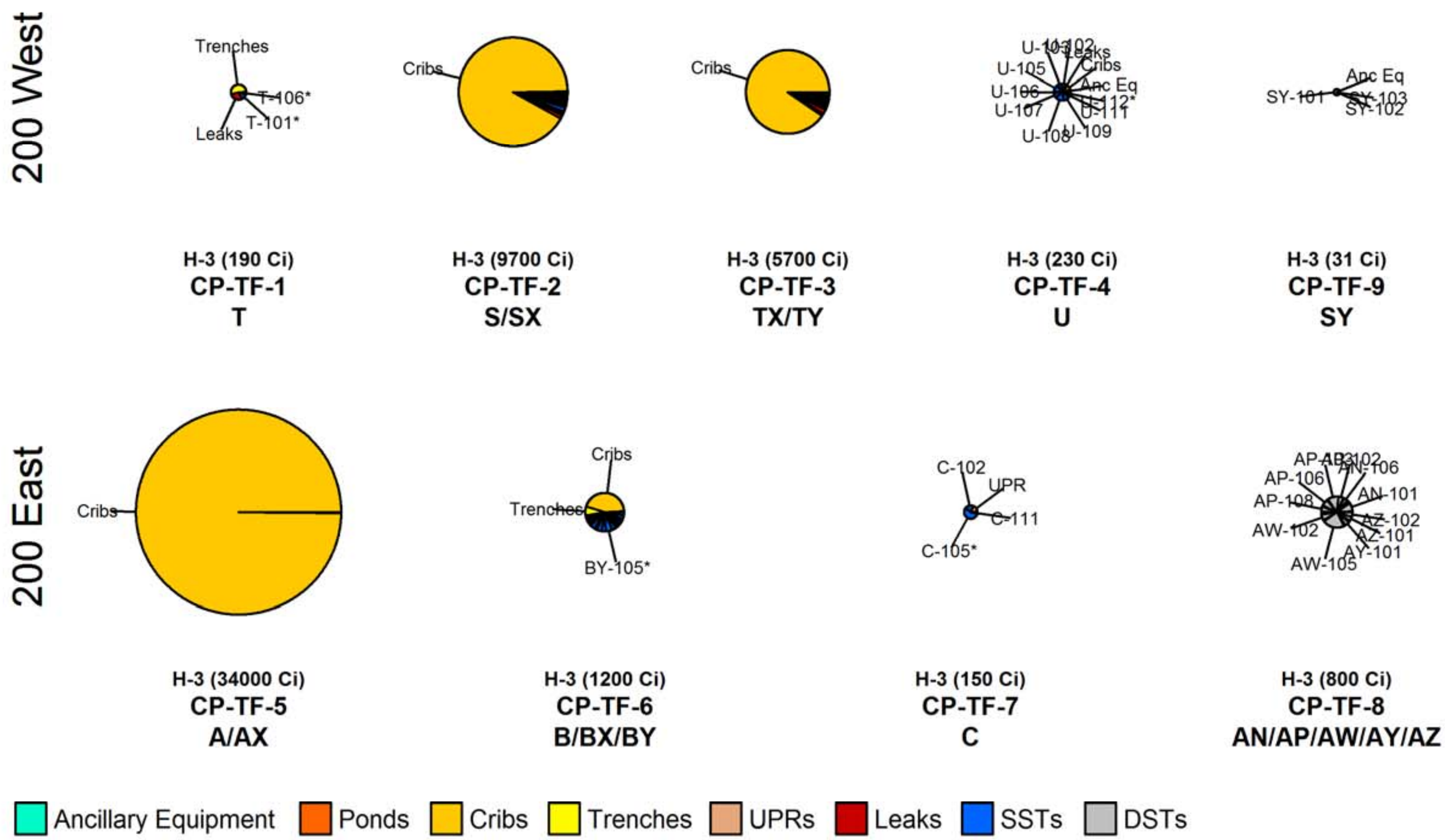

Figure 3-11. Tritium (H-3) as tritiated water (^3H_2O): Inventory distribution between waste within tanks and existing environmental contamination from past disposal practices (i.e., discharges to cribs and trenches) and leaks. Each pie represents a single tank waste and farm EU. The relative inventory within each EU is scaled by relative area for each pie. Asterisk (*) indicates an assumed leaker tank.

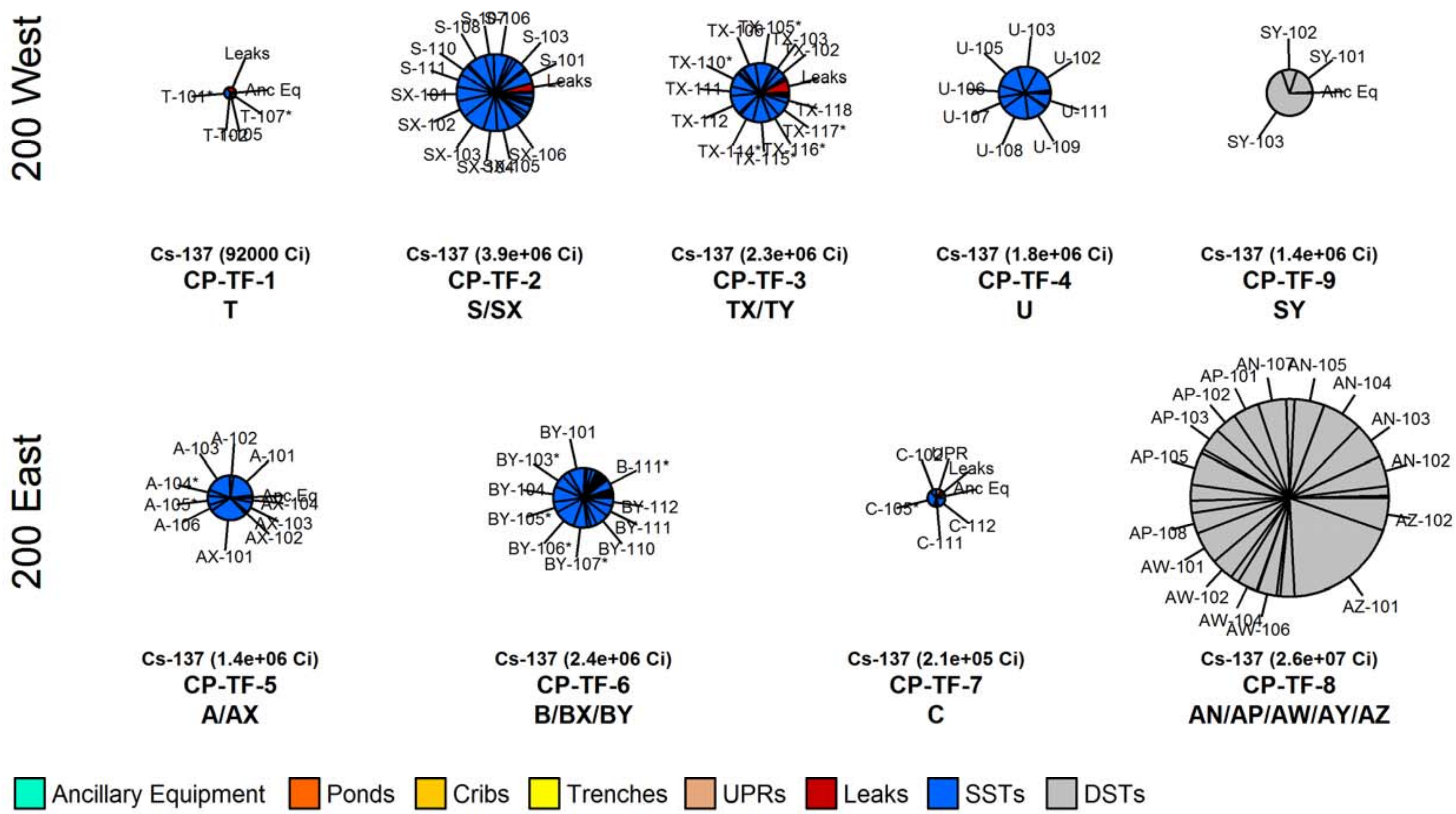

Figure 3-12. Cesium-137: Inventory distribution between waste within tanks and existing environmental contamination from past disposal practices (i.e., discharges to cribs and trenches), leaks, and unplanned releases (UPRs). The relative amount of inventory within each EU is scaled by relative area for each pie. Asterisk (*) indicates an assumed leaker tank.

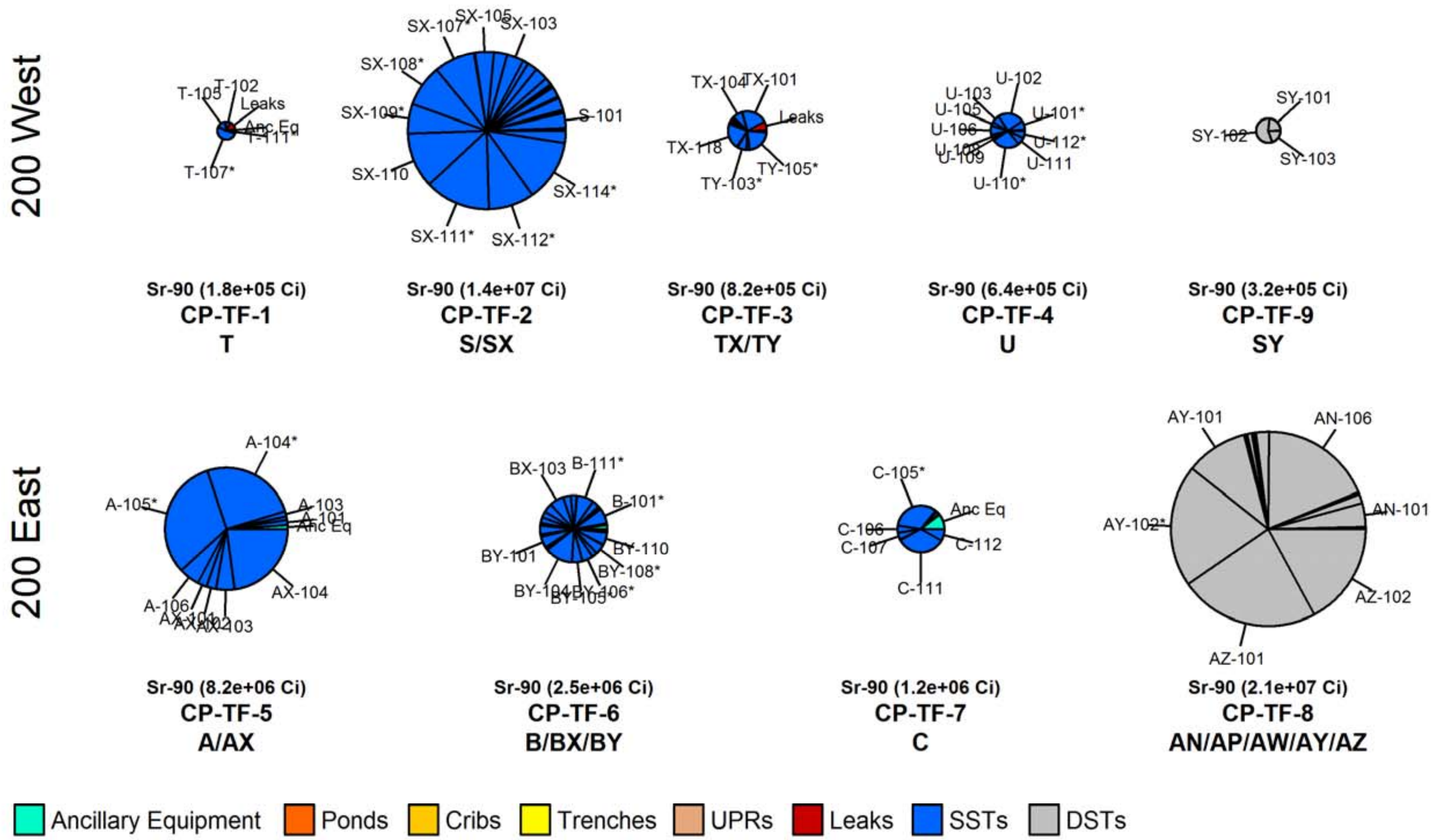

Figure 3-13. Strontium-90: Inventory distribution between waste within tanks and existing environmental contamination from past disposal practices (i.e., discharges to cribs and trenches), leaks, and UPRs. The relative amount of inventory within each EU is scaled by relative area for each pie. Asterisk (*) indicates an assumed leaker tank.

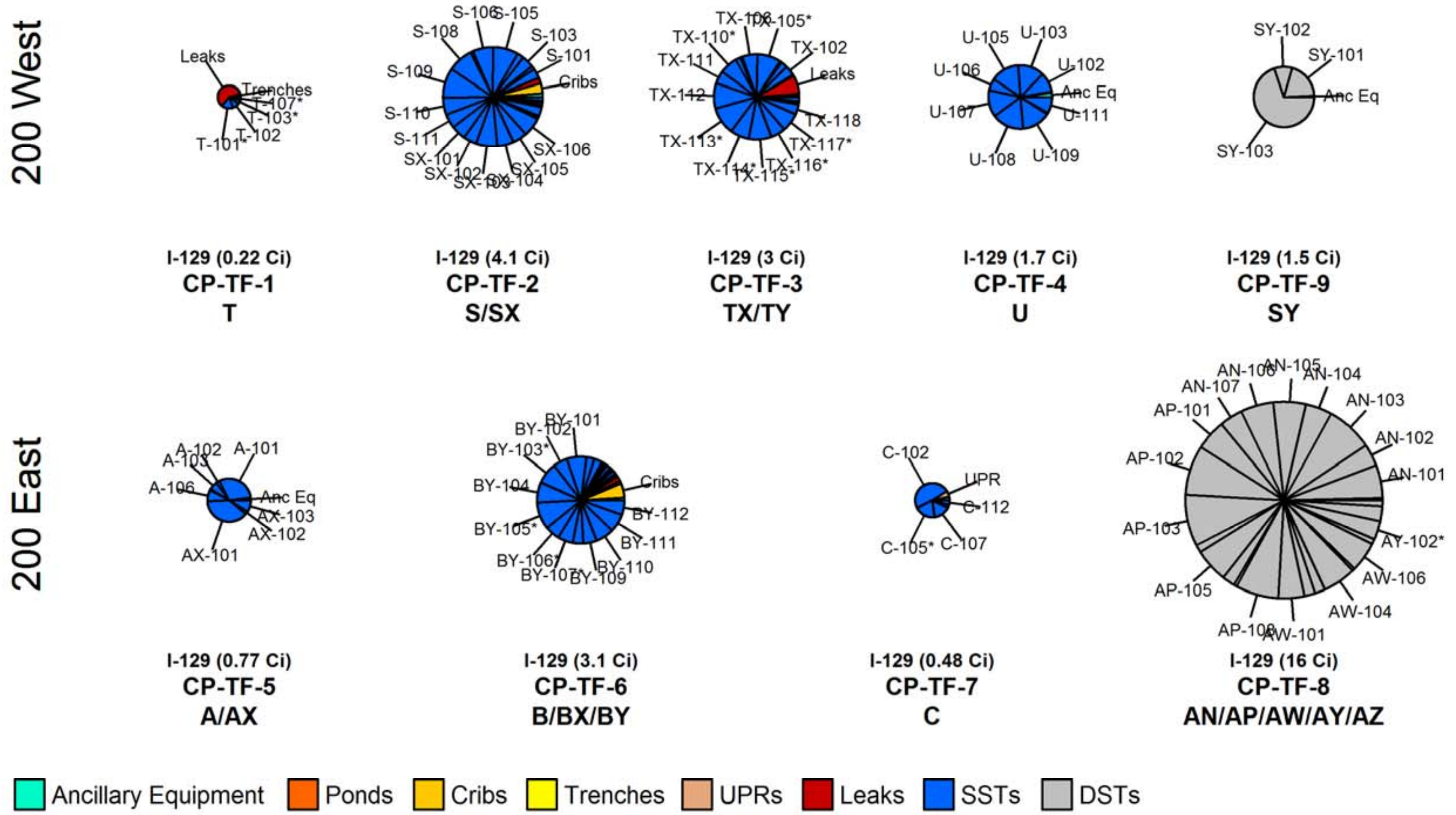

Figure 3-14. Iodine-129: Inventory distribution between waste within tanks and existing environmental contamination from past disposal practices (i.e., discharges to cribs and trenches), leaks, and UPRs. The relative amount of inventory within each EU is scaled by relative area for each pie. Asterisk (*) indicates an assumed leaker tank.

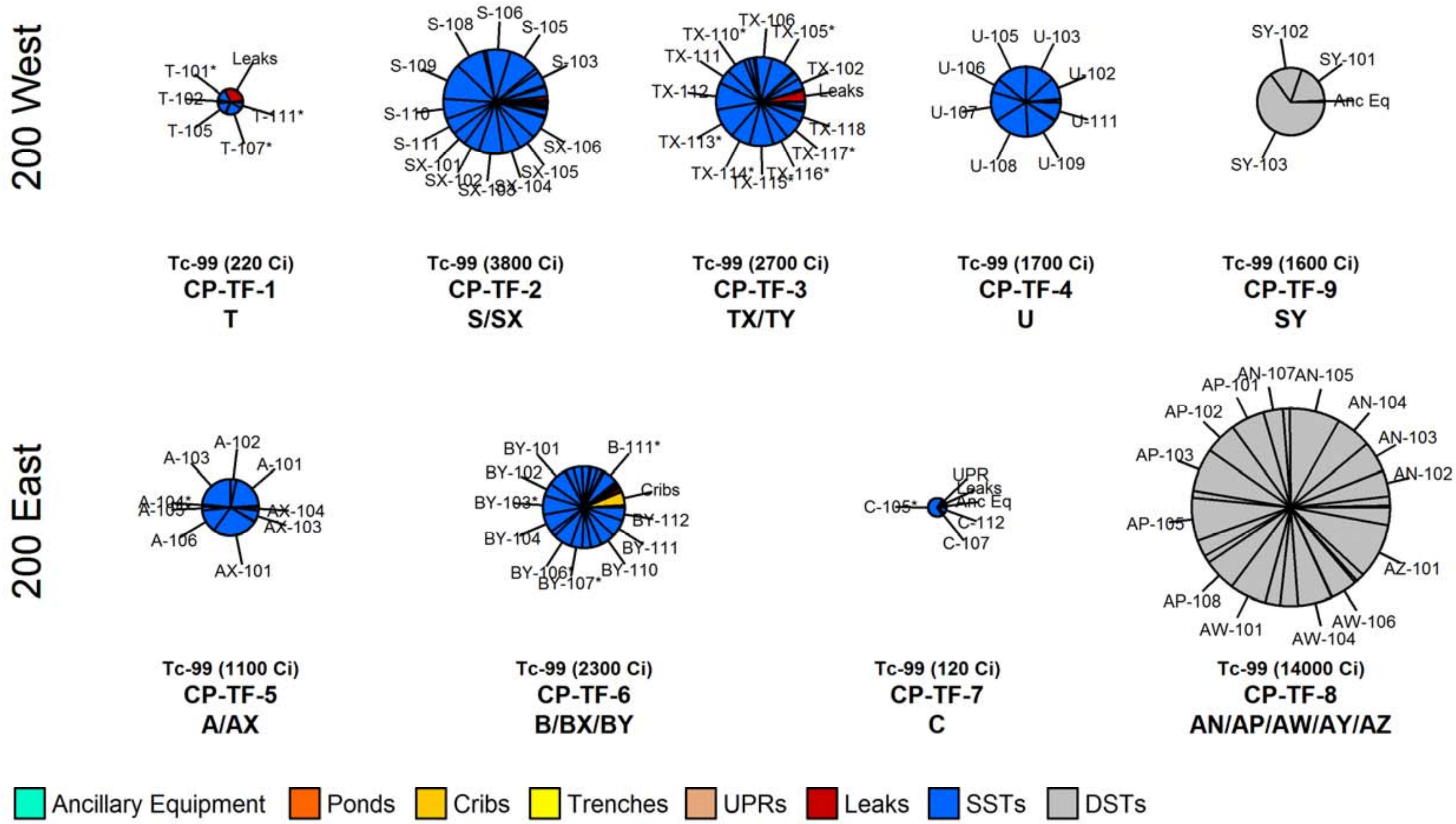

Figure 3-15. Technetium-99: Inventory distribution between waste within tanks and existing environmental contamination from past disposal practices (i.e., discharges to cribs and trenches), leaks, and UPRs. The relative amount of inventory within each EU is scaled by relative area for each pie. Asterisk (*) indicates an assumed leaker tank.

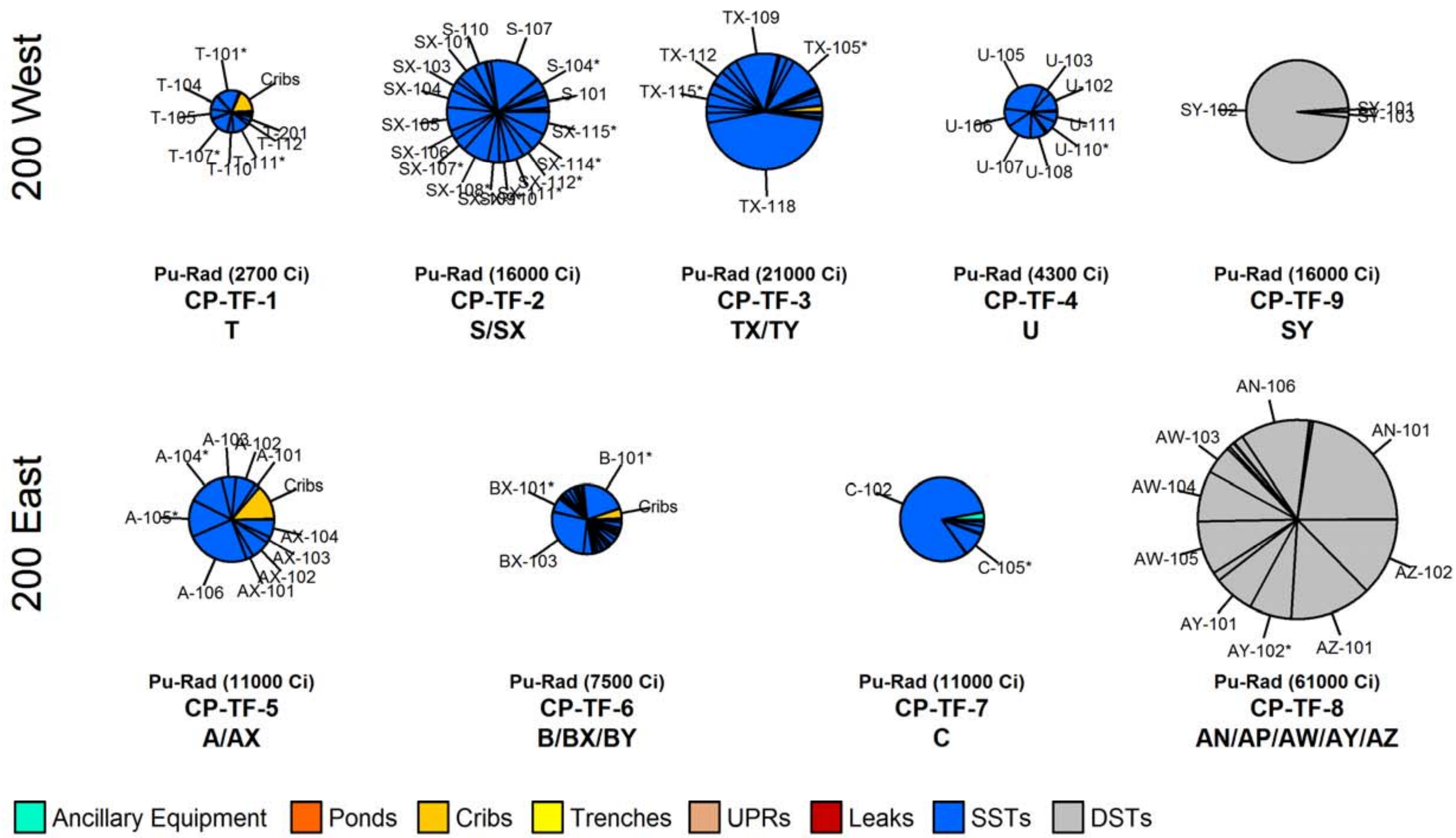

Figure 3-16. Plutonium-Rad (sum of isotopes 238, 239, 240, 241, and 242): Inventory distribution between waste within tanks and existing environmental contamination from past disposal practices (i.e., discharges to cribs and trenches), leaks, and UPRs. The relative amount of inventory within each EU is scaled by relative area for each pie. Asterisk (*) indicates an assumed leaker tank.

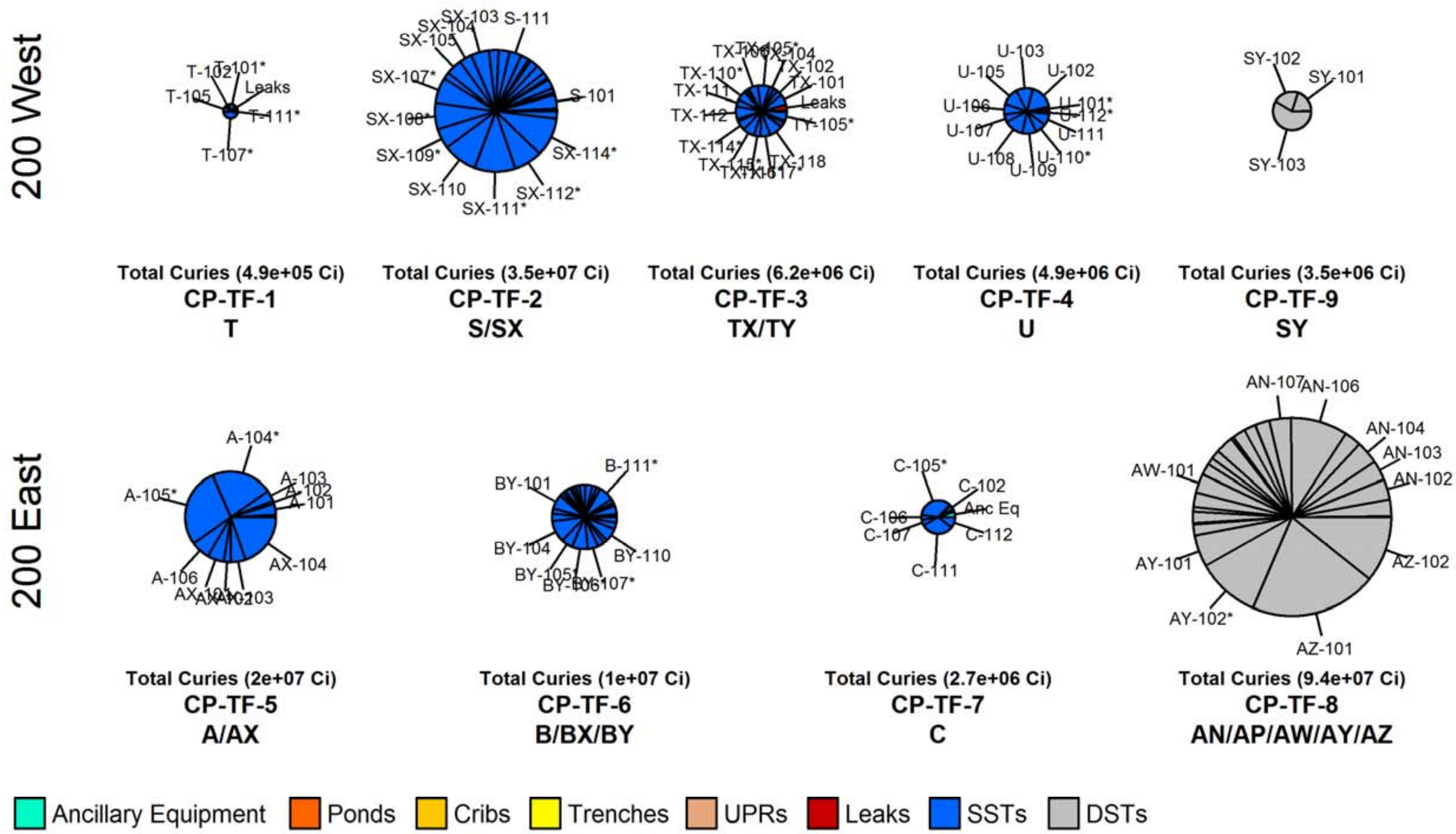

Figure 3-17. Summary of total radionuclide content (Ci) associated with each tank farm: Inventory distribution between waste within tanks and existing environmental contamination from past disposal practices (i.e., discharges to cribs and trenches), leaks, and UPRs. The relative amount of inventory within each EU is scaled by relative area for each pie. Asterisk (*) indicates an assumed leaker tank.

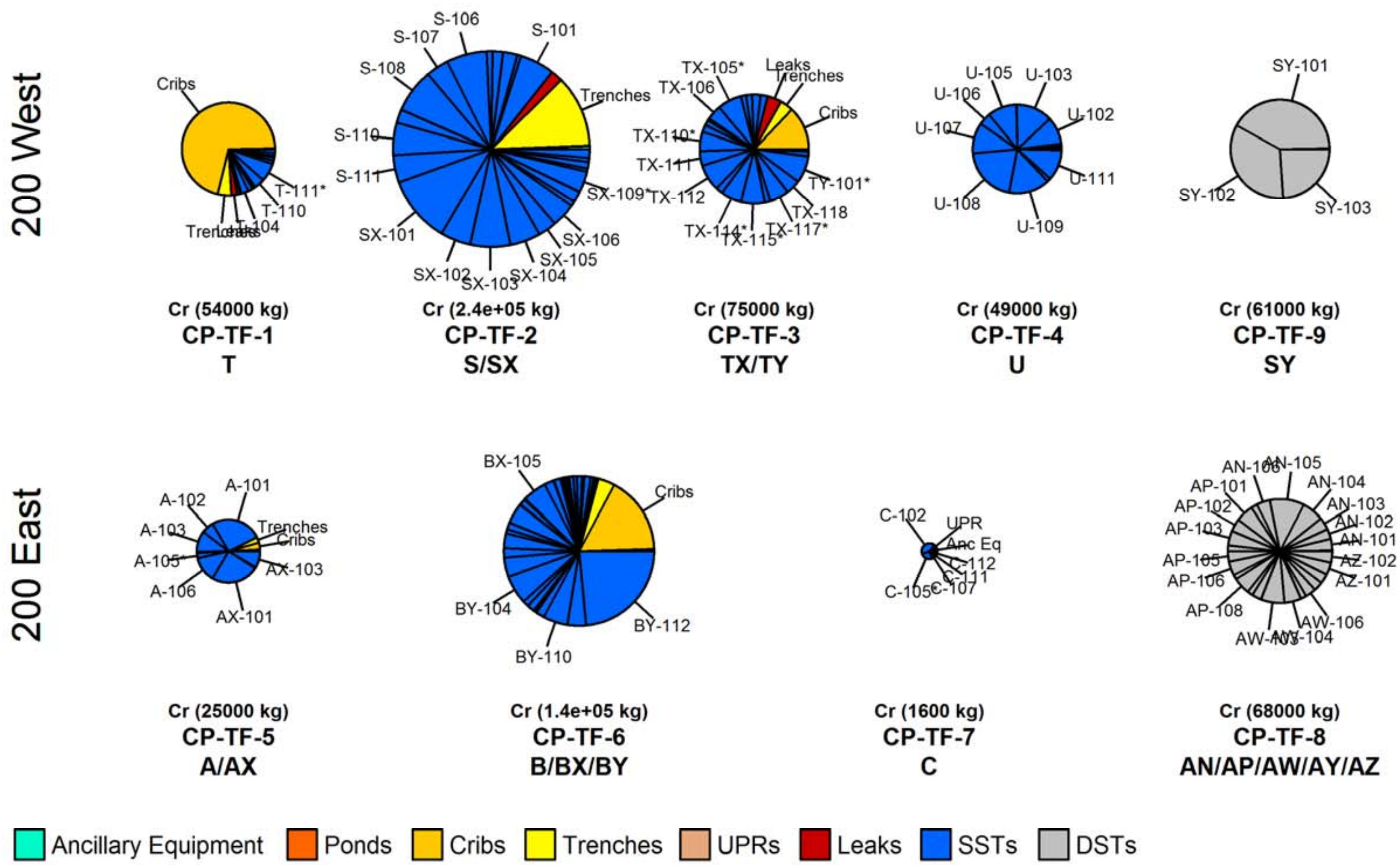

Figure 3-18. Total chromium: Inventory distribution between waste within tanks and existing environmental contamination from past disposal practices (i.e., discharges to cribs and trenches), leaks, and UPRs. The relative amount of inventory within each EU is scaled by relative area for each pie. Asterisk (*) indicates an assumed leaker tank.

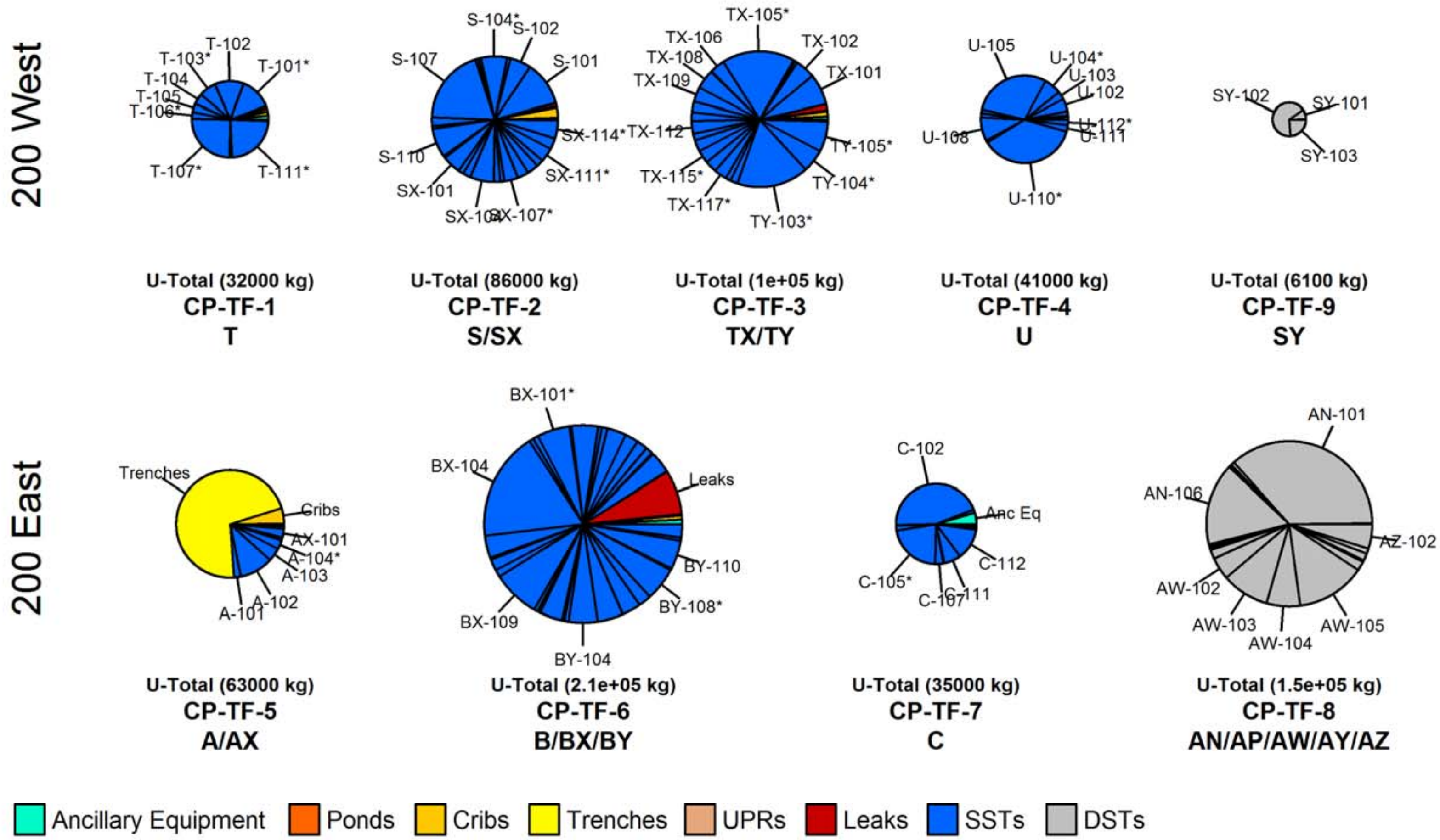

Figure 3-19. Total uranium: Inventory distribution between waste within tanks and existing environmental contamination from past disposal practices (i.e., discharges to cribs and trenches), leaks, and UPRs. The relative amount of inventory within each EU is scaled by relative area for each pie. Asterisk (*) indicates an assumed leaker tank.

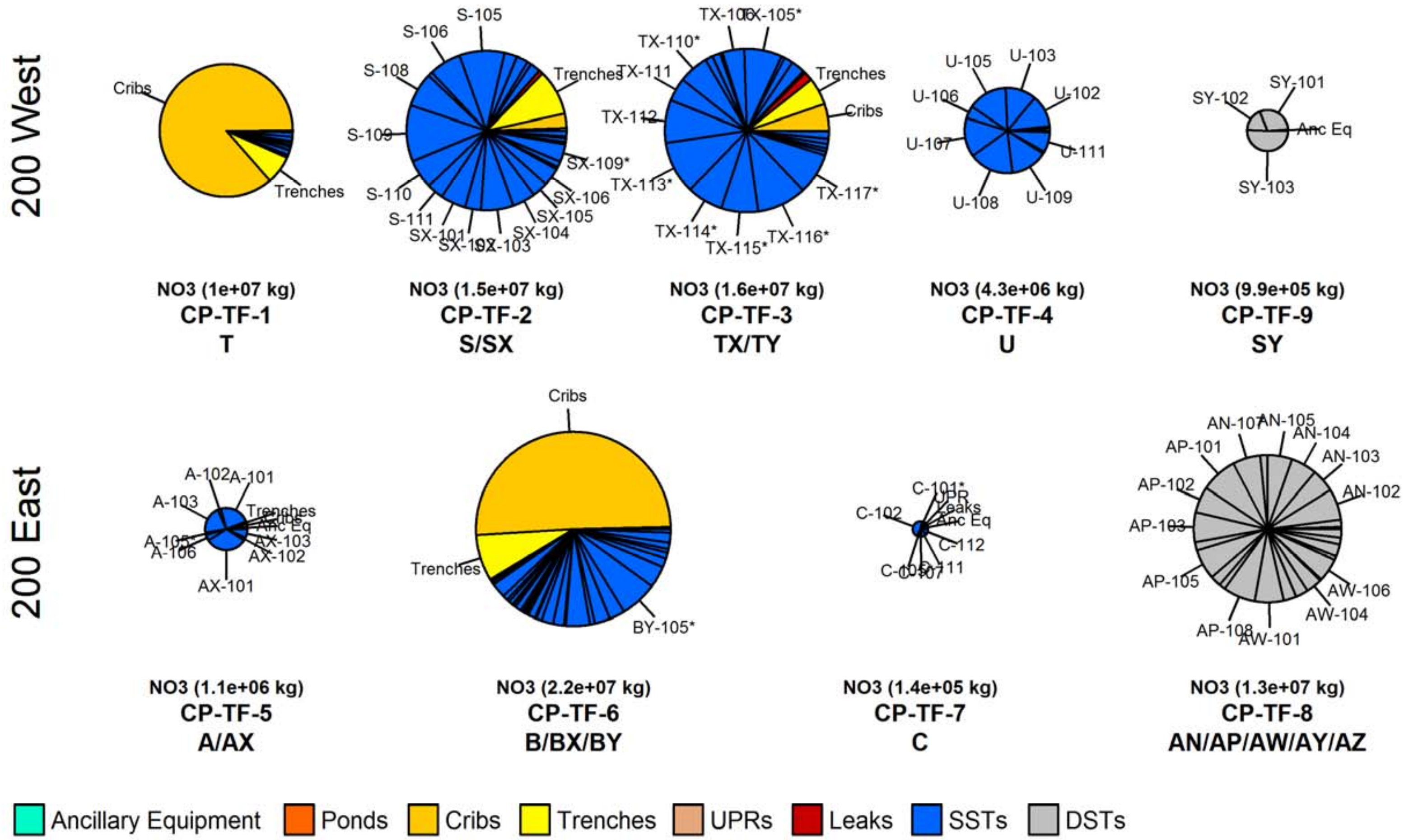

Figure 3-20. Nitrate: Inventory distribution between waste within tanks and existing environmental contamination from past disposal practices (i.e., discharges to cribs and trenches), leaks, and UPRs. The relative amount of inventory within each EU is scaled by relative area for each pie. Asterisk (*) indicates an assumed leaker tank.

PRIMARY NUCLEAR SAFETY AND HUMAN HEALTH RISKS

Major Event Scenarios with the Potential for Significant Human Health and Environmental Impacts

The potential accidents evaluated in the tank farms DSA include flammable gas accident leading to fire/explosion; nuclear criticality resulting in a localized high-energy event; waste transfer leak or air blow accident leading to a spill, leak, or aerosolized spray; release from a contaminated facility; excessive load resulting in partial or total tank (dome) failure; mixing of incompatible materials resulting in unwanted chemical reactions; tank bump leading thermally induced release; and filter failure leading to unfiltered releases of contaminants (RPP-13033).

There are four accidents designated as *Anticipated*[52] for Hanford waste tanks ***if no controls are in place*** **(i.e., unmitigated)**:

- *Flammable gas accidents* – This accident involves flammable gas deflagrations in waste storage vessels/containers (including SSTs) where the bounding event is a flammable gas deflagration from the steady-state generation and accumulation or a gas release event in a DST/SST.
- *Waste transfer leaks* – This accident involves a wide spectrum of waste leaks where the bounding event is a fine spray leak using a high head waste transfer pump.
- *Releases from a contaminated facility* – This accident involves various release mechanisms (i.e., flammable gas deflagrations, fires, load handling accidents, or compressed gas system failures) in contaminated facilities.
- *Air blow accidents* – This accident involves a waste release from a contaminated hose-in-hose transfer line (HIHTL) primary hose assembly and connected waste transfer piping system pressurized by compressed air where the bounding event is a small crack leak below the waste surface.

A nuclear criticality accident is considered *Beyond Extremely Unlikely* (i.e., a frequency of less than once in a million years) (RPP-13033). The flammable gas accident (specifically a detonation in a DST/SST) and waste transfer leaks (specifically a fine spray when using a high head pump) was selected as the bounding accident for evaluation in the tank farms DSA.

Separate evaluations are carried out for radiological doses and toxicological effects (i.e., chemical effects) as part of DOE safety analyses. Of the four anticipated accidents listed above, only the waste transfer leak is considered to have the potential for an onsite radiological total effective dose (consequence) >100 rem. None of the design basis accidents[53] is considered to have the potential for an off-site dose greater than the 25 rem standard that would require safety class engineered systems (i.e., safety class structures, systems, or components) or other technical safety requirements. For onsite toxicological consequences, both the waste transfer leak and air blow accidents are considered less than Protective Action Criteria[54] 3 (life-threatening health effects), and accidents are considered to have

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[52] An anticipated event has frequency greater than once in 100 operating years (RPP-13033). External and natural events are not treated separately since they lead to the same accident types.

[53] A design basis accident is an "accident explicitly considered as part of the facility design for a new facility (or major modifications) for the purpose of establishing functional and performance requirements for safety class and/or safety significant controls" (DOE-STD-3009-2014). There are design basis accidents considered other than the four listed (RPP-13033).

[54] Protective Action Criteria may be used "to evaluate the severity of the event, to identify potential outcomes, and to decide what protective actions should be taken" and may be used "to estimate the severity of consequences of an uncontrolled release and to plan for an effective emergency response." There are benchmark values (i.e., PAC-

offsite toxicological consequences (in contrast to radiological consequences) of less than Protective Action Criteria 2 (irreversible or other serious health effects that could impair the ability to take protective action).

Qualitatively, only the air blow accident (of the four accidents listed above) was judged not to represent a significant impact to a facility worker (i.e., result in "prompt death, serious injury, or significant radiological or chemical exposure to the facility worker") (RPP-13033).

Other representative accidents are considered to have consequences that are less than onsite worker guidelines, and thus do not pose significant facility worker hazards. However, defense-in-depth features are in place at Hanford Site to mitigate the potential for the following additional accident scenarios (RPP-13033):

- SST failure may be caused by excessive concentrated loads or excessive uniform loads, excessive vacuum, load drops, or seismic events and failures of other tanks; dome loading requirements are selected as the defense-in-depth protection feature.
- SST failure could result from chemical reactions resulting from mixing incompatible materials; the verification of paperwork to ensure that the correct chemical is being delivered has been selected as a defense-in-depth feature.
- Contaminated soils may be released (from a crib, ditch, pond) from unplanned excavations or drilling into contaminated soils or ruptures of underground pressurized lines in contaminated soils; environmental air permitting requirements and the excavation permitting process are selected as defense-in-depth features.
- A thermally induced upset (e.g., steam bump in an SST liner gap) could cause a failure in an SST.

There are other representative accidents (e.g., aboveground tank or structure failure, transportation-related waste sample handling accidents, filtration failures, organic solvent fires) that are considered to have consequences less than the guidelines for an onsite worker, do not pose significant facility worker hazards, and have no defense-in-depth features.

The air blow accident and most other accidents evaluated in the tank farms DSA pertain to the active cleanup period (until 2064) evaluated in this Risk Review Project. After closure, the preferred alternative for the SST farms as stated in the Tri-Party Agreement (Ecology, EPA, and DOE 1998) is to have 99% of the waste retrieved (although this may not be practically achievable). Each tank will be filled with grout and covered with an engineered cap that would mitigate potential initiating events, such as fire and natural events that degrade barriers and increase infiltration of water. The manner in which the DSTs will be closed after tank wastes are treated is still to be determined.

Hanford Tank Farm Vapor Exposures

Among the hazards related to the Hanford tank farms are facility worker reports of exposure to vapors from the tanks. Short-term, intermittent vapor exposure has led to respiratory irritation symptoms. Several dozen workers reported upper respiratory symptoms requiring medical evaluation during calendar year 2013; exposures have been attributed to vapors from the tanks. Such events have

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1, -2, and -3) for a set of evaluated chemicals. Each successive benchmark represents an increasingly severe effect involving a higher exposure level: (1) mild, transient health effects, (2) irreversible or other serious health effects that could impair the ability to take protective action, and (3) life-threatening health effects. http://orise.orau.gov/emi/scapa/chem-pacs-teels/.

occurred for more than a decade (NIOSH 2004), although the specific offending chemical(s) and sources have not been identified.

An independent review of Washington River Protection Solutions (WRPS) Tank Farm Chemical Vapors Strategy (jointly requested by WRPS and Hanford Challenge, a non-profit group) found that a proposed periodic sampling strategy should be expanded to strengthen the exposure assessment process, the WRPS job hazard analysis should be expanded, and Hanford Site industrial hygienists should expand their capabilities to make sound technical judgements and perform qualitative exposure assessments (especially when quantitative data are not available) (Hanford Concerns Council 2010).

In 2014, the Hanford Tank Vapor Assessment Team (TVAT) from Savannah River National Laboratory concluded that current, available information suggested a causal link between tank vapor releases and the adverse health effects experienced by Hanford tank farm workers (SRNL 2014). Further, an industrial hygiene program emphasizing full-shift exposure measurements and compliance with standard occupational exposure limits cannot adequately characterize the complex, episodic nature of likely tank vapor releases. The team made several recommendations, which DOE and the contractor are implementing, including increased use of personal respiratory protection, improved personal sampling and vapor monitoring, and further tank vapor characterization.

Mitigation of Flammable Gas Accidents

Flammable gas accidents are a concern because of two potential conditions that may result in the accumulation of hydrogen gas in the vapor space of a tank:

- Long-term loss of ventilation that could occur when a regional scale event reduces power to ventilation and other active control systems and passive ventilation is reduced or lost (e.g., from ash fall or other ventilation plugging events)
- Accumulation of gas through entrainment within the settled solids in the tank, followed by a sudden rapid gas coalescence and release event that exceeds the dilution rate to below the LFL by ventilation systems.[55]

Even in the event of flammable gas accumulation as described above, an ignition source still would be necessary for a flammable gas accident to occur.

The following engineered systems are in place to mitigate the potential for flammable gas accidents in the tank farms (RPP-13033, p. T3.3.2.4.1-4):

- *DST primary tank ventilation systems* to maintain the concentration of flammable gases below the LFL in the DST headspace for steady-state releases and induced gas release events due to water or chemical additions and waste transfers into DSTs.
- *Waste transfer primary piping systems* to confine the waste to protect the facility worker from flammable gas accidents in a DST annulus due to a misrouting of materials.

The following flammable gas operational controls for the Hanford tank farms are defined (RPP-13033, p. T3.3.2.4.1-5&6):[56]

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[55] The flammability range of a gas is the range (often provided in volumetric terms) in which the gas and air are in the right proportions to burn when ignited. Below the LFL, there is not enough fuel to burn (http://energy.gov/eere/fuelcells/glossary#l).
[56] There are additional controls related to double-contained receiver tanks (DCRTs); inactive/miscellaneous tanks/facilities and waste intruding equipment; and waste packaging that are external to the waste tanks.

- *DST primary tank ventilation systems* for all DSTs ensure the DST primary tank ventilation systems are operable and operating to prevent flammable gas hazards from steady-state releases and slow, continuing induced gas releases following water additions, chemical additions, and waste transfers into DSTs.
- *SST steady-state flammable gas control* for all SSTs, except those in the 241-AX and 241-SX tank farms, protect the facility worker from a flammable gas deflagration caused by steady-state flammable gas releases in an SST by monitoring the flammable gas concentration, verifying passive ventilation for 241-B-203 and 241-B-204, and reducing the flammable gas concentration or eliminating potential ignition sources before the flammable gas concentration exceeds the LFL.
- *DST-induced gas release event flammable gas controls* for all DSTs protect the facility worker from a flammable gas deflagration in a DST due to an operations-induced gas release event by requiring evaluations of waste transfers from DSTs and water additions, chemical additions, and waste transfers into DSTs to determine restrictions or required controls to prevent an induced gas release event flammable gas deflagration.[57]
- *DST-induced gas release event flammable gas control* for all DSTs (when required) ensure the DST primary tank ventilation systems are operable and operating to prevent flammable gas hazards from induced gas release events during water additions, chemical additions, and waste transfers into DSTs.
- *DST annulus flammable gas control* for all DSTs protects the facility worker from a flammable gas deflagration in a DST annulus caused by steady-state flammable gas releases from waste in the DST annulus by monitoring the DST annulus waste level and controlling the flammable gas concentration or eliminating potential ignition sources if a significant quantity of waste is detected in the DST annulus.

The key elements evaluated relative to flammable gas accidents in the Hanford tank farms are (RPP-13033, p. T3.3.2.4.1-7):

- *DST and SST time to LFL* to protect assumptions used to develop surveillance frequencies and action completion times in the limiting conditions of operation for DST primary tank ventilation systems and safety administrative controls for SST steady-state flammable gas control and DST annulus flammable gas control.
- *Ignition controls* to be consistent with the National Fire Protection Association requirements for eliminating potential flammable gas ignition sources; to evaluate activities, equipment, and materials to determine the applicability of and compliance with ignition source control requirements; and to be an important contributor to defense-in-depth by applying ignition controls for the spontaneous gas release event hazard in DSTs 241-AN-103, 241-AN-104, 241-AN-105, 241-AW-101, and 241-SY-103.

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[57] In 2012, the Defense Nuclear Facilities Safety Board submitted Recommendation 2012-2, *Hanford Tank Farms Flammable Gas Safety Strategy*, which identified the need to reduce risk posed by flammable gas events at the Hanford tank farms. DOE responded with an implementation plan including a revision to the DSA to include a new control that measures ventilation flow through each DST periodically, supplementing the existing flammable gas monitoring control. This DSA revision also placed requirements on operability of the in-service and standby primary ventilation trains. DOE is working toward installing safety-significant instrumentation for real-time monitoring of the ventilation exhaust flow from each DST.

- *Waste characteristics controls* to protect assumptions used to develop controls for flammable gas deflagrations due to gas release events by preventing the formation of waste gel in DSTs and SSTs.
- *Emergency preparedness requirements* to reduce the risk from seismic-induced flammable gas accidents in DSTs.

The potential for flammable gas-related accidents in the Hanford tank farms is indicated by hydrogen generation rates (HGRs) and times to reach LFLs. Both are provided for each tank in each tank waste and farms EU summary section (Appendices E.1 through E.10). A summary showing tanks with times to reach 25% of the LFL[58] under the zero ventilation scenario (i.e., most restrictive) of less than 6 months[59] is provided in Figure 3-21. The time it would take for a tank to reach 25% of the LFL was selected as a safety indicator by the Risk Review Project because a range of site or regional initiating events potentially could result in temporary or extended loss of ventilation controls (e.g., prolonged loss of power, severe seismic event, high ash fall from volcanic eruption) and indicate the needed response time in an event. Most of the tanks shown are DSTs in the 200 East Area. Under the potential accident scenario of loss of ventilation, current tank waste inventories reveal that three tanks would reach 25% of the LFL in less than 14 days, 13 tanks would reach 25% of the LFL in less than 30 days, and 27 tanks would reach 25% of the LFL in less than 180 days.

The Risk Review Project considered variables that would increase the time to reach the 25% LFL in the tanks, thereby reducing the risk of a flammable gas accident. Removal of Cs-137 was considered because it is very water soluble and potentially could be removed from tanks by the LAW Pretreatment System (LAWPS) currently under design to enable startup of LAW vitrification prior to startup of the entire set Waste Treatment Project facilities (e.g., prior to startup of the WTP HLW Vitrification Facility and Pretreatment Facility). The current design basis for LAWPS is to return separated Cs-137 to the tank farms. Modifications could allow for separation without return to the tank farms if a viable disposition pathway is identified. This analysis also can provide insights into which tanks to consider for Cs-137 return when necessary.

Figure 3-22 depicts the contribution of Cs-137 to the hydrogen generation rate (HGR), which, in conjunction with the amount of waste in the tank, and the volume of the tank vapor space, is a primary variable for the time to reach 25% LFL for an individual tank. The contribution of Cs-137 to the HGR varies by tank from less than 1% to 46% for the tanks with less than 180 days to reach 25% of the LFL under unventilated conditions. Figure 3-23 depicts the resulting impact of Cs-137 removal from the tanks that have less than 180 days to reach 25% of the LFL. The total number of tanks with less than 180 days remains at 27, but the number of tanks with less than 14 days is reduced from 3 to 2, and the number of tanks with less than 30 days is reduced from 13 to 9. Removal of Cs-137 also eliminates a significant source of penetrating radiation (gamma radiation) associated with tank wastes.

[58] NFPA Standard 69 (2008) requires that fuel concentration only reach 25% of the LFL value, which has been the long-standing practice in the United States.
[59] Typical response times of 14 and 30 days also are shown in Figure 3-21 for reference only.

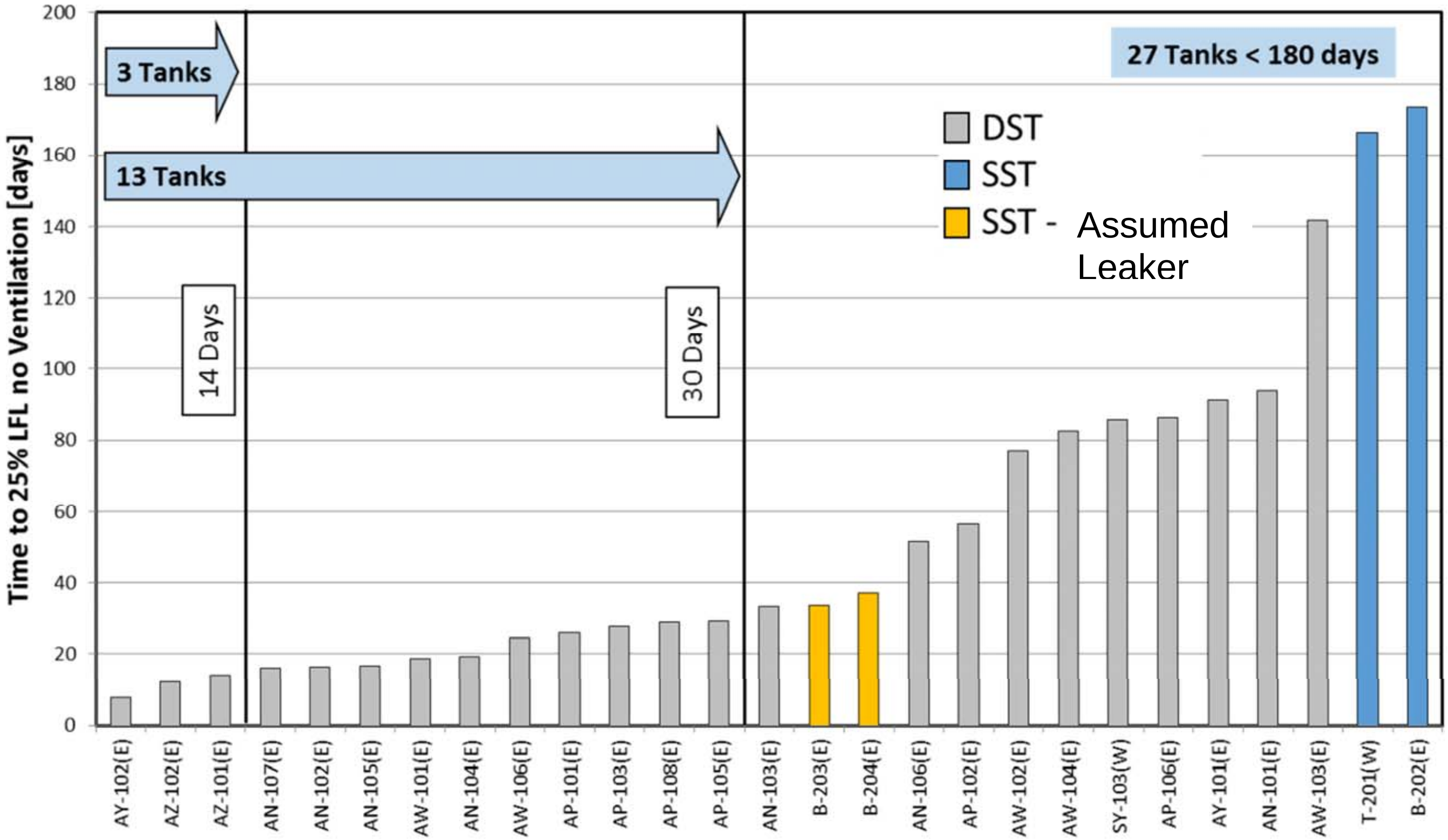

Figure 3-21. Current conditions: Time to 25% LFL for tanks with less than 6 months assuming loss of controls leads to no ventilation (after RPP-5926, Rev. 15). The location (E = 200 East and W = 200 West) is provided after each tank name.

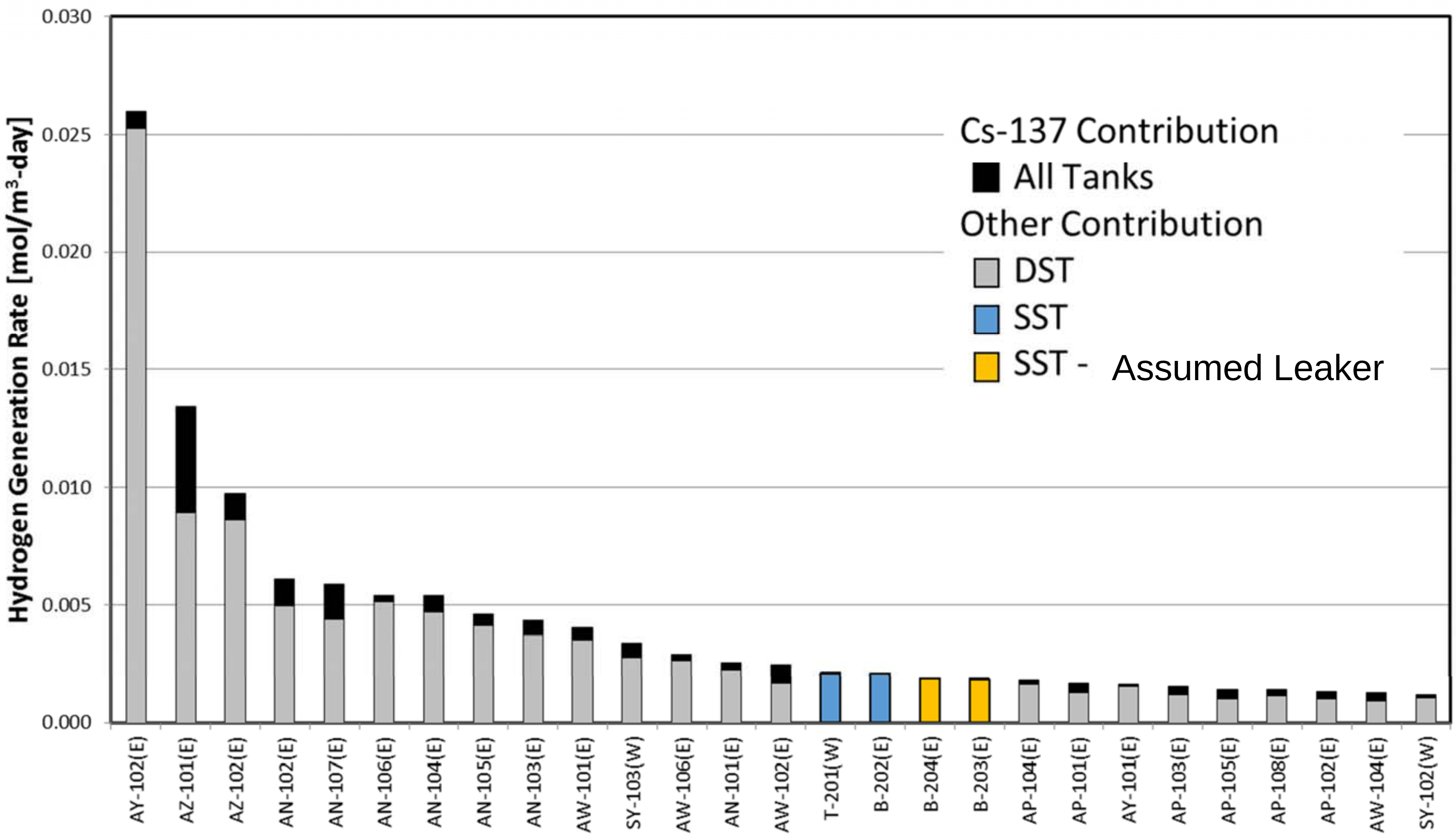

Figure 3-22. Cesium-137 contribution to the HGR for tanks having less than 6 months to 25% of the LFL rate under unventilated conditions (Kirch 2015).

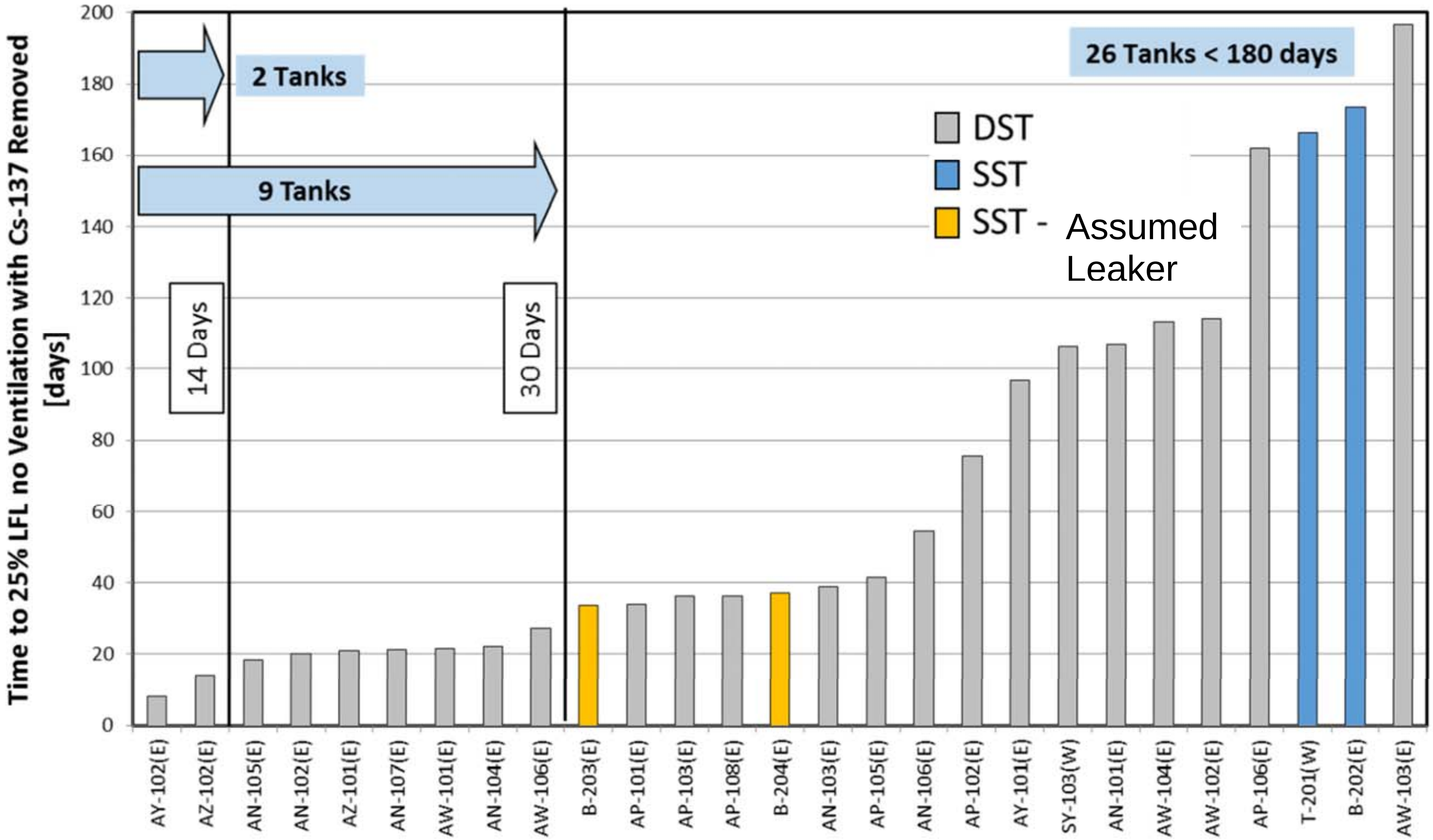

Figure 3-23. Impact of cesium-137 removal: Time to 25% LFL for tanks with less than 6 months assuming removal of Cs-137 and loss of controls leads to no ventilation (based on Kirch 2015 after RPP-5926, Rev. 15). The location (E = 200 East and W = 200 West) is provided after each tank name.

Mitigation of Waste Transfer Leak Accidents and Release from a Contaminated Facility

The following engineered systems are in place to mitigate waste transfer leak accidents and release from contaminated facilities (RPP-13033, p. T3.3.2.4.3-2):

- *Waste transfer primary piping systems* confine waste to decrease the frequency of a fine spray leak, which also protects the facility worker from wetting spray/jet/stream leaks into a normally occupied area and from flammable gas deflagrations in a waste transfer-associated structure due to a waste transfer leak.
- *Hose-in-hose transfer line systems (HIHTL)* confine waste, thus decreasing the frequency of a fine spray leak and protecting the facility worker from wetting spray/jet/stream leaks into a normally occupied area and from flammable gas deflagrations in a waste transfer-associated structure due to a waste transfer leak. This is also an important contributor to defense-in-depth by providing secondary confinement of leaks in the hose-in-hose transfer line primary hose assemblies.
- *Isolation valves for double valve isolation* limit the leakage of waste (through valve leakage), decreasing the consequences of a fine spray leak due to a misrouting and thus protecting the facility worker from wetting spray/jet/stream leaks into a normally occupied area and from flammable gas deflagrations in a waste transfer-associated structure (or other facility) due to a misrouting.

The following additional operational controls are in place to mitigate the potential for waste transfer leaks and releases from contaminated facilities for the Hanford tank farms (RPP-13033, p. T3.3.2.4.1-5-7):

- *Double valve isolation* is required to ensure that safety-significant isolation valves for double-valve isolation are in the closed or block flow position when used to physically disconnect waste transfer primary piping systems, HIHTL primary hose assemblies, and interfacing water systems. This limits waste leakage into the physically disconnected systems, thus decreasing the consequences of a fine spray leak due to a misroute and protecting the facility worker from a wetting spray/jet/stream leak and from a flammable gas deflagration in a waste transfer-associated structure (or other facility) due to a misrouting.
- *Waste transfer-associated structure cover installation and door closure* is an important contributor to defense-in-depth that provides secondary confinement of leaks into waste transfer-associated structures.

Mitigation of Air Blow Accidents

The following engineered systems are used to mitigate the potential for air blow accidents (RPP-13033, p. T3.3.2.4.5-2):

- *Compressed air system pressure relieving devices* limit compressed air system pressure.
- *Waste transfer primary piping systems* provide confinement of waste.

External and Natural Events

No specific engineered systems or operational controls related to external or natural events were identified in the tank farms DSA. The external events evaluated in the DSA include aircraft crash, vehicle accident, and range fire. The external event frequencies range from *Beyond Extremely Unlikely* for accidents like commercial or military aircraft impacting a tank or facility to *anticipated* for range fires.

The natural events evaluated in the DSA include lightning, high winds, earthquakes, volcanic eruptions/ashfall, severe dust storms, heavy snow, hail storms, and floods. For natural events, frequencies range from *not credible* for floods to *anticipated* for extreme temperatures, high winds, hail storms, and dust storms. Natural flooding was determined to be not a credible hazard because of the relative elevations of the tanks and the potential maximum sources of flooding; the physical location of the tanks precludes any potential for impact. The consequences, which relate to the operating accidents described above, would not be increased specifically because the initiating event was an external or natural event. Thus, additional engineered systems and controls were not considered necessary. The only unique aspect of natural events is the possibility that these events cause multiple failures both within a tank farm and also across the Hanford site; however, it was considered unreasonable to expect all releases to be at their highest estimated releases for individual accidents (RPP-13033, p. 3.3.2.4.7-3) in the event of multiple failures. The consequences that relate to the operating accidents described above (e.g., waste transfer leaks, air blow events) would not be increased as a result of external or natural initiating events.

THREATS TO GROUNDWATER

Impact Pathways and Timeframes

The estimated inventories for the vadose zone, groundwater, and treatment amounts associated with the Tank Waste and Farm EUs are found in Appendix E.1 through E.10. These values are used to estimate the inventory remaining in the vadose zone using the process described in Chapter 6 of the methodology report (CRESP 2015). These estimates necessarily have high uncertainties. Recharge travel times for water through the vadose zone have been estimated (Figure 3-24), and while rapid during active site operations with high discharge rates, they are relatively slow, with 50 to 75 years expected for recharge rates of 100 and 50 mm/yr, which correspond with gravel cover or disturbed soil conditions. Lower infiltration rates associated with vegetated cover or engineered covers (less than 3.5 mm/yr) are estimated to result in vadose zone travel times of several hundred years. The focus here is on the Group A and B contaminants in the vadose zone due to their mobility and persistence and thus their potential threats to groundwater. To summarize:

- *Tc-99, I-129* (Figure 3-14 and Figure 3-15) – The vadose zone inventory is dominated by past leaks in the EU CP-TF-1 (T tank farm and associated legacy waste sites, 200 West) and the EU CP-TF-3 (TX-TY tank farms and associated legacy waste sites, 200 West), along with legacy disposal activities in the EU CP-TF-6 (B-BX-BY tank farms and associated legacy waste sites, 200 East).
- *Sr-90* (Figure 3-13) – The vadose zone inventory is dominated by past leaks in the EU CP-TF-1 (T tank farm and associated legacy waste sites, 200 West) and the EU CP-TF-3 (TX-TY tank farms and associated legacy waste sites, 200 West). Thus, the majority of the Sr-90 originally discharged into the vadose zone would have to travel through much of the vadose zone to impact groundwater. The Tank Farm Closure and Waste Management (TC&WM) EIS groundwater transport analysis (DOE/EIS-0391 2012, Appendix O) indicates that Sr-90 is not expected to reach the boundary (T Barrier) closest to the T and TX-TY tank farm EUs.[60]

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[60] The barrier represents the edge of the infiltration barrier to be constructed over disposal areas that are within 100 meters [110 yards] of facility fence lines (DOE/EIS-0391 2012). The T Barrier is the closest to the T and TX-TY Tank Farm EUs. Despite including sources other than those for the T and TX-TY Tank Farm EUs, the analysis in the

- Furthermore, the average time for water to travel through the vadose zone to groundwater is 64 years, with a range estimated from 50 to greater than 100 years (Figure 3-24) for the 200 West Area (DOE/EIS-0391 2012, Table N-52); thus, the resulting average travel time for Sr-90 to move through the vadose zone to groundwater is more than 300 years (or 10+ half-lives), accounting for retardation by sediment adsorption.[61] It would likely require more time to reach groundwater in a sufficient amount to exceed the drinking water standard over an appreciable area. Thus, a Sr-90 plume is not expected to reach groundwater in significant quantities in the next 150 years due to retardation or after 150 years due to radioactive decay (+99.99% reduction in Sr-90 inventory).
- *Chromium* (Figure 3-18) – The vadose zone inventory is dominated by past discharges to cribs and trenches (for the CP-TF-1, CP-TF-3, and CP-TF-6 TF EUs).
- *Uranium* (Figure 3-19) – The vadose zone inventory is divided among discharges to trenches and cribs (predominantly EU CP-TF-5, but also EUs CP-TF-2, CP-TF-3) and leaks (predominantly EU CP-TF-6). Thus, at least part of the uranium originally discharged into the vadose may have been driven deeper into the vadose zone (with high volume discharges) and may have less of the vadose zone to travel until potentially impacting groundwater. There is an existing uranium plume in the groundwater underlying CP-TF-5 (A-AX tank farms); however, this plume is associated with PUREX and not tank farm operations.

TC&WM EIS was considered reasonable to assess rate of movement of contaminants to groundwater through the vadose zone.

[61] The minimum K_d for Sr-90 for WMAs T and TX-TY is 0.6 mL/g (PNNL-17154, p. 3.87), which translates to a retardation factor of ~6.

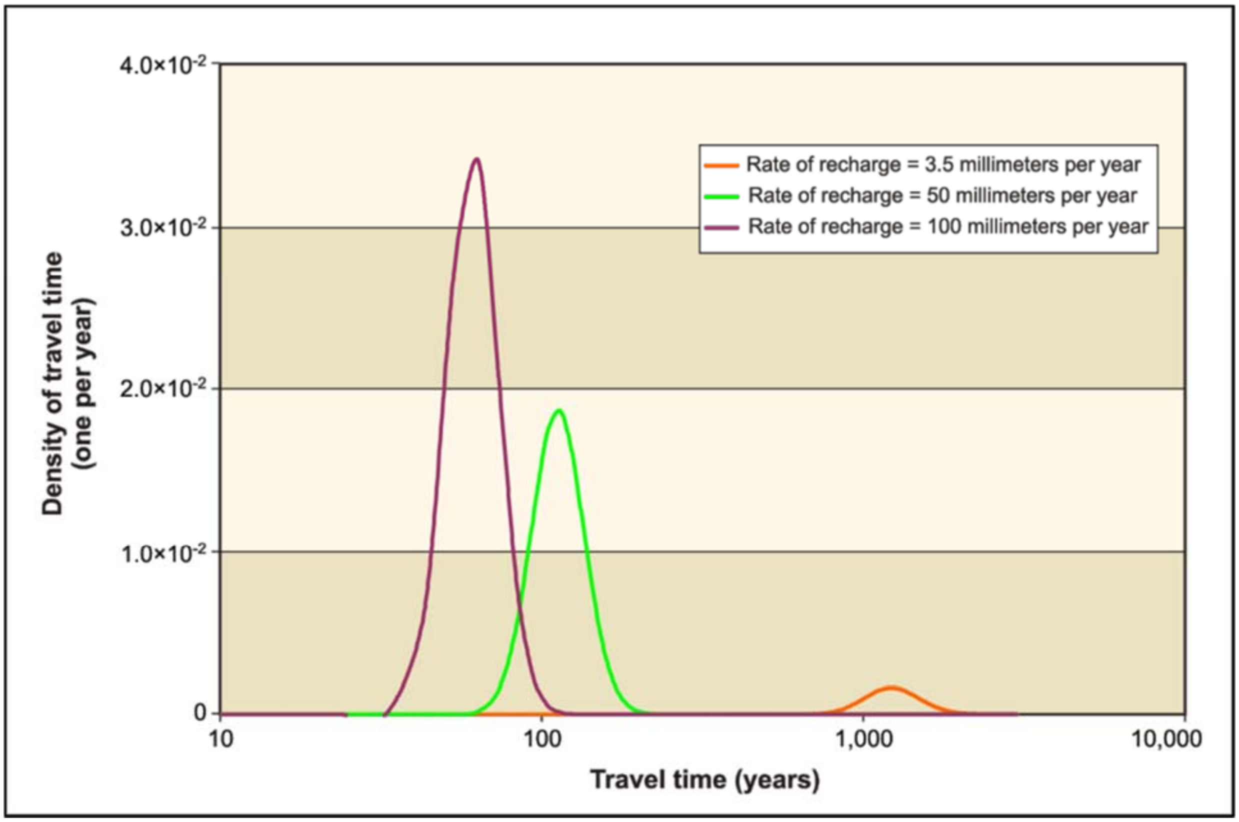

Figure 3-24. Distribution of travel time in the vadose zone for the 200 West Area (DOE/EIS-0391 2012, Fig. N-159, Appendix N).

Estimated Groundwater Threat Metric

The GTM, which represents the maximum volume of water that could be contaminated from a source at the reference threshold (e.g., water quality standard), is used in conjunction with consideration of the time estimated for specific contaminants to reach the groundwater as the primary basis to evaluate the potential for existing contamination in the vadose zone to contaminate groundwater. Similarly, the GTM is used to estimate the potential extent of groundwater contamination if releases from individual tanks occurred. The GTM is defined as the volume of groundwater that could potentially be contaminated by the inventory of a primary contaminant from a source (groundwater plume, vadose zone contamination, tank, etc.) if it was found in the saturated zone at the WQS (e.g., drinking water standard) and in equilibrium with the soil. The GTM accounts only for (1) source inventory, (2) partitioning with the surrounding subsurface, and (3) the WQS. The GTM reflects a snapshot in time (assuming no loss by decay/degradation or dispersion, etc.) and does not account for differences in contaminant mobility or bulk groundwater flow. Refer to the methodology report, Chapter 6, for a more complete discussion of the GTM (CRESP 2015).

The GTM is summarized for each tank in Figure 3-25. For evaluating groundwater threats from tank wastes, the GTM is presented using the maximum GTM value obtained from I-129 and Tc-99 for each tank, existing environmental contamination (from legacy sources), and each EU. The focus is placed on I-129 and Tc-99 because the TC&WM EIS (DOE/EIS-0391 2012) identified these as the risk-driving primary contaminants in the tank wastes that potentially threaten groundwater and the Columbia River.[62] The chart in Figure 3-25 and those like it show the relative fractions of the GTM (or other metrics) for individual tanks and legacy sources across the tank farm EUs; the sizes of the diagrams are also scaled to be relative to the total GTM in the tank farm EU.

Figure 3-25 indicates that the threat to groundwater posed by the tank wastes is very unevenly distributed between tank farms and among tanks within each tank farm EU. The greatest GTM, 15,000 Mm^3, is associated with the 200 East DSTs (CP-TF-8). The next greatest grouping of GTM is associated with EUs CP-TF-2 (S-SX, 200 West, 4200 Mm^3), CP-TF-3 (TX-TY, 200 West, 3000 Mm^3) and CP-TF-6 (B-BX-BY, 200 East, 2700 Mm^3), which are essentially indistinguishable given uncertainties in the tank waste inventory estimates associated with I-129 and Tc-99. The lowest grouping of GTM is associated with EUs CP-TF-1 (T, 200 West, 250 Mm^3) and CP-TF-7 (C, 200 East, 270 Mm^3), noting that the C tank farm has undergone partial waste retrieval and waste retrieval currently is ongoing.

Figure 3-26 illustrates the uneven distribution of GTM among individual tanks within a tank waste and farm EU. For the A-AX tank farm EU, the GTM is dominated by tanks A-101, A-103, A-106 and AX-101 (4 of 10 tanks). For the T tank farm EU, the GTM is dominated by tanks T-101, T-105, T-107, and T-111, three of which are assumed leakers (4 of 14 tanks). Also note that for the T tank farm EU, the GTM associated with past leaks is greater than the GTM associated with any individual tank and dwarfs the GTM associated with all but the 4 tanks with the greatest GTMs. For the T tank farm EU, reducing 99% of the tank inventory in all tanks would reduce the overall GTM for that tank farm EU by only 67.2%, while a 99% reduction for tanks T-101, T-105, T-107, and T-111, along with a 90% reduction of the tank inventory for the remaining 12 tanks, would reduce the overall GTM by 67.6%.

Figure 3-27 compares the GTM for waste in all tanks within each EU to the GTM for the existing environmental contamination in the vadose zone from legacy discharges and leaks. These results indicate that reducing the GTM remaining in the tanks after waste retrieval to levels commensurate with the surrounding vadose zone GTM should be considered, especially in the context where residual inventories in the tanks after retrieval would be grouted in place and would therefore have significantly less leaching potential to impact groundwater than inventories in the vadose zone. Waste retrievals that result in reduction of the GTM contained in the tanks within each tank farm EU by 90% would meet this criteria (tank end-states less than the GTM in the vadose zone) for all SST tank farms except for U and A-AX tank farms. Overall, the GTM in the vadose zone is approximately 3% of the GTM in the SSTs for both 200 East and 200 West tank farms.

Figure 3-28 presents the GTM for all DSTs and SSTs. The waste inventory in 19 tanks (18 DSTs and 1 SST) accounts for 50% of all of the GTM within tanks, while 68 of 177 tanks (26 DSTs and 42 SSTs, including 10 assumed SST leakers) account for 90% of the total GTM within tanks (Table 3-13). All DSTs and SST in the group that accounts for 90% of the total GTM have greater than 100 Mm^3.

If the focus is solely on SSTs, then 90% of the total GTM within SSTs is contained in 58 tanks (Figure 3-29). All of these SSTs have a GTM greater than 78 Mm^3, with 52 of the 58 SSTs having a GTM greater than 100 Mm^3.

[62] Cr(VI) also is identified as having significant potential to threaten groundwater and the Columbia River, but the potential threat from Cr(VI) is from existing environmental contamination (legacy discharges), not from chromium currently in the tanks. Chromium in the tank wastes is primarily precipitated in solids as Cr(III) and is not reported based on fractional speciation between Cr(III) and Cr(VI).

If the focus is on SSTs that are assumed leakers (Figure 3-30), 10 are in the group of tanks that comprises 90% of the total GTM (DSTs and SSTs), and each of these 10 tanks has a GTM greater than 100 Mm^3 (i.e., 7 in the TX tank farm, 2 in the BY tank farm, 1 in the B tank farm). Thirty-six SSTs that are assumed leakers have a GTM greater than 10 Mm^3.

Table 3-12. Groundwater threat metric by tank waste and farm EU, existing contamination within the vadose zone and within tanks.

		GTM (Mm^3)		
Tank Waste and Farms EUs	**200 West SSTs**	**Vadose Zone**	**Within Tanks**	**(GTM Vadose Zone)/ (GTM within Tanks)**
CP-TF-1	T	73	170	43%
CP-TF-2	S-SX	83	4,093	2%
CP-TF-3	TX-TY	124	2,910	4%
CP-TF-4	U	3.1	1,847	0.2%
	Sum:	282	9,020	
	200 East SSTs			
CP-TF-5	A-AX	1.5	1,224	0.1%
CP-TF-6	B-BX-BY	118	2,495	5%
CP-TF-7	C	12	238	5%
	Sum:	132	3,957	

a. The groundwater threat metric (GTM) represents the maximum volume of water that could be contaminated from a source at the reference threshold (e.g., water quality standard).

Table 3-13. 26 of 28 DSTs and 42 of 149 SSTs account for 90% of the total DST+SST GTM based on maximum of I-129 and Tc-99 GTM by tank. Asterisk (*) indicates an assumed leaker tank.

200 East (35 of 91 tanks)		200 West (33 of 86 tanks)	
CP-TF-5 4 Tanks	A-101, A-103, A-106, AX-101	CP-TF-1 0 Tanks	
CP-TF-6 8 Tanks	B-111*, BY-101, BY-103*, BY-104, BY-106*, BY-110, BY-111, BY-112	CP-TF-2 13 Tanks	S-103, S-105, S-106, S-108, S-109, S-110, S-111, SX-101, SX-102, SX-103, SX-104, SX-105, SX-106
CP-TF-7 0 Tanks		CP-TF-3 10 Tanks	TX-105*, TX-106, TX-110*, TX-111, TX-112, TX-113*, TX-114*, TX-115*, TX-116*, TX-117*
CP-TF-8 23 Tanks (DSTs)	AN-101, AN-102, AN-103, AN-104, AN-105, AN-106, AN-107, AP-101, AP-102, AP-103, AP-104, AP-105, AP-106, AP-107, AP-108, AW-101, AW-102, AW-103, AW-104, AW-106, AY-102*, AZ-101, AZ-102	CP-TF-4 7 Tanks	U-102, U-103, U-105, U-107, U-108, U-109, U-111
		CP-TF-9 3 Tanks (DSTs)	SY-101, SY-102, SY-103

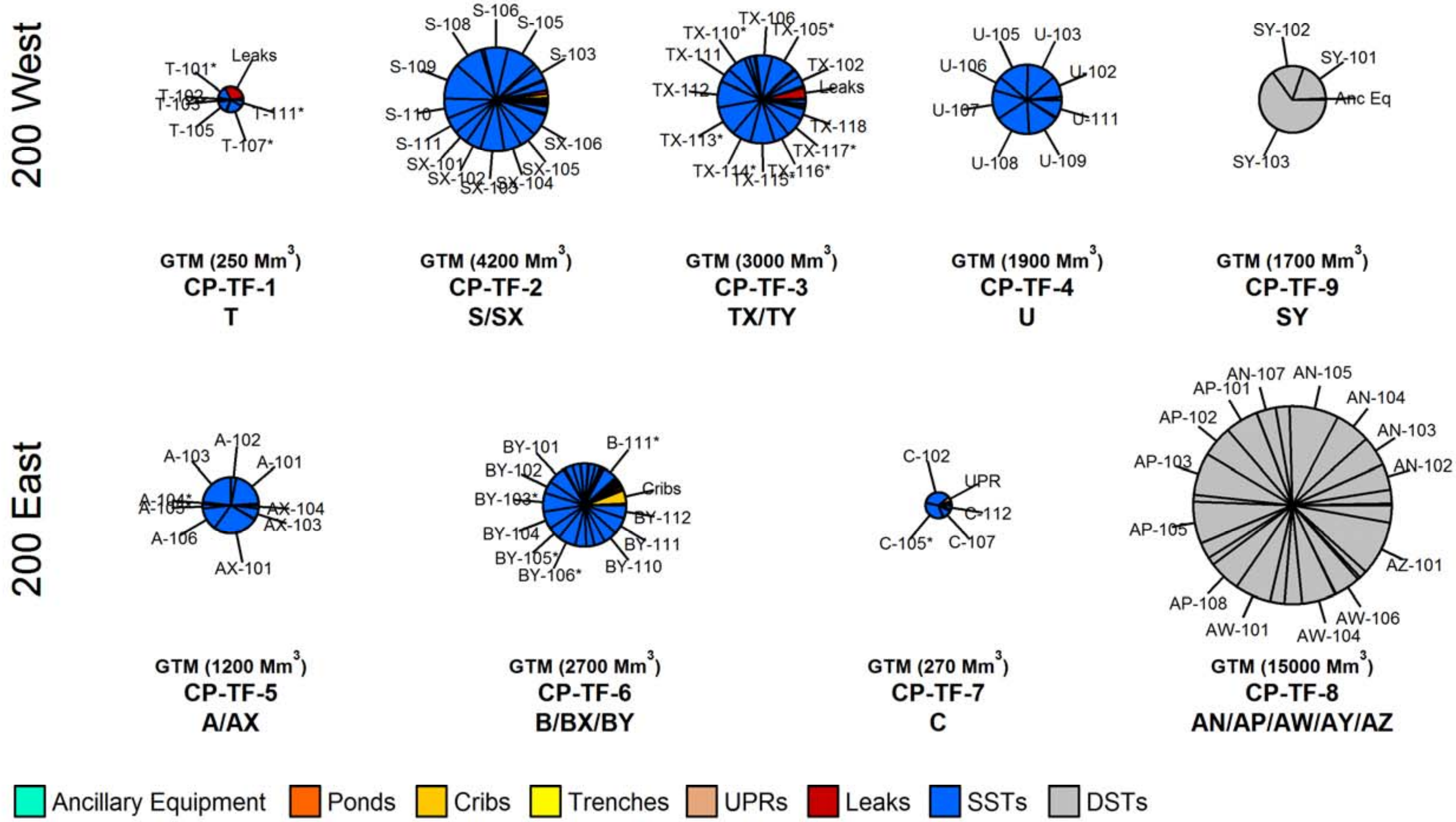

Figure 3-25. Groundwater threat metric based on the maximum GTM between I-129 and Tc-99. The GTM distribution between waste within tanks and existing environmental contamination from past disposal practices (i.e., discharges to cribs and trenches), leaks, and UPRs. The relative GTM within each EU is scaled by relative area for each pie. Asterisk (*) indicates an assumed leaker tank.

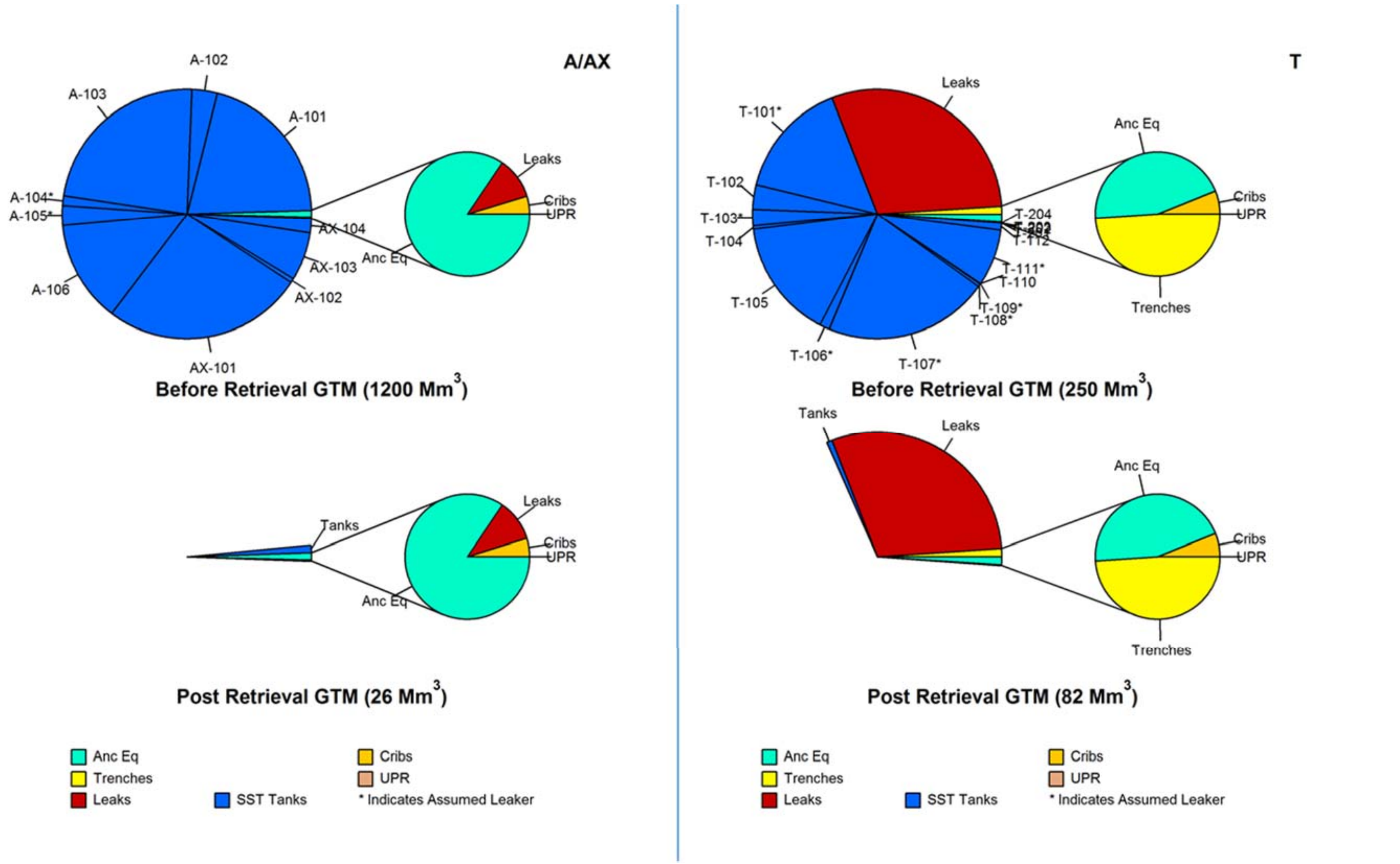

Figure 3-26. Distribution of the GTM based on the maximum GTM of I-129 and Tc-99 among individual tanks and existing environmental contamination for two tank waste and farm EUs (CP-TF-5, A/AX, 200 East; CP-TF-1, T, 200 West). Asterisk (*) indicates an assumed leaker tank.

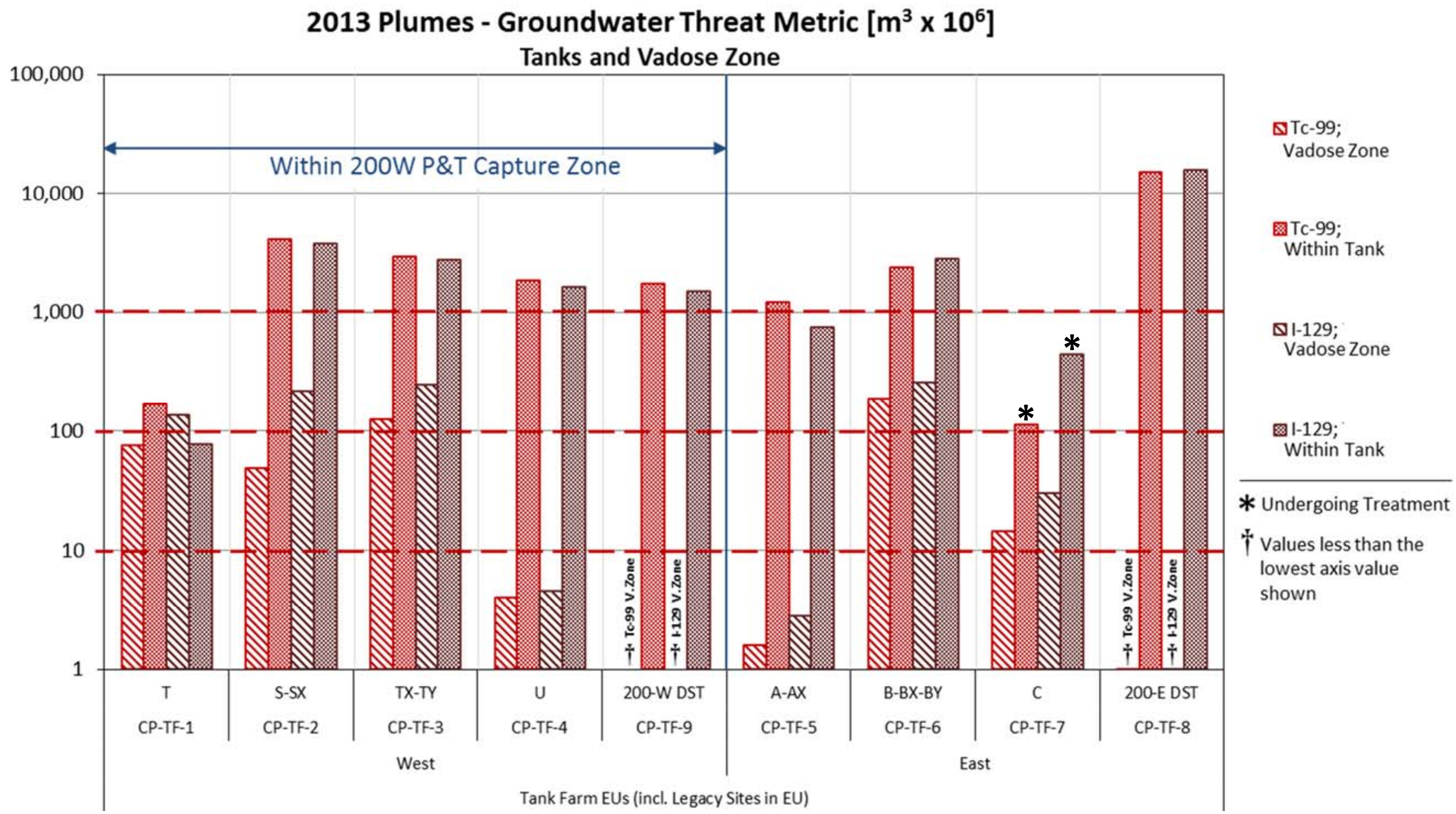

Figure 3-27. Comparison of the GTM (Mm^3) from existing contamination in the vadose zone to the GTM associated with the inventories in each tank waste and farm EU.

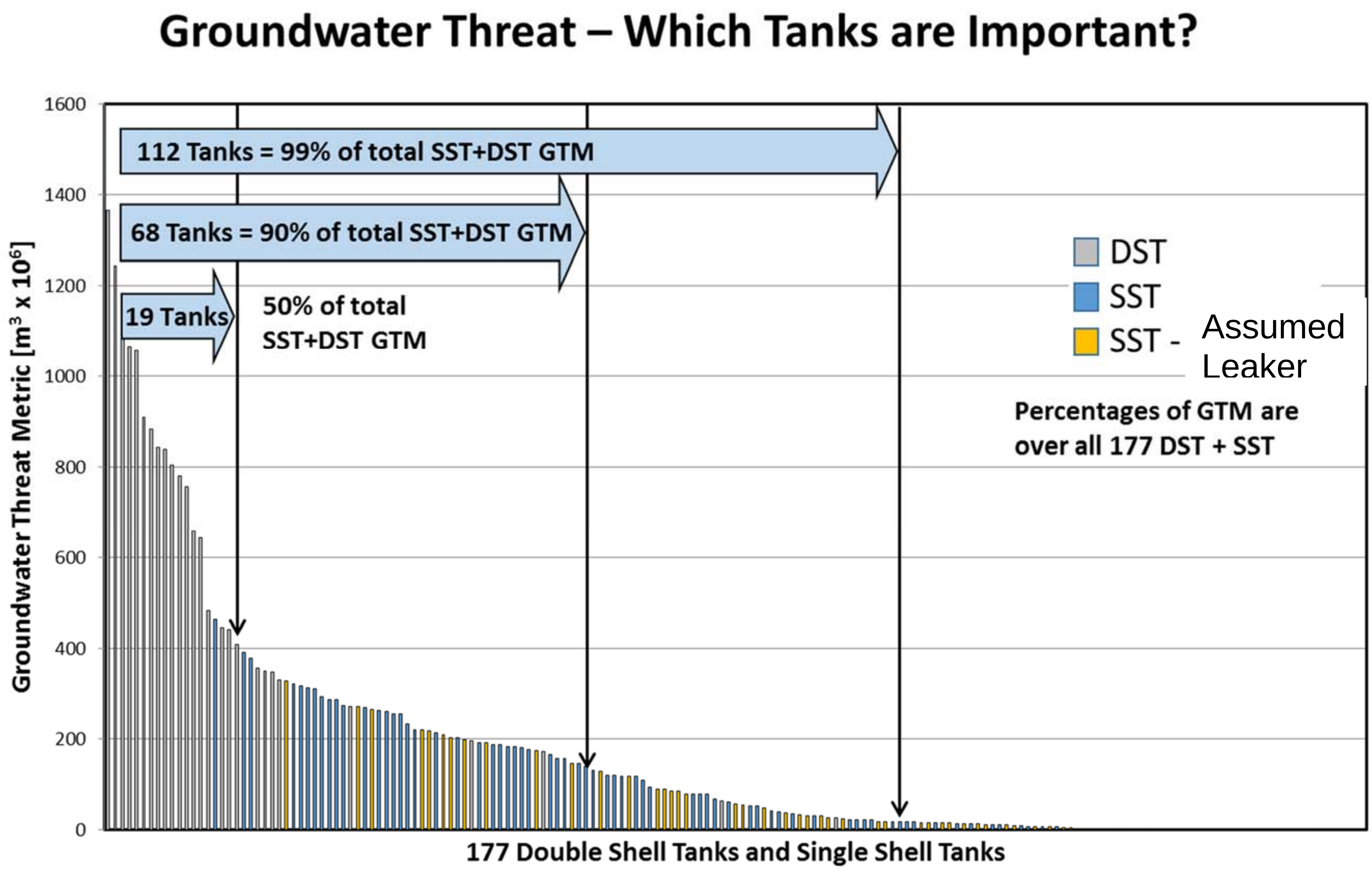

Figure 3-28. Groundwater threat: Which tanks are important? Comparison of GTM within DSTs and SSTs by tank.

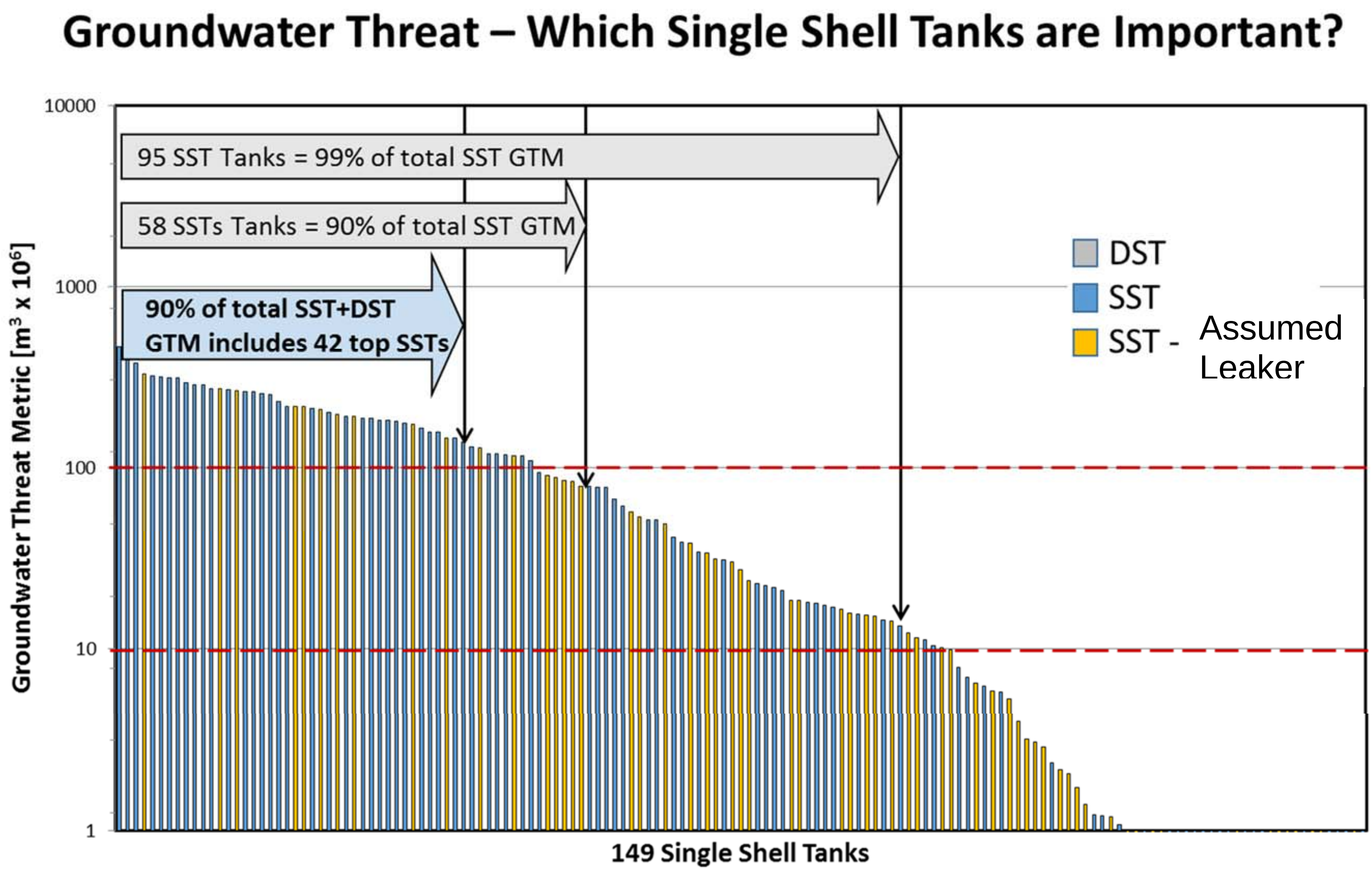

Figure 3-29. Groundwater threat: Which single-shell tanks are important? Comparison of GTM within SSTs by tank.

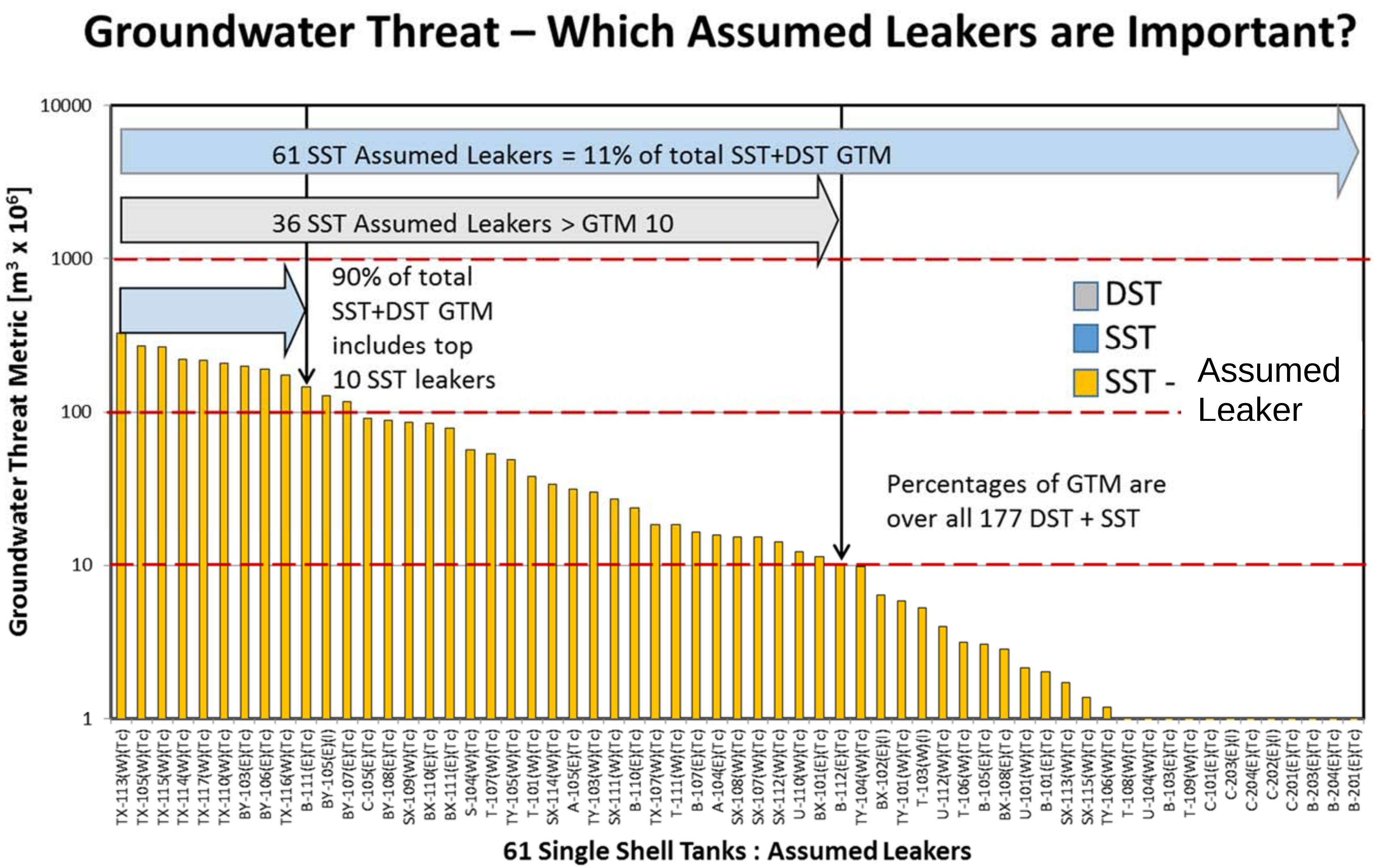

Figure 3-30. Groundwater threat: Which assumed leakers are important? Comparison of GTM for SST assumed leakers by tank.

THREATS TO THE COLUMBIA RIVER

200 West Tank Farm EUs

Current impacts from the tank farm EUs to the benthic, riparian, and free-flowing ecology associated with the Columbia River are rated as *Not Discernible* (ND) for the 200 West tank waste and farms EUs. The groundwater plumes in the 200 West Area (CP-GW-2) resulting from releases related to the 200 West tank farm EUs are managed using the 200-UP-1 and 200-ZP-1 CERCLA groundwater OUs (DOE/RL-2014-32, Rev. 0). The ND rating is based on the information in the 2013 Hanford Annual Groundwater Report (DOE/RL-2014-32, Rev. 0) and PHOENIX (http://phoenix.pnnl.gov/), which indicates that even though contaminants associated with the 200 West tank farm EUs (including Tc-99, I-129, and chromium) are in the saturated zone (as reflected in the 200-ZP-1 and 200-UP-1 OUs), no plumes from the these OUs (and thus the 200 West tank farm EUs) are currently intersecting the Columbia River at concentrations exceeding the WQS.

Because the 200 West tank farm EU plumes originate from 200 West (CP-GW-2 EU), it is unlikely that a plume would reach the Columbia River in the next 150 years (see Figure 3-31) at a concentration that exceeds thresholds since the *water* travel time is greater than 50 years (and likely significantly more) from 200 West to 200 East and approximately 10 to 30 years from 200 East to the Columbia River (Gephart 2003; PNNL-6415 Rev. 18). It is likely that significantly more time would be required to reach the river in sufficient quantity to exceed the WQS or appropriate aquatic screening values.[63]

An ecological screening analysis was performed in the TC&WM EIS (DOE/EIS-0391 2012, Appendix P) to evaluate potential long-term impacts of radioactive and chemical contaminants (*from sources in addition to those in the 200-West Tank Farm EUs under a No Action Alternative*[64]) discharged with groundwater on aquatic and riparian receptors at the Columbia River. The screening results indicate that exposure to radioactive contaminants from peak groundwater discharge was below benchmarks (0.1 rad per day for wildlife receptors and 1 rad per day for benthic invertebrates and aquatic biota, including salmonids, consistent with DOE-STD-1153-2002) (DOE/EIS-0391 2012, Appendix P, p. P-52), indicating adverse effects from radionuclides should not be expected, which would lead to an *ND* rating for radionuclides for benthic, riparian, and free-flowing receptors (for Current, Active Cleanup, and Near-term, Post Cleanup periods). Compared with the DOE technical standard, recent European Union work has estimated a no observed adverse effects level (NOAEL) at 0.024 rad/d (10 µGy/h) (Anderson et al. 2009) and a LOAEL at 0.24 rad/d (100 µGy/h) (Real et al. 2004) for nonhuman biota.[65]

The screening ecological evaluation in the TC&WM EIS (Appendix P, DOE/EIS-0391 2012) for potential impacts of chemical contaminants discharged with groundwater to the near-river ecology (benthic and riparian) indicates that chromium and nitrate would have predicted hazard quotients exceeding one for aquatic and riparian receptors over the EIS evaluation period (10,000 years). Furthermore, the results of the screening evaluation at the near-shore region under the No Action Alternative (DOE/EIS-0391 2012, Appendix O) that were used to support the screening ecological evaluation indicate that the nitrate peak

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[63] Based on current and expected subsurface conditions, the only path currently considered from 200 West to the Columbia River is that from 200 West to 200 East to the Columbia River (Chapter 6, methodology report).

[64] The results were not provided for specific tank farms so the aggregated screening analysis in the TC&WM EIS (DOE/EIS-0391 2012) was used as an indicator of contaminant travel from the Central Plateau to the Columbia River for the purposes of this Review.

[65] For aquatic biota, the maximum Hazard Index (HI), which is the sum the external and internal radiation doses from exposure to all radioactive COPCs divided by the toxicity reference value (TRV) or 1 rad-per-day, is 2.81×10^{-4} (DOE/EIS-0391 2012, Appendix P, p. P-49) or a total dose of 2.81×10^{-4} rad/d, which is significantly less than the European Union NOAEL of 0.024 rad/d.

concentration (and discharge) occurred in the past and that future concentrations are anticipated not exceed either the drinking water standard or AWQC in the future. Furthermore, the potential impact of increased nitrate levels may depend on other factors (e.g., phosphorus) and are highly uncertain.

The EIS results of the screening evaluation at the near-shore region under the No Action Alternative (DOE/EIS-0391 2012, Appendix O) indicate that the chromium concentration was predicted to exceed the drinking water standard for total chromium (100 µg/L) and the EIS benchmark threshold (as well as the AWQC of 10 µg/L) for hexavalent chromium within the next decade.[66] However, the predicted concentrations are likely overestimated since all discharge is assumed to occur in a 40-m near-shore region. Furthermore, well measurements indicate that chromium movement towards the Columbia River is significantly slower than that predicted in the TC&WM EIS, and that the plume would be unlikely to reach the river in either the Active Cleanup or Near-term, Post Cleanup periods. Because of the long travel times expected from 200-West, the ratings for all evaluation periods is ND.

As described in Chapter 6 of the methodology report (CRESP 2015), the large dilution effect of the Columbia River on the contamination from the seeps and groundwater upwellings results in long-term ratings of *ND* for the free-flowing ecology.

Finally, the No Action Alternative evaluation in the TC&WM EIS (DOE/EIS-0391 2012) suggests that remedial actions (e.g., surface barrier emplacement that would decrease recharge near the tank farms) do not significantly affect the long-term peak concentrations in the near-shore area (benthic and riparian receptors) of the Columbia River. This is not due to an ineffective barrier but instead likely due to large amounts of contaminants already in the subsurface and possible impacts from sources outside the 200-West Tank Waste and Farms EUs. Thus, the ratings are not changed based on the remedial actions (landfill closure or surface barrier emplacement) assumed in the TC&WM EIS.

[66] The benchmark value used for chromium (hexavalent) in the TC&WM EIS was the sensitive-species-test-effect concentration, defined as the concentration that affects 20% of a test population (EC_{20}), despite the fact that the less toxic trivalent form of chromium is more like to be present in oxygenated, aquatic environs (DOE/EIS-0391 2012, Appendix P, pp. P-52 to P-53).

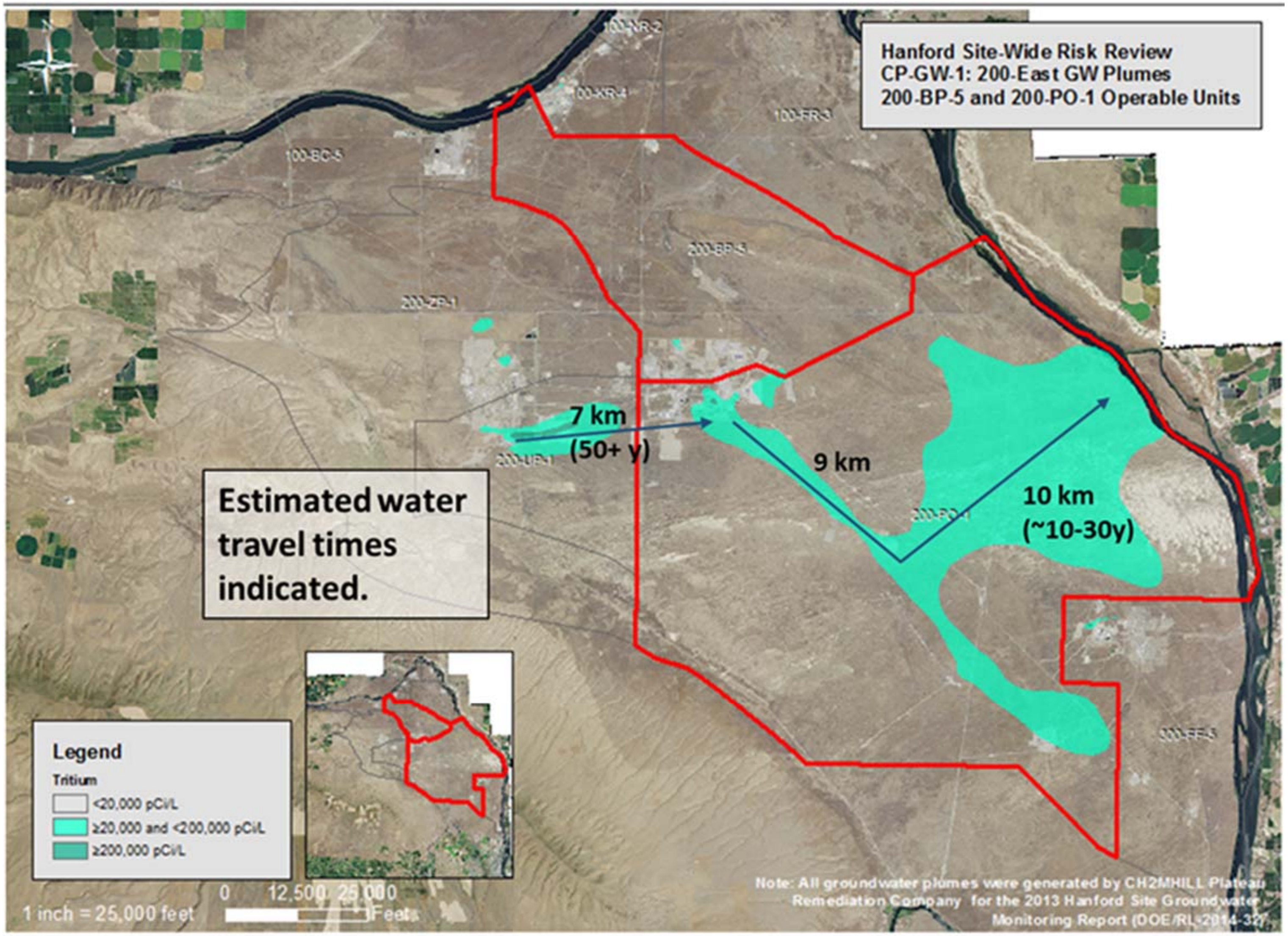

Figure 3-31. Estimating pathways and travel times of groundwater from the 200 Areas to the Columbia River based on past tritium plume movement.

200 East Area Tank Farm EUs

The groundwater plumes in the 200 East Area (CP-GW-1) resulting from releases related to the 200 East tank farm EUs are managed using the 200-BP-5 and 200-PO-1 CERCLA groundwater OUs (DOE/RL-2014-32, Rev. 0). Only the tritium (H-3) plume from the 200-PO-1 OU currently intersects the Columbia River at concentrations exceeding the appropriate WQS; however, this plume is from past PUREX-related operations and is not related to 200 East Tank Farm EUs. The Risk Review Project rating for tritium for all evaluation periods is *ND*.

Because current 200-PO-1 OU plumes originate from 200 East, it is possible that a current plume might reach the Columbia River in the next 150 years since the *water* travel time is relatively fast (approximately 10 to 30 yr) from 200 East to the Columbia River (Gephart 2003; PNNL-6415 Rev. 18). In addition, a plume has reached the Columbia River from 200 East. Following the framework process (Figure 2-11), the ratio, R1, of the predicted peak concentration (Table O-8, Appendix O, DOE/EIS-0391 2012, p. O-59) to the BCG for each radioactive contaminant associated with the 200-East Tank Farm EUs with a current plume (including I-129 and Tc-99) is far less than 1, again indicating low risk. These results agree with those from the TC&WM EIS ecological screening evaluation (Appendix P, DOE/EIS-0391 2012). For 200-East Tank Farm EU chemical contaminants with existing plumes (nitrate and TCE), the predicted peak concentration (Table O-8, Appendix O, DOE/EIS-0391 2012, p. O-59) is less than the standard indicating no adverse risk and an ND rating.

The alternatives (No Action versus Landfill Closure) evaluation in the TC&WM EIS (DOE/EIS-0391 2012, Appendix O) suggests that planned remedial actions (namely surface barrier emplacement that would decrease recharge in the areas near the tank farms) would have little moderating impact on nearshore contaminant concentrations. This is likely due to the large amounts of contaminants already in the subsurface from the 200-East and other sources considered and not due to an ineffective barrier. Thus, the ratings would not be modified based on projected changes in recharge.

Results of the Threat Evaluation to the Benthic Zone and Riparian Zone Ecology

An ecological screening analysis was performed in the TC&WM EIS (DOE/EIS-0391 2012, Appendix P) to evaluate potential long-term impacts of radioactive and chemical contaminants (*from all sources under a No Action Alternative*) discharged with groundwater on aquatic and riparian receptors located in the near-shore region of the Columbia River. The screening results indicate that exposure to radioactive contaminants from peak groundwater discharge was below benchmarks (0.1 rad per day for wildlife receptors and 1 rad per day for benthic invertebrates and aquatic biota, including salmonids consistent with DOE-STD-1153-2002 (DOE/EIS-0391 2012, Appendix P, p. P-52), indicating there should be no expected adverse effects from radionuclides. The Risk Review Project ratings for radionuclides during the active cleanup and near-term post-cleanup evaluation periods are thus *ND*. This rating is consistent with the indication of no adverse impacts from radionuclides for both benthic and riparian receptors made under the TC&WM EIS evaluation period, which was a 10,000-year period (DOE/EIS-0391 2012).

The screening evaluation in the TC&WM EIS (DOE/EIS-0391 2012) of potential impacts of chemical contaminants discharged with groundwater to the near-river ecology (benthic and riparian) indicates that nitrate would have expected hazard quotients exceeding 1 (implying moderate risk) for aquatic and riparian receptors over the 10,000-year evaluation period in the TC&WM EIS. However, the nitrate peak concentration (and discharge) occurred in the past and that future concentrations would not exceed either the drinking water standard or AWQC in the future. Furthermore, the potential impact of increased nitrate levels may depend on other factors (e.g., phosphorus) and be highly uncertain. Thus an ND rating is ascribed to nitrate for the Current, Active Cleanup, and Near-term, Post-Cleanup periods.

The EIS results of the screening evaluation at the near-shore region under the No Action Alternative (DOE/EIS-0391 2012, Appendix O) indicate that, although not a current plume from the 200 East Area, the chromium concentration is predicted to exceed thresholds for chromium (48 or 100 µg/L) and the EIS benchmark threshold[67] (as well as the AWQC of 10 µg/L) for hexavalent chromium. The predicted concentrations are likely overestimated since all discharge is assumed to occur within a 40 m, near-shore region. Using the framework outlined in Chapter 6 of the methodology report (CRESP 2015), the peak predicted concentrations would correspond to ratings of *Medium* and *High* for the benthic and riparian ecology, respectively, for the active cleanup and near-term post-cleanup evaluation periods. However, well data suggest that the chromium is moving much slower than predicted in the TC&WM EIS, and it is unlikely that a chromium plume would reach the Columbia River from the 200-East Tank Farm EU sources in the next 50 or 150 years. Thus a rating of ND is ascribed for the benthic and riparian zones for the Current and Active Cleanup periods, and a corresponding rating of Low is ascribed for the Near-term, Post-Cleanup period.

The TC&WM EIS Alternative 2B (*Tank Closure Alternative 2B: Expanded WTP Vitrification; Landfill Closure*) (DOE/EIS-0391 2012) gives an idea of the impact on chromium in the near-shore region if surface barriers are emplaced (i.e., landfill closure). The maximum predicted chromium concentration (over the 10,000-year EIS evaluation period) for the landfill closure alternatives is 228 µg /L (DOE/EIS-0391 2012, Appendix O, p. O-67 for cribs and trenches) versus a value of 232 µg/L for the No Action Alternative. Thus, the rating would not change based on surface barrier installation and changes in recharge rates. This is likely because there is already significant contamination in the groundwater as well as possible impacts from sources outside the 200-East Tank and Waste Farm EUs that were considered in the screening analysis.

Threats to the Columbia River Free-flowing Ecology

The threat determination approach for evaluating the free-flowing river ecology is similar to that described above for benthic receptors (Chapter 6 of the methodology report (CRESP 2015)). However, because the Columbia River has a large dilution effect on contamination from the seeps and groundwater upwellings,[68] the differences from EU to EU are not distinguishable and groundwater contaminant discharges from Hanford Site have a very remote potential to achieve surface water concentrations above relevant water quality standard thresholds.[69]

RISK RATINGS

Table 3-14 summarizes the Risk Review Project ratings for the tank waste and farms EUs. Additional supporting information is provided in Appendix E.1 through Appendix E.10.

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[67] The benchmark value used for chromium (hexavalent) in the TC&WM EIS was the sensitive-species-test-effect concentration that affects 20% of a test population (EC_{20}), even though the less-toxic trivalent form of chromium is more likely to be present in oxygenated, aquatic environs (DOE/EIS-0391 2012, Appendix P, pp. P-52 to P-53).

[68] Groundwater is a potential pathway for contaminants to enter the Columbia River. Groundwater flows into the river from springs above the water line and through areas of upwelling in the riverbed. 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 ~3400 cubic meters per second (DOE/RL-2014-32, Rev. 0). This represents a dilution effect of more than eight orders of magnitude (a dilution factor of greater than 100 million).

[69] Bioaccumulation and biomagnification of some contaminants in aquatic biota may be possible; however, these effects typically are considered in the development of surface water quality standards, and insufficient information exists at the Hanford Site to consider these effects in the screening process for the Risk Review Project.

Risks and Potential Impacts during the Active Cleanup Period

Groundwater: The ratings for potential impacts or threats to groundwater as a protected resource are described in the appropriate section for each tank farm EU and summarized in

Table 3-15. The Overall High ratings for most 200 West and 200 East Tank and Waste Farms EUs are typically driven by chromium (total and hexavalent) with the exceptions of the A-AX tank farm EU (200-East) where uranium drives risk, the C Tank Farm EU (200-East) where I-129 has a Medium rating, and the U tank farm EU (200-West) that has an overall *Low* rating. The TX-TY tank farm EU (200-West) also includes carbon tetrachloride and Tc-99, and the B-BX-BY Tank Farm EU (200-East) includes Tc-99 and I-129.

Columbia River: The ratings for potential impacts or threats to the Columbia River are described in the appropriate section for each tank farm EU and summarized Table 3-16. The ratings for radionuclides are all *ND*. The Overall Low ratings (benthic and riparian zone) for the 200 East Tank Farm EUs in the Near-Term, Post-Cleanup evaluation period are related to total and hexavalent chromium from Central Plateau sources, including sources other than those for the specific tank farm EUs.

Near-Term Post-Cleanup Risks and Potential Impacts

The EIS preferred HLW tank closure alternative includes 99% retrieval of waste from the SSTs for staging in DSTs and treatment elsewhere onsite, operations and necessary maintenance, waste transfers and associated operations, and upgrades to existing tanks or construction of waste receipt facilities (DOE/EIS-0391 2012, Chapter 2, p. 2-321). SST closure operations include filling the tanks and ancillary equipment with grout to immobilize residual waste contaminants. Disposal of contaminated equipment and soil would occur on site. Decisions on the extent of soil removal and/or treatment are planned to be made on a tank farm or WMA basis through the RCRA closure permitting process. The tanks would be stabilized with grout, and an engineered modified RCRA Subtitle C barrier put in place followed by post-closure care.

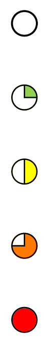
Thus, workers and the public would be isolated from the residual contamination in the tanks by the tank structure, grout and soil cover. Tank waste contamination already in the vadose and saturated zones would experience reduced infiltrating water (the primary driver for the release and transport of contaminants) because of the surface barrier.

Continued monitoring could disturb the ecological resources in the T tank farm EU and buffer lands. Remediation may improve habitat through revegetation (and increased monitoring may increase exotic species and change species composition).

Indirect effects to a historic trail may be permanent (cultural resources). Capping could cause permanent indirect effects to the viewshed of a traditional cultural place due to presence of contamination.

Risk Review Rating Symbols: Risk review ratings for each receptor are tabulated in summary tables using a combination of text summaries and symbolism. Specific symbology was developed for the Risk Review Project and is defined on page xxviii and repeated here for convenience. Symbols used in the rating tables indicate the highest rating when a rating range is present, although the accompanying text indicates the risk rating range, where applicable, to reflect uncertainty. Symbols within each entry in rating tables are a combination of a risk rating symbol and additional symbols used to indicate 1) the presence of engineered barriers to prevent release to the environment or further dispersion of radionuclides and chemicals, 2) when treatment, waste retrieval or remediation is in progress, and 3) if interim stabilization has occurred (only for single-shell tanks). Examples of resulting combined symbols are on page xxix.

Symbol **Meaning**



ND Rating

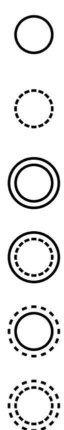
Low Rating

Medium Rating

High Rating

Very High Rating

Barrier Symbols



One engineered barrier, Intact (barriers include tanks, covers, liners, buildings, etc.)

One engineered barrier, barrier compromised (e.g., leaking tank)

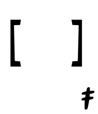
Two engineered barriers, both barriers intact

Two engineered barriers, inner barrier compromised and outer barrier intact

Two engineered barriers, inner barrier intact and outer barrier compromised

Two engineered barriers, both barriers compromised.

Treatment, Remediation and Waste Treatment Symbols



Treatment, remediation or waste retrieval in progress

Interim stabilized (single shell tank, stabilization through removal of pumpable liquid)

Table 3-14. Impact rating summary for human health (unmitigated basis with mitigated basis provided in parentheses (e.g., "High (Low)").

	Population or Resource	Evaluation Period — Active Cleanup (to 2064) — **Current Condition:** Maintenance & Monitoring (M&M)		Evaluation Period — Active Cleanup (to 2064) — **From Cleanup Actions:** Retrieval & Closure	
Human Health	Facility Worker	***M&M***:	Low-High[a] (Low-High)[a]	***Preferred method***:	High (Low)
		Soil:	ND-High (ND-Low)	***Alternative***:	High (Low)
	Co-located Person	***M&M***:	Low-Medium (Low)	***Preferred method***:	Low-Medium (Low)
		Soil:	ND (ND)	***Alternative***:	Low-Medium (Low)
	Public	***M&M***:	Low (Low)	***Preferred method***:	Low (Low)
		Soil:	ND (ND)	***Alternative***:	Low (Low)
Environmental	Groundwater	SST Farm EUs[c] 200 W Overall: Low to High 200 E Overall: Medium to High DST Farm EUs[c] Not Discernible		SST Farm EUs[c] 200 W Overall: Low to High 200 E Overall: Medium to High DST Farm EUs[c] Not Discernible	
	Columbia River	DST & 200 W SST Tank Farm EUs[d] **Overall**: Not Discernible 200 East SST Farm EUs[d] **Overall**: Not Discernible		DST & 200 W SST Tank Farm EUs[d] **Overall**: Not Discernible 200 East SST Farm EUs[d] **Overall**: Not Discernible	
	Ecological Resources[b]	Refer to specific tank farm EU		Refer to specific tank farm EU	
Social	Cultural Resources[b]	Refer to specific tank farm EU		Refer to specific tank farm EU	

a. ***Industrial safety*** consequences range from Low to High (based on the evaluation scale used) for both mitigated (with controls) and unmitigated (without controls). ***Radiological and toxicological*** consequences to facility workers are High (unmitigated) and Low (mitigated).
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.
c. Refer to

Table 3-15 for details. The Overall High ratings for the 200 West SST farm EUs are driven by chromium (total and hexavalent) for most EUs with the TX-TY tank farm EU also including carbon tetrachloride and Tc-99. The U tank farm EU has a Low rating. The Overall Medium and High ratings for the 200 East SST farms result from I-129 (C), total and hexavalent chromium (A-AX), and I-129, Tc-99, and total and hexavalent chromium (B-BX-BY). The large amounts of Sr-90 would translate to High or

Population or Resource	Evaluation Period Active Cleanup (to 2064) **Current Condition:** Maintenance & Monitoring (M&M)	 **From Cleanup Actions:** Retrieval & Closure

Very High in many of these EUs; however, the relative immobility of Sr-90 in the Hanford subsurface results in *Low* ratings. This is also true for uranium for the A-AX Tank Farm EU.

d. Refer to Table 3-16 for details. The ratings with respect to radionuclides and chemicals are all *ND* consisted with the results of the TC&WM EIS screening analysis.

Table 3-15. Summary of groundwater threat ratings for current vadose zone contaminant inventories in the Hanford tank farm evaluation units.[(a)]

EU Name	EU	Risk Driver	Current	Risk Driver	Active Cleanup	Risk Driver	Near-Term Post-Cleanup
T Tank Farm	CP-TF-1	Cr[(a)]	High ǂ	Cr[(a)]	High ǂ	Cr[(a)]	High
S-SX Tank Farms	CP-TF-2	Cr[(a)]	High ǂ	Cr[(a)]	High [ ]ǂ	Cr[(a)]	High
TX-TY Tank Farms	CP-TF-3	Tc-99, CCl4, Cr[(a)]	High ǂ	Tc-99, CCl4, Cr[(a)]	High [ ]ǂ	Tc-99, CCl4, Cr[(a)]	High
U Tank Farm	CP-TF-4	Various[(b)]	Low ǂ	Various[(b)]	Low [ ]ǂ	Various[(b)]	Low
A-AX Tank Farms	CP-TF-5	Cr[(a)]	Medium ǂ	Cr[(a)]	Medium [ ]ǂ	Cr[(a)]	Medium
B-BX-BY Tank Farms	CP-TF-6	I-129, Tc-99, Cr[(a)]	High ǂ	I-129, Tc-99, Cr[(a)]	High [ ]ǂ	I-129, Tc-99, Cr[(a)]	High
C Tank Farms	CP-TF-7	I-129	Medium [ ]ǂ	I-129	Medium [ ]ǂ	I-129	Medium
200 East (DSTs)	CP-TF-8	Various[(b)]	Low		Low [ ]		Low
200 West (DSTs)	CP-TF-9		ND		ND [ ]		ND

a. Cr represents both total and hexavalent chromium

b. The various non-zero inventory PCs are C-14, I-129, Sr-90, Tc-99, Cr[(a)], U-Total

Table 3-16. Summary of Columbia River threat ratings for contaminants currently in the vadose zone at the Hanford tank farm evaluation units.

	EU Name	EU	Current	Active Cleanup	Near-Term Post-Cleanup
200 W	T, S-SX, TX-TY, and U Tank Farms	CP-TF-1 CP-TF-2 CP-TF-3 CP-TF-4	Benthic – ND (all)	Benthic – ND (all)	Benthic – ND (all)
			Riparian – ND (all)	Riparian – ND (all)	Riparian – ND (all)
			Overall: ND	Overall: ND	Overall: ND
200 E	A-AX, B-BX-BY, and C Tank Farms	CP-TF-5 CP-TF-6 CP-TF-7	Benthic –	Benthic –	Benthic –
			ND (radionuclides)	ND (radionuclides)	ND (radionuclides)
			ND (chemicals)	ND (chemicals)	Low (chemicals[a])
			Riparian –	Riparian –	Riparian –
			ND (radionuclides)	ND (radionuclides)	ND (radionuclides)
			ND (chemicals)	ND (chemicals)	Low (chemicals[a])
			Overall: ND	Overall: ND	Overall: Low
200 East (DSTs)		CP-TF-8	Benthic – ND (all)	Benthic – ND (all)	Benthic – ND (all)
			Riparian – ND (all)	Riparian – ND (all)	Riparian – ND (all)
			Overall: ND	Overall: ND	Overall: ND
200 West (DSTs)		CP-TF-9	Benthic – ND (all)	Benthic – ND (all)	Benthic – ND (all)
			Riparian – ND (all)	Riparian – ND (all)	Riparian – ND (all)
			Overall: ND	Overall: ND	Overall: ND

a. The threat to the Columbia River related to chemicals is driven by hexavalent chromium in the vadose zone (where none is measured in groundwater above thresholds). Also, chromium is from Central Plateau sources in addition to those for the specific tank farm EU.

IMPLICATIONS FOR SEQUENCING TANK WASTE PROCESSING

Taken together, the information above suggests the following:

- Hydrogen gas generation[70] poses a threat to nuclear safety and human health through loss of safety systems from a major external event.
- Tc-99 and I-129, both being persistent and highly mobile in the subsurface, pose threats to groundwater through leakage from tanks.
- As a first-order analysis, groundwater threats can be substantially reduced by removing water soluble constituents (Tc-99 and I-129) from a selected set of tanks.[71] Similarly, nuclear safety threats also can be reduced for several tanks by removing water soluble Cs-137. This is consistent with the priority given by the Tri-Party agencies to treat LAW at WTP as early as possible if Cs-137, Tc-99, and I-129 separated from the waste are not returned to the tanks. However, the risk to groundwater profile will neither be reduced significantly nor increased if Tc-99 and I-129 are returned to the tanks during LAWPS treatment. The nuclear safety risk profile will be reduced if separated Cs-137 is not returned to the tanks or to tanks with low HGR, and may remain the same or be increased or reduced depending on the time to hydrogen flammability thresholds for the tank(s) accepting returned Cs-137.
- The sequencing of SST retrieval should focus on assumed leakers with significant GTM, and if it is assumed that retrievals are to be staged by tank farm, the initial focus should be on the BY tank farm in 200 East and the TX tank farm in 200 West.
- Processing LAW from the 200 East DSTs would substantially reduce the overall GTM.
- If a target of 95 % reduction in GTM across all SSTs is selected and in-tank grouting of the residual waste inventory is completed, the threat of groundwater contamination from SSTs would be reduced to substantially less than the GTM from existing environmental contamination in the vadose zone in both the 200 West and 200 East Areas from leaks and legacy disposal activities near the SST farms. Waste retrievals that result in reduction by 90% of the GTM contained in the tanks collectively across all tanks within each tank farm EU would meet the criteria of tank end-states being less than the GTM in the vadose zone for all SST tank farms except for U and A-AX tank farms.
- If selective waste retrieval targets of 99% or the limits of multiple technologies are applied to the group of 26 DSTs and 42 SSTs that comprise 90% of the total GTM in all tanks, the result would be a residual GTM of 1% of the initial inventory. Waste retrieval targets of 90% of the GTM or the limits a single technology (if greater than 90% retrieval) would result in a residual GTM of less than an additional 1% of the current GTM, and with a cumulative result that is indistinguishable from a target of 99% across all tanks, considering the inventory uncertainties. Similarly selective retrieval targets can be used if the target reduction was 90% of the GTM across individual tank farms. Selective waste retrieval targets as discussed above may allow for

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[70] Hydrogen generation rate is primarily related to Cs-137 and Sr-90 content of the waste.

[71] For hydrogen generation,200 East DSTs, and SSTs B-202, B-203, B-204, and T-201 have times to 25% of the LFL of less than 6 months under unventilated conditions; for groundwater threat, greater than 70% of the GTM is from 200 East DSTs, SY-101 and SY-103 (200 West DSTs) and SSTs AX-101, S-105, S-106, S-108, S-109, SX-106, TX-105,* TX-113,* TX-115,* U-109, U-105 (* indicates assumed SST leaker).

significant acceleration of tank waste retrievals and much more rapid reduction in groundwater threats from tank wastes than currently planned. Selective retrieval targets can be accomplished for individual tanks within each tank farm, allowing for different amounts of retrieval while completing waste retrievals at an entire tank farm. Further evaluation of this concept is warranted. A tank farm waste retrieval and processing system plan evaluation of this approach is suggested.

3.3. GROUNDWATER EVALUATION UNITS AND THE COLUMBIA RIVER

The process developed as a general framework for binning EUs using the evaluation metrics has been applied to the Risk Review Project groundwater EUs considering three distinct potential impacts: (1) groundwater as a protected resource, (2) groundwater as a pathway to impact the Columbia River, and (3) impact to groundwater from potential future sources (e.g., tank leaks) and current vadose zone contamination to groundwater and the Columbia River.

The focus on the evaluation metrics allows for differentiation of the potential groundwater-related risks from the EUs. This process is not concerned directly with highly uncertain point estimates of risks and impacts often used for other analyses (e.g., performance assessments or baseline risk assessments). The uncertainties associated with the analyses related to EUs become more tractable when evaluation metrics are considered in relative, rather than absolute terms. A detailed description of the methodology used for rating risks to groundwater and the Columbia River is provided in the methodology report (CRESP 2015). Detailed results for each groundwater EU are provided in Appendices G.1 through G.6.

The evaluation metrics for risks to groundwater *as a protected resource* from current groundwater plumes and near surface or vadose zone sources are:

1. The estimated time interval until groundwater would be *impacted* over the three evaluation periods by a primary contaminant if the specific contaminant source is not currently causing a groundwater plume. Groundwater is considered *impacted* when a primary contaminant concentration exceeds a threshold value (e.g., a drinking water standard or maximum contaminant level).
2. The estimated amount of groundwater (e.g., areal extent) currently *impacted* by the primary contaminants with existing plumes.
3. The *GTM*, defined as the volume of groundwater that could potentially be contaminated by the inventory of a primary contaminant from a source (be it groundwater plume, vadose zone contamination, tank, etc.) if it was found in the saturated zone at the WQS (e.g., drinking water standard) and in equilibrium with the soil. The GTM accounts only for (1) source inventory, (2) partitioning with the surrounding subsurface and (3) the WQS. The GTM reflects a snapshot in time (assuming no loss by decay/degradation or dispersion, etc.) and does not account for differences in mobility or bulk groundwater flow.

The selected evaluation metrics for risks to the Columbia River from near-surface, vadose zone, and groundwater contamination sources are:

1. The estimated time interval until the Columbia River is *impacted* over the three evaluation periods. The Columbia River is considered *impacted* when a primary contaminant concentration exceeds a benthic or free-flowing threshold value.

2. The ratio (R1) of the maximum primary contaminant concentration within the plume to the reference threshold screening value (e.g., BCG for radionuclides or AWQC for chemicals).
3. The ratio (R2) of the upper 95th percentile UCL on the log-mean plume concentration to the reference threshold screening value.
4. For benthic impacts, the length of river shoreline estimated to be impacted by the plume above a reference threshold.
5. For riparian zone impacts, the area of the riparian zone estimated to be impacted by the plume above a reference threshold.

The screening thresholds used in the Risk Review Project are provided in Table 3-17. The primary contaminant groups used in this Risk Review Project are described in Section 2.3 and Table 2-6, which categorizes them according to mobility and persistence in the Hanford Site environment. When considering groundwater as a protected resource, the drinking water standard is used as the screening threshold, except for Cr(VI), where a drinking water standard is not available, and a screening threshold of 48 µg/L is used. When considering impacts to the Columbia River, a combination of the AWQC and the BCG are used, whichever is value is more stringent and therefore more conservative. However, for total uranium, the natural background groundwater concentration of uranium at 12.9 µg/L is used, which is greater than the Tier II screening concentration value (SCV) reported.

Table 3-17. Thresholds considered in the Risk Review Project for the Group A and B primary contaminants. The primary thresholds used in the analysis are indicated in the red boxes.

PC	Grp	WQS[a]	DWS	DOE DCS[b]	BCG[c]	AWQC[d]/SCV[e]
Tc-99	A	900 pCi/L	900 pCi/L	44000 pCi/L	667000 pCi/L	---
I-129	A	1 pCi/L	1 pCi/L	330 pCi/L	38500 pCi/L	---
C-14	A	2000 pCi/L	2000 pCi/L	62000 pCi/L	609 pCi/L	---
Cr-VI	A	10-48 ug/L[f]	---	--- Human	--- Benthic/	10 ug/L[f]
CCl_4	A	3.4 ug/L[g]	5 ug/L	--- Health	--- Riparian	9.8 ug/L
Sr-90	B	8 pCi/L	8 pCi/L	1100 pCi/L	279 pCi/L	7 ug/L (Sr)
U(tot)	B	30 ug/L	30 ug/L	750 pCi/L (U-238)	224 pCi/L (U-238)	12.9 ug/L[h]
Cr(tot)	B	48 ug/L[f]	100 ug/L[f]	---	---	55 ug/L
CN	B	200 ug/L	200 ug/L	---	---	5.2 ug/L
TCE	B	4[g]-5 ug/L	5 ug/L	---	---	47 ug/L

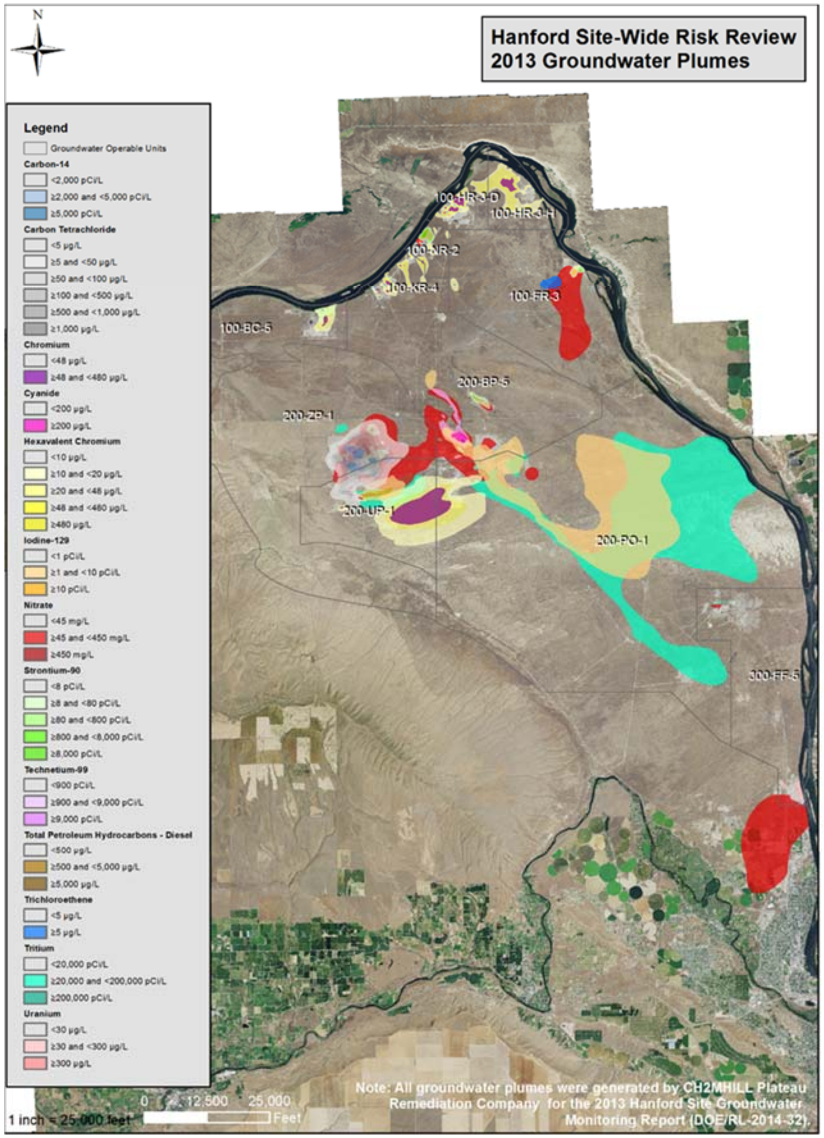
a. Water Quality Standard (WQS) from 2013 Annual GW Report (DOE/RL-2014-32, Rev. 0). Some values vary by Operable Unit.
b. DOE Derived Concentration Standard (Ingested Water DCS from Table 5 in DOE-STD-1196-2011).
c. Biota Concentration Guide (BCG) from RESRAD-BIOTA v1.5 (consistent with DOE Technical Standard DOE-STD-1153-2002).
d. Ambient Water Quality Criterion (AWQC) (Table 6-1 in DOE/RL-2010-117, Rev. 0).
e. Tier II Screening Concentration Value (SVC) (http://rais.ornl.gov/documents/tm96r2.pdf) when AQWC not provided.
f. Different values tabulated for different GW Operable Units. 10 ug/L is the surface water standard for Cr-VI. 20 ug/L is the groundwater cleanup target for Cr-VI identified for interim remedial action. 48 ug/L is the MTCA groundwater cleanup standard. 100 ug/L is the drinking water standard for total chromium.
g. Risk-based cleanup value from the record of decision as reported in the 2013 Annual GW Report (DOE/RL-2014-32, Rev. 0).
h. Uranium (total) screening values were 0.5 ug/L (DOE/RL-2007-21 2012) and 5 ug/L (DOE/RL-2010-117, Rev. 0, 2010). Background uranium levels of 0.5-12.8 µg/L were detected near the 300-F Area with a value of 12.9 µg/L selected (Peterson et al, 2008, p. 6.9). No effect levels span 3-900 µg/L reflecting considerable uncertainty (DOE/RL-2010-117, Rev. 0, 2010).

GROUNDWATER CONTAMINANT PLUMES ASSOCIATED WITH EACH EVALUATION UNIT

Figure 3-32 provides an overview of all primary groundwater contaminant plumes present within the Hanford Site, which are further grouped into three groundwater EUs along the River Corridor and two groundwater EUs in the Central Plateau.[72] Figure 3-33 focuses on the Central Plateau groundwater plumes and Figure 3-34 provides a simplified version of the Central Plateau groundwater plumes (excluding nitrate and tritium) in the 200 East Area (EU CP-GW-1) and 200 West Area (EU CP-GW-2) that includes only the Group A primary contaminants (high mobility and high persistence; Tc-99, I-129, C-14, Cr(VI) and carbon tetrachloride) and Group B primary contaminants (high mobility with medium persistence, i.e., cyanide, TCE, and PCE, and medium mobility with high or medium persistence, i.e., U(total), Cr(total), and Sr-90).

An overview of the River Corridor groundwater contaminant plumes is provided in Figure 3-35 through Figure 3-37. Figure 3-35 is enlarged to show the intersection of the existing groundwater plume with the riparian zone (magenta cross hatch area) and also provides the primary contaminant groupings, plume areas, and AWQS.

[72] 2013 groundwater monitoring data (DOE/RL-2014-32, Rev. 0. 2014) is used for evaluation as the most recent published data set available at the time of preparation of this report.



Hanford Plumes

River Corridor

EU: RC-GW-1 **OU:** 300-FF-5 (uranium)
EU: RC-GW-2 **OU:**100-NR-2 (strontium-90)
EU: RC-GW-3 **OUs:** 100-BC-5, 100-HR-3 (D/H), 100-FR-3, 100-KR-4 (chromium, strontium-90, others)

Central Plateau

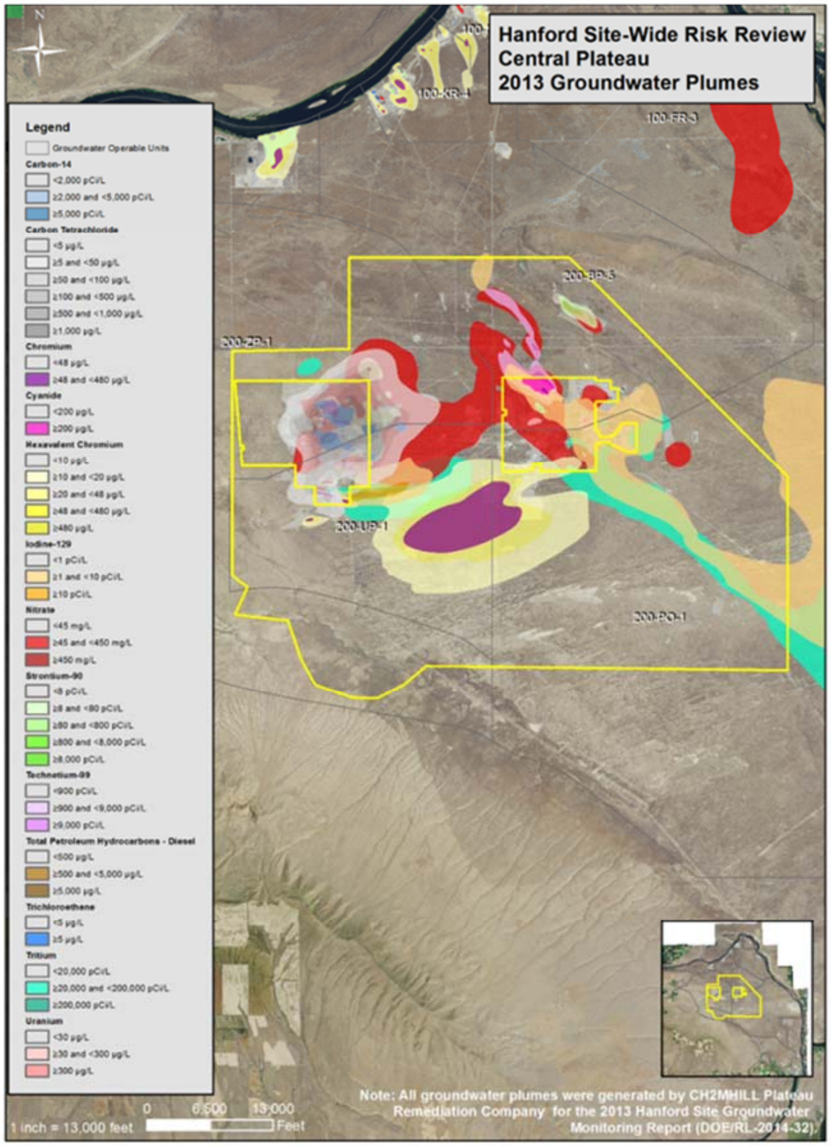
200 East Groundwater –

EU: CP-GW-1 **OUs:** 200-BP-5, 200-PO-1 (iodine-129, tritium)

200 West Groundwater –

EU: CP-GW-2 **OUs:** 200-UP-1, 200-ZP-1 (carbon tetrachloride, technetium-99)

Figure 3-32. Groundwater plumes at the Hanford Site based on 2013 groundwater monitoring data (DOE/RL-2014-32, Rev. 0. 2014) and listing of EU and corresponding regulatory operable unit designations.



EU: CP-GW-1 (200 East GW OUs)

PC	PC Grp	WQS	200-BP-1 Area (km²)	200-PO-1 Area (km²)
H-3	C	2E4 pCi/L	0.2	83.4
I-129	A	1 pCi/L	4.5	52.1
NO_3	C	45 mg/L	7.9	3.71
Tc-99	A	900 pCi/L	2.4	0.03
Sr-90	B	8 pCi/L	0.6	0.01
U (tot)	B	30 µg/L	0.5	0.02
CN	B	200 µg/L	0.4	---

EU: CP-GW-2 (200 West GW OUs)

PC	PC Grp	WQS	200-ZP-1 Area (km²)	200-UP-1 Area (km²)
CCl_4	A	3.4 µg/L	13.3	
NO_3	C	45 mg/L	9.77	5.80
H-3	C	2E4 pCi/L	0.08	5.50
Cr-VI	A	48 µg/L	0.22	3.85
I-129	A	1 pCi/L	0.10	3.10
TCE	B	5 µg/L	1.16	---
U (tot)	B	30 µg/L	---	0.34
Tc-99	A	900 pCi/L	0.07	0.29

Figure 3-33. Central Plateau groundwater plumes (200 E, 200 W, and Central Plateau indicated by yellow outlines), plume areas, primary contaminant (PC) groups, and applicable WQS based on 2013 monitoring data (DOE/RL-2014-32, Rev. 0. 2014).

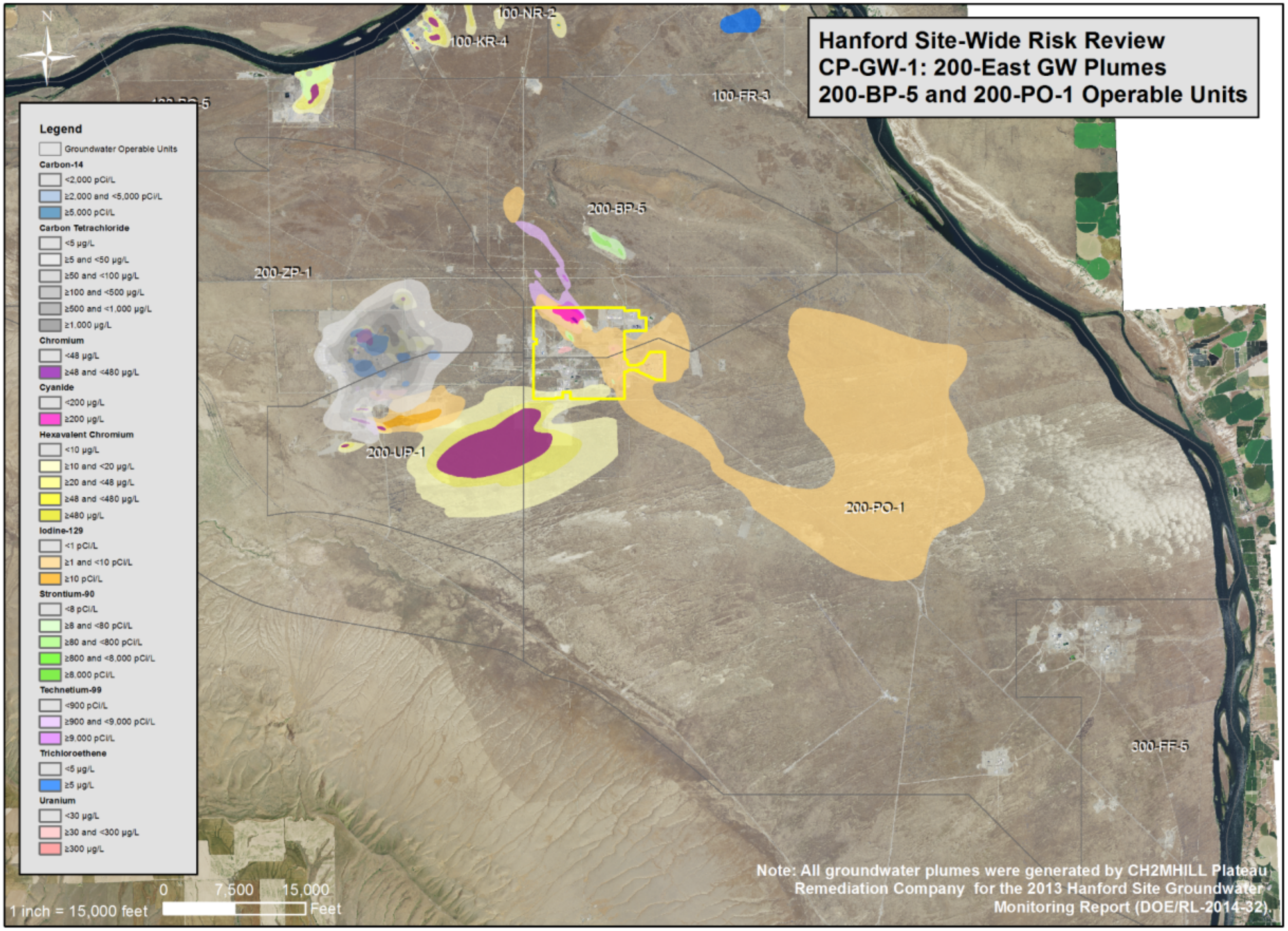
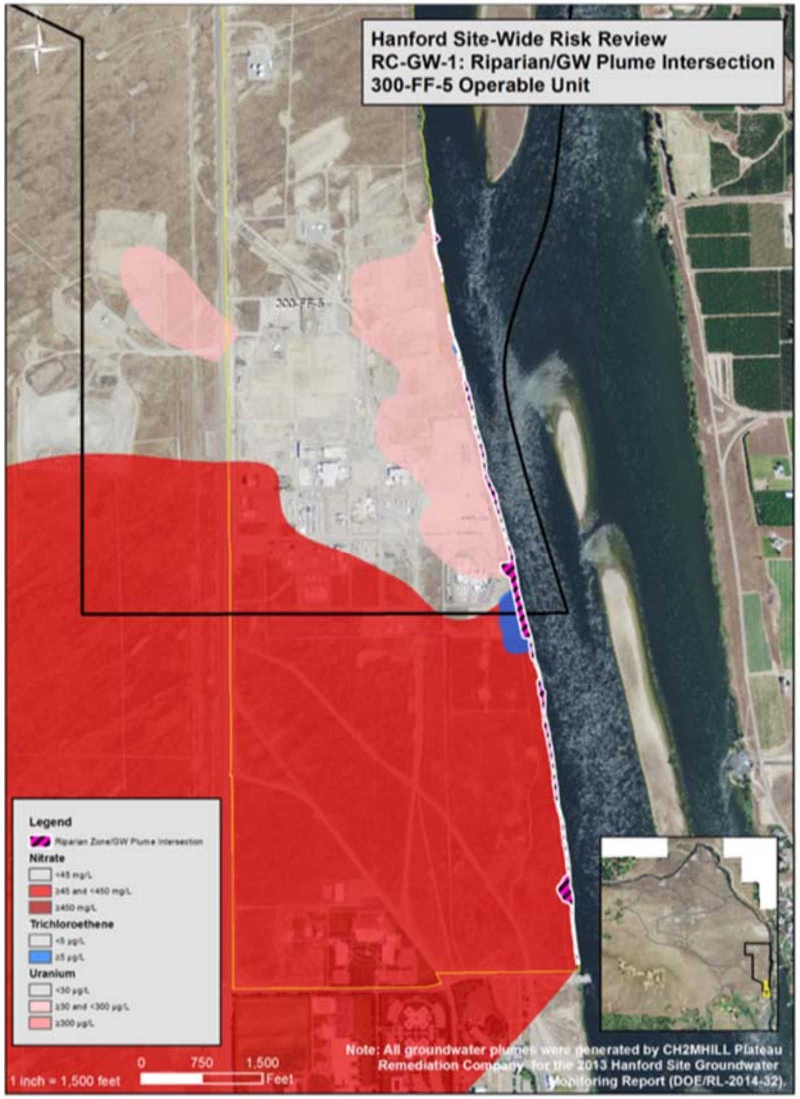


Figure 3-34. 200 East Area groundwater plumes (EU: CP-GW-1) and 200 West Area groundwater plumes (EU: CP-GW-2) based on 2013 groundwater monitoring data, excluding tritium and nitrate. 200 East Area is indicated by the yellow outline.



Columbia River Corridor Plumes

PC	Grp	WQS	RC-GW-1 300-FF-5 Area (km²)	RC-GW-2 100-NR-2 Area (km²)
Cr-VI	A	10 µg/L	0.22	0.73
Sr-90	B	8 pCi/L	---	0.61
U (tot)	B	30 µg/L	0.5	---
H-3	C	2E4 pCi/L	0.13	0.003
NO_3	C	45 mg/L	0.1	0.49

PC	Grp	WQS	RC-GW-3 100-BC-5 Area (km²)	RC-GW-3 100-HR-3 Area (km²)
Cr-VI	A	48 µg/L	1.6	7.3
Sr-90	B	8 pCi/L	0.6	0.03
NO_3	C	45 mg/L	---	0.06

PC	Grp	WQS	RC-GW-3 100-FR-3 Area (km²)	RC-GW-3 100-KR-4 Area (km²)
NO_3	C	45 mg/L	9.3	0.03
Cr-VI	A	48 µg/L	0.34	2.1
TCE	B	5 µg/L	0.81	0.01
Sr-90	B	8 pCi/L	0.16	0.05
C-14	A	2000 pCi/L	---	0.03
H-3	C	2E4 pCi/L	---	0.02

Figure 3-35. 300 Area groundwater plume map (EU: RC-GW-1) indicating intersection with the riparian zone along with Columbia River plume areas, PC groups, and applicable WQS (DOE/RL-2014-32, Rev. 0. 2014). Contaminant plumes in top left not shown to allow enlargement to indicate riparian zone.

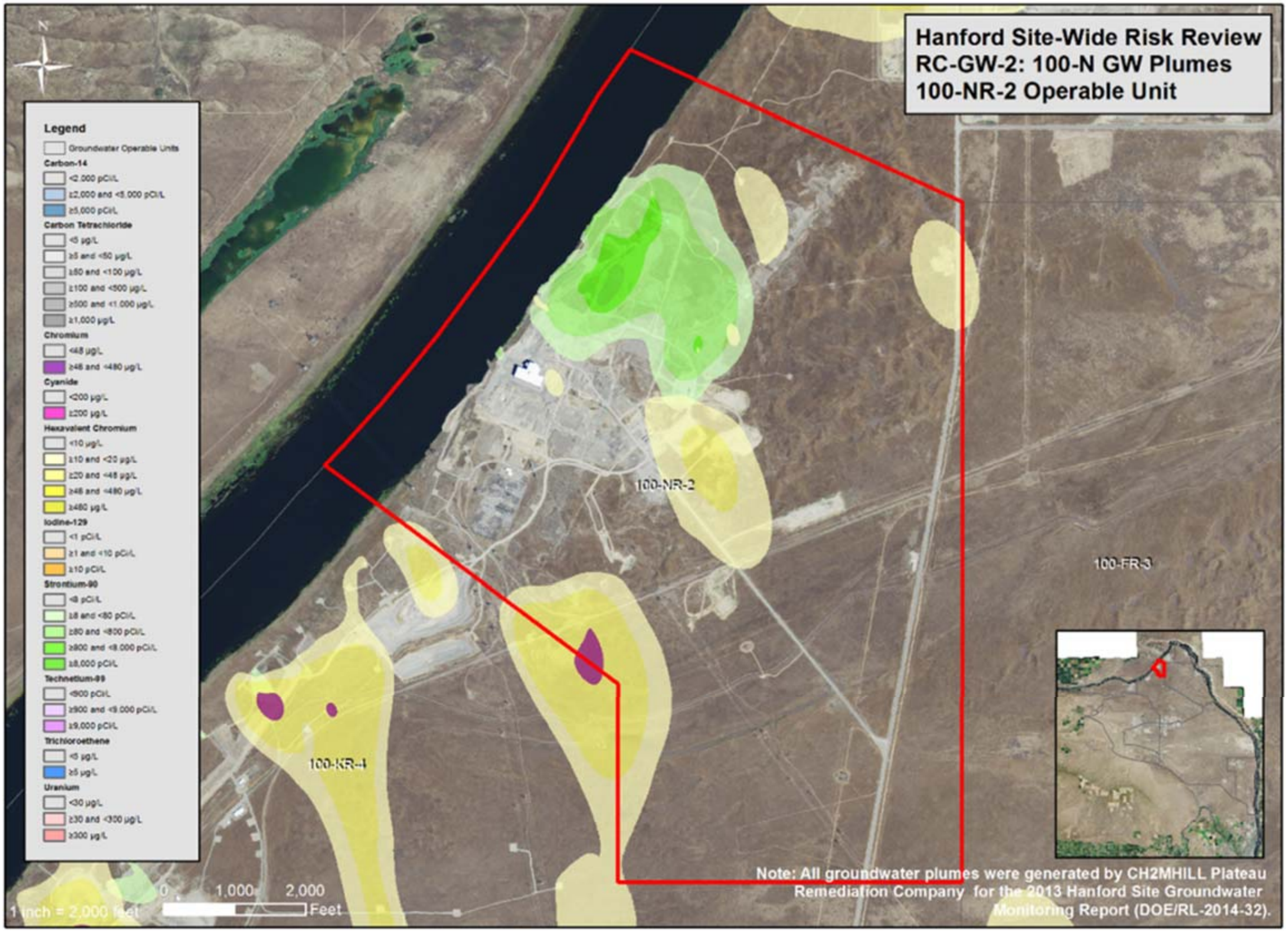


Figure 3-36. 100-N Area River Corridor groundwater plumes (EU: RC-GW-2, based on 2013 monitoring data; riparian zone not indicated).

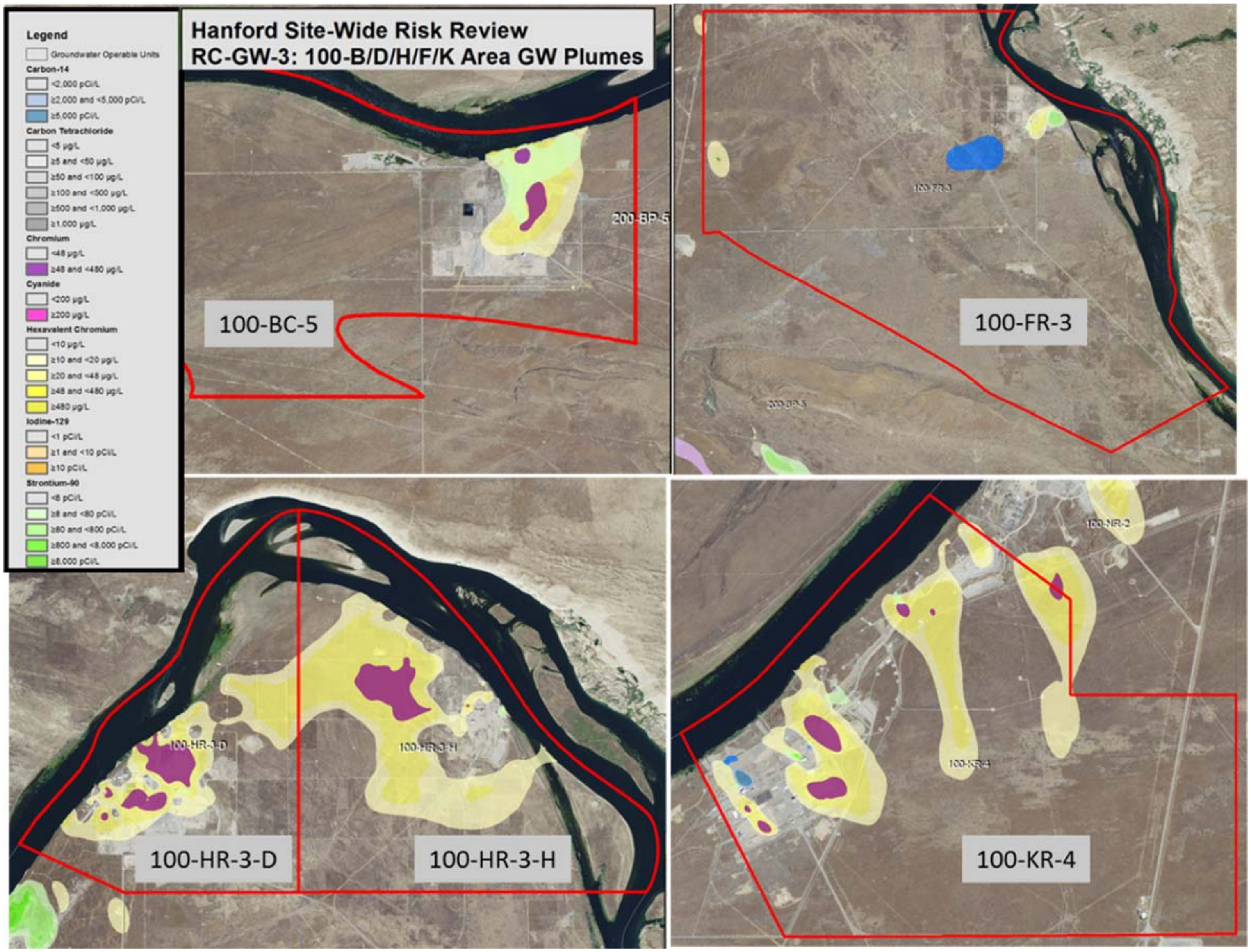


Figure 3-37. 100-B/D/H/F/K Area groundwater plumes (DOE/RL-2014-32, Rev. 0. 2014) (EU: RC-GW-3, based on 2013 monitoring data; riparian zone not indicated).

Threats to Groundwater as a Protected Resource

The scale used to rate threats to groundwater as a protected resource is focused on the amount of groundwater that is currently or could become contaminated above the screening threshold (see Table 3-17). Table 3-18 provides the rating scale used for Group A and Group B primary contaminants, which is based on the GTM. For Group C contaminants, the area of the groundwater plume above the screening threshold is used to rate each plume,[73] where Group C contaminant plume areas of less than 0.1 km^2 are rated as *Low* and plume areas of greater than 0.1 km^2 are rated as *Medium*.[74]

Table 3-18. Groundwater threat metric rating table for Group A and B primary contaminants.

GTM (millions of m^3)	Rating
GTM ≤ 10	Low
10 < GTM ≤ 100	Medium
100 < GTM ≤ 1,000	High
GTM > 1,000	Very High

Currently Contaminated Groundwater

Figure 3-38 compares the results of calculating the GTM for each Group A and Group B contaminant in the River Corridor and Central Plateau groundwater plumes. Contaminant plumes currently undergoing treatment are indicated with an asterisk.

When considering contaminant impacts to groundwater as a protected resource, all contaminant plumes along the River Corridor are rated as *Low*, except the strontium-90 plume in EU RC-GW-2 (OU 100-NR-2), which is rated as *Medium* and is undergoing treatment using an in situ reactive barrier. For groundwater contaminant plumes in the Central Plateau, the highest GTM value (rated *Very High*) is associated with carbon tetrachloride plume in EU CP-GW-2 (200 West, OU 200-ZP-1), which is being treated with along with other contaminants through the 200 West Area pump-and-treat system. The next highest GTM value (rated *Very High*) is for the I-129 plume, which is very large (>53 km^2) and may be too dispersed for effective treatment (Figure 3-34). The next highest rated plumes (rated *High*) are Tc-99, I-129, and Sr-90 plumes in EU CP-GW-1 (200 East, OU 200-BP-5) and are not currently undergoing treatment.

Threats to Groundwater from Contaminants in the Vadose Zone

Figure 3-39 compares the results of the GTM applied to contaminants currently present in the vadose zone for the Central Plateau with the GTM for contaminants in the saturated zone (i.e., groundwater contaminant plumes). Results are not provided for the vadose zone in the River Corridor because prior extensive excavation and remediation prevents meaningful estimates of remaining vadose zone contaminant inventories. The highest vadose zone GTM value (rated *Very High*) is associated with carbon tetrachloride in EU CP-LS-2, which is currently being treated in the 200-West pump-and-treat system.[75] Strontium-90 is the cause of five GTM values greater than 1000 and four additional GTM

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[73] Group C includes tritium, which has a relatively short radioactive decay half-life (12.3 years), and nitrate, which is readily biodegraded. Additional information is provided in the methodology report (CRESP 2015).

[74] Group D contaminants have very low mobility in the vadose zone and groundwater. Additional information is provided in the methodology report (CRESP 2015).

[75] Carbon tetrachloride was treated using soil vapor extraction (SVE) in the 200-PW-1 OU overlying the 200-ZP-1 groundwater OU. Over 80,000 kg of carbon tetrachloride was removed. The SVE system did not operate in 2013.

values greater than 100. However, the relatively low mobility of strontium-90 in the vadose zone, coupled with its relatively short half-life for natural radioactive decay indicates a low potential for substantial groundwater contamination resulting from these vadose zone sources under current recharge rates. Several of the vadose zone contaminant sources with GTM values greater than 100 (rated *High*) are located in the 200 East Area, either associated with the BC Cribs and Trenches (EU CP-LS-1) or the legacy sites at the A-AX and B-BX-BY tank waste and farms EUs (EUs CP-TF-5 and CP-TF-6) and currently are not undergoing treatment (except for perched water with uranium in EU CP-TF-6). Many of the GTM values greater than 100 in the 200 West Area are associated with legacy sites within tank waste and farms EUs (CP-TF-1 (T), CP-TF-2 (S, SX), CP-TF-3 (TX-TY)) and are within the current or planned capture zones of the 200 West pump-and-treat system. These results suggest that if groundwater cleanup and quality is a priority, then focus on the 200 East Area is warranted.

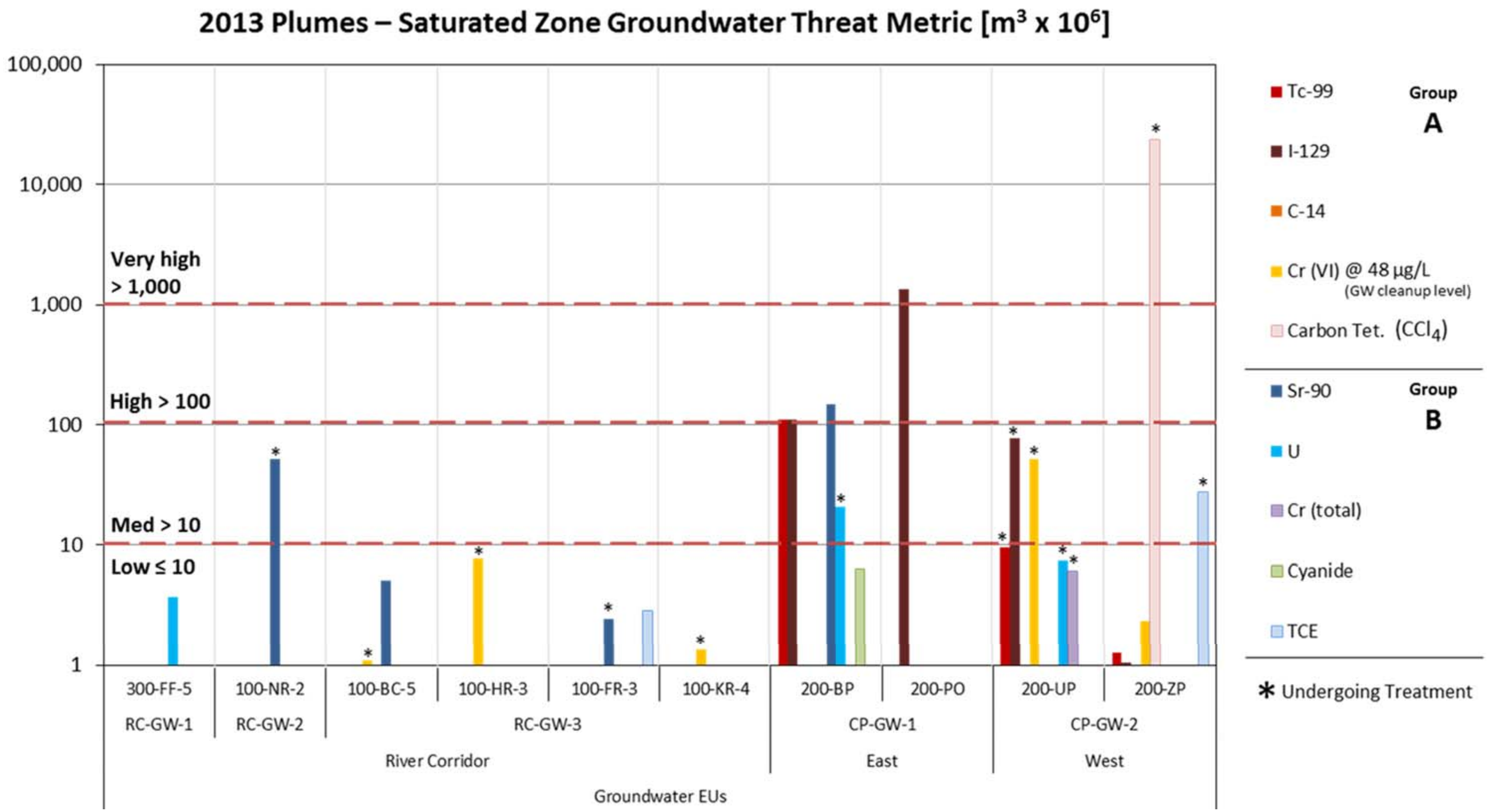

Figure 3-38. Rating groundwater contaminant plumes as a threat to *groundwater as a protected resource* based on the groundwater threat metric. Groundwater threat metric in millions of cubic meters.

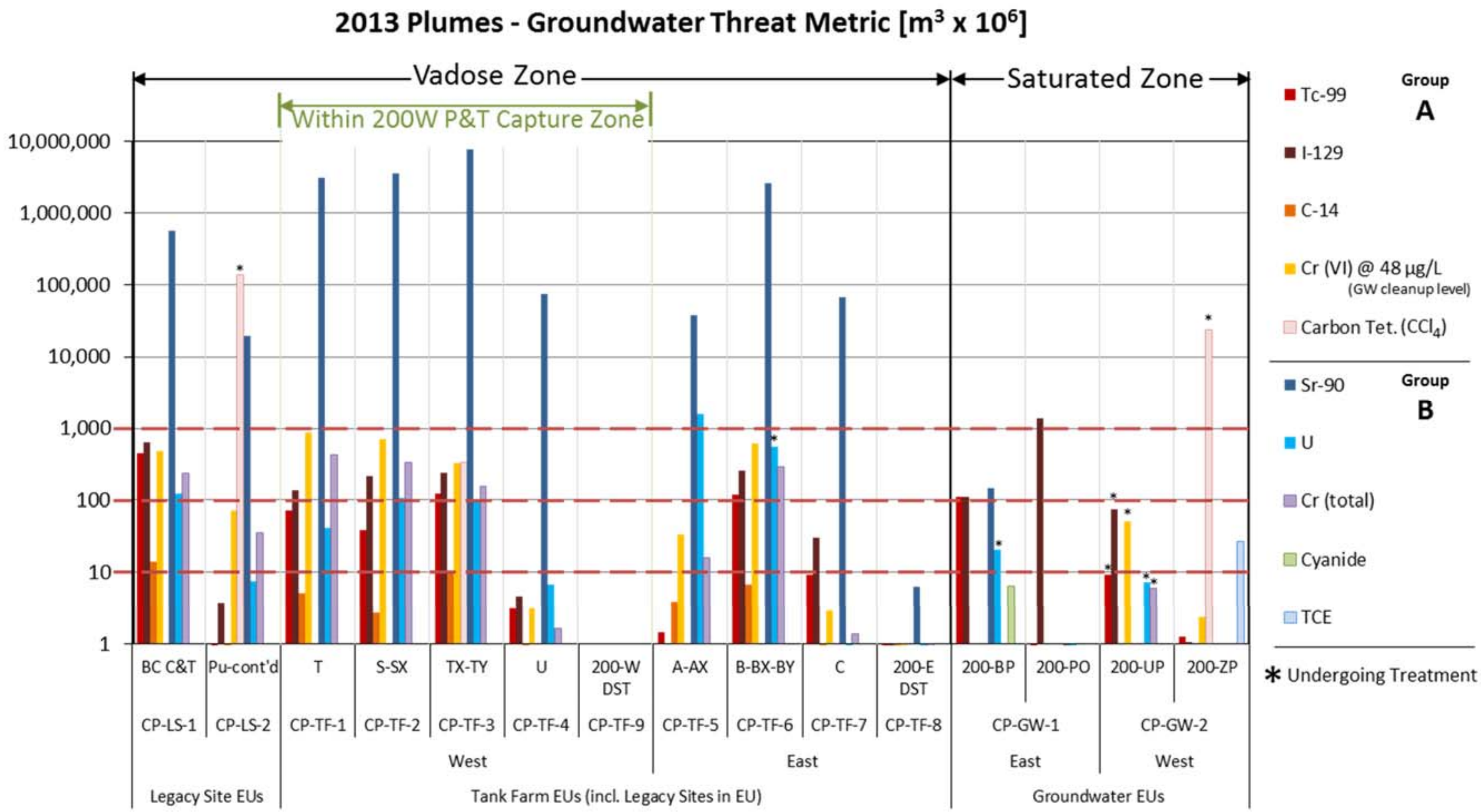

Figure 3-39. Rating vadose zone contaminant inventories as a threat to *groundwater as a protected resource* based on the groundwater threat metric. Groundwater threat metric in millions of cubic meters.

Groundwater Contamination Mitigation Efforts in the Central Plateau

A number of groundwater (GW) interim remedial actions have been conducted in the 200 West Area as part of the 200-UP-1 and 200-ZP-1 OUs. Figure 3-38 and Figure 3-39 indicate where remediation efforts have been undertaken by an asterisk (*) associated with vertical bar representing each contaminant source. In the 200-UP-1 OU, these actions include (EPA 2012):

- *216-U-1 Crib and 216-U-2 Crib Groundwater Interim Remedial Action (1985)*: An interim remedial action was designed to pump-and-treat (P&T) groundwater below these cribs. Pumping started in June 1985 and continued until November 1985. The system removed 687 kg of uranium via ion exchange treatment.
- *200-UP-1 Groundwater OU Interim Remedial Action (1997, amended in 2009 & 2010)*: A pilot-scale treatability test consisting of a P&T system was constructed adjacent to the 216-U-17 Crib. Phase I operations commenced September 1995 and continued until February 1997. The test demonstrated that the ion exchange resin and granular activated carbon were effective at removing Tc-99, uranium, and carbon tetrachloride from groundwater. Based on the success of the pilot system, and interim groundwater extraction and treatment system was implemented. Cleanup started in 1997 and met its remedial action objective of reducing highest concentrations to below 10 times the cleanup level of 48 µg/L for uranium and 10 times the maximum contaminant level of 900 pCi/L for Tc-99. This system removed 220.5 kg of uranium, 127 g (2.17 Curies) of Tc-99, 41 kg of carbon tetrachloride, and 49,000 kg of nitrate (see also DOE/RL-2014-32, Rev. 0, p. UP-2). The system was shut down in 2012.
- *WMA S-SX Groundwater Extraction System*: A groundwater extraction system for Tc-99 was constructed in 2011 and started operation in August 2012. The design consists of a three-well extraction system, aboveground pipelines, and a transfer building to pump extracted groundwater to the 200 West Groundwater Treatment Facility for treatment and reinjection. As of the 2013, the system has removed 60.8 g (1.03 Ci) of Tc-99, 17.9 kg of chromium, 9,560 kg of nitrate, and 121 kg of carbon tetrachloride since startup (DOE/RL-2014-32, Rev. 0, p. UP-34).
- The final ROD for the 200-UP-1 OU will be pursued when future groundwater impacts are adequately understood and potential technologies to treat I-129 are evaluated (EPA 2012).

In addition to the actions above, the following actions have been or are being taken to address groundwater contamination in the 200-ZP-1 OU:

- *200-ZP-1 OU Interim Remedial Action (1995)*: In 1996, a pump-and-treat system was started to reduce the mass of carbon tetrachloride (as well as secondary contaminants TCE and chloroform) in the groundwater primarily from waste sites south and east of the Plutonium Finishing Facility (DOE/RL-2012-03, Rev. 0). This action was completed and the interim P&T system was deactivated in May 2012 (with startup of the 200 West Area P&T facility). From 1996 through 2012, the system removed 13,911 kg of carbon tetrachloride, 14.5 kg of chromium, 84,693 kg of nitrate, 81.7 g (1.3 Ci) of Tc-99, and 0.73 kg of TCE (DOE/RL-2014-32, Rev. 0, p. ZP-25).
- *200-ZP-1 Record of Decision (2008)*: The 200-ZP-1 ROD was issued in 2008 and selected P&T, MNA, and Institutional Controls (ICs) to remediate contaminated groundwater including impacting the direction of groundwater flow and further reducing the levels of carbon tetrachloride present and migrating towards the 200-UP-1 OU. The P&T system was started in 2012 and removed 3,580 kg of carbon tetrachloride, 91.24 kg of chromium, 0.000242 µCi of

I-129, 243,905 kg of nitrate, 98.03 g (1.5 Ci) of Tc-99, and 15.49 kg of TCE, and 1.08 kg of U[76] by 2013 (DOE/RL-2014-32, Rev. 0, p. ZP-25).

- *200-PW-1 Interim Record of Decision (1992)*: Soil vapor extraction was implemented as an interim action in 1992 to remove carbon tetrachloride from the vadose zone in 200-PW-1 overlying the 200-ZP-1 groundwater (DOE/RL-2014-32, Rev. 0). The system has removed 80,107 kg of carbon tetrachloride to date; however, the mass removed each year has been decreasing (DOE/RL-2014-32, Rev. 0, p. ZP-28). The system did not operate in 2013.

The 200-BP and 200-PO OUs, both within the 200 East Area, have neither interim nor final RODs with groundwater being monitored under requirements of the Atomic Energy Act of 1954, CERCLA, and RCRA. The 200-PO-1 OU is being monitored to determine the impact to groundwater prior to determining the path forward for remedial action. For 200-BP-5, the following actions are being conducted:

- Ongoing perched water treatability test (200-DV-1) at WMA B-BX-BY to remove uranium. By 2013, approximately 691,000 L of perched water containing approximately 373 Kg of nitrate, 0.022 Ci of Tc-99, and 31.9 kg of uranium was extracted (DOE/RL-2013-22, Rev. 0; DOE/RL-2014-32, Rev. 0, page BP-8).
- WMA C Tank Waste Retrieval. Tank wastes are currently being retrieved from WMA C. Waste retrieval has been completed in nine of the 16 tanks, has been completed to various limits of technology in four tanks, and retrievals are in progress in the remaining three tanks (Weyns 2015).
- The final action ROD for the 200-BP-5 OU is scheduled for 2016 (DOE/RL-2014-32, Rev. 0, p. BP-3).

GROUNDWATER-RELATED THREATS TO THE COLUMBIA RIVER

The assessment of threats from primary contaminants to the Columbia River is based on consideration of the benthic and riparian zones. Impacts to benthic and riparian zones were considered more sensitive evaluation bases than free-stream concentrations because of the very high dilution of groundwater discharges within the Columbia River. The basic concept employed is that the threat or risk is a function of three factors: i) contaminant characteristics, ii) how much greater the contaminant concentration is with respect to the relevant screening threshold (i.e., informed by ecotoxicity), and iii) how large of an area (either river reach or riparian zone) is impacted.

Threats to the Columbia River Benthic Ecology from Contaminants

The first step in the threat determination process for impacts to the Columbia River (Figure 2-11) was to determine if the plume is in contact with the Columbia River at concentrations exceeding the WQS based on the 2013 Hanford Annual Groundwater Report (DOE/RL-2014-32, Rev. 0) and the aquifer tube data from PHOENIX (http://phoenix.pnnl.gov/). If the plume is not in contact with the Columbia River, then available information (EISs, baseline risk assessments, records of decision, etc.) is used to determine if a plume can be expected to intersect the Columbia River in the next 150 years. If not, then available modeling results are used to describe potential long-term impacts (1050 years or longer, if appropriate).

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[76] Uranium is not a contaminant of concern for the 200-ZP-1 OU; it is included to track 200-UP-1 groundwater treated.

If the plume either is in contact with the Columbia River or expected to intersect the River in 150 years, then the threat to the Columbia River is evaluated using the multi-step process illustrated in Figure 2-11.

First the ratio (R1) of the maximum concentration to the appropriate benthic screening value is computed using the screening values provided in Table 3-17:

- For radionuclides, the BCG consistent with DOE-STD-1153-2002 is used.
- For chemicals, the AWQC is used (the Tier II screening risk values are used when the AWQC is unavailable). The only exception is (total) uranium where the AWQC (5 µg/L) from the Columbia River Component Risk Assessment (DOE/RL-2010-117, Rev. 0, 2010) is less than most measured background concentrations (e.g., ranging from 0.5 - 12.8 µg/L in the 300 Area) (PNNL-17034, p. 6.9). A value (12.9 µg/L) was selected for total uranium to identify those areas contaminated by the Hanford Site.[77]

The rating process for ***benthic threats*** under current conditions (Figure 2-11) proceeds as follows:

- If the ratio R1 ≤ 1 (i.e., the maximum concentration is less than the screening threshold), then the rating for benthic threats is *ND*. Results for calculation of the ratio R1 are provided in Figure 3-40. Note that total uranium, and TCE in EU RC-GW-1 (OU 300-FF-5), chromium in EU RC-GW-2 (OU 100-NR-2) and EU RC-GW-3 (OUs 100-BC-5, 100-HR-3, 100-FR-3 and 100-KR-4) as well as carbon-14 and strontium-90 in EU RC-GW-3 (OU 100-KR-4) have R1 values that exceed 1, and therefore proceed to the next steps.
- If the primary contaminant is in Group C (Table 2-6), then the rating for benthic impacts is *Low*.
- If the primary contaminant is in Group A or B (Table 2-6), then the rating is *Low* if the ratio R1 ≤ 5.
- If the ratio R1 > 5, then rating is *Low* if the plume is not currently intersecting the Columbia River (using aquifer tube data or contours exceeding the threshold). If the plume is currently intersecting the River, then the ratio R2 of the log-mean 95% upper confidence limit (UCL) estimate to the screening value (BCG or AWQC) is computed. Results of the calculated ratio R2 are presented for the River Corridor groundwater EUs in Figure 3-41.
- If the ratio R2 ≤ 1 (i.e., the mean concentration is less than the screening threshold), then the rating is *Low* if the ratio R1 ≤ 5.
- If the ratio R2 > 1, then the matrix represented in Table 2-8 is used to determine the rating based on the ratio R2 and the Shoreline Impact provided in the 2013 Hanford Annual Groundwater Report (DOE/RL-2014-32, Rev. 0). The relative lengths of shoreline impact for each plume is presented in Figure 3-42.

Results of the above assessment process for the River Corridor EUs is presented in Figure 3-43. The results for the uranium plume in the 300 F Area are reflected by a range from ND to High because of the large uncertainty associated with the uranium no observed effects level (NOEL).

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[77] The selected value of 12.9 µg/L represents between the 90th and 95th percentile for site-wide background uranium concentration (DOE/RL-96-61, 1997). Note that there is a large uncertainty relative to the No Effects level for total uranium. As stated in the Columbia River Component Risk Assessment, "Effect levels span nearly three orders of magnitude (3 µg/L to 900 µg/L), reflecting considerable uncertainty in selection of a no-effect concentration. The value selected is a probable no effect concentration and is the 5th percentile of the toxicity data set." (DOE/RL-2010-117, Rev. 0, p. 6.2)

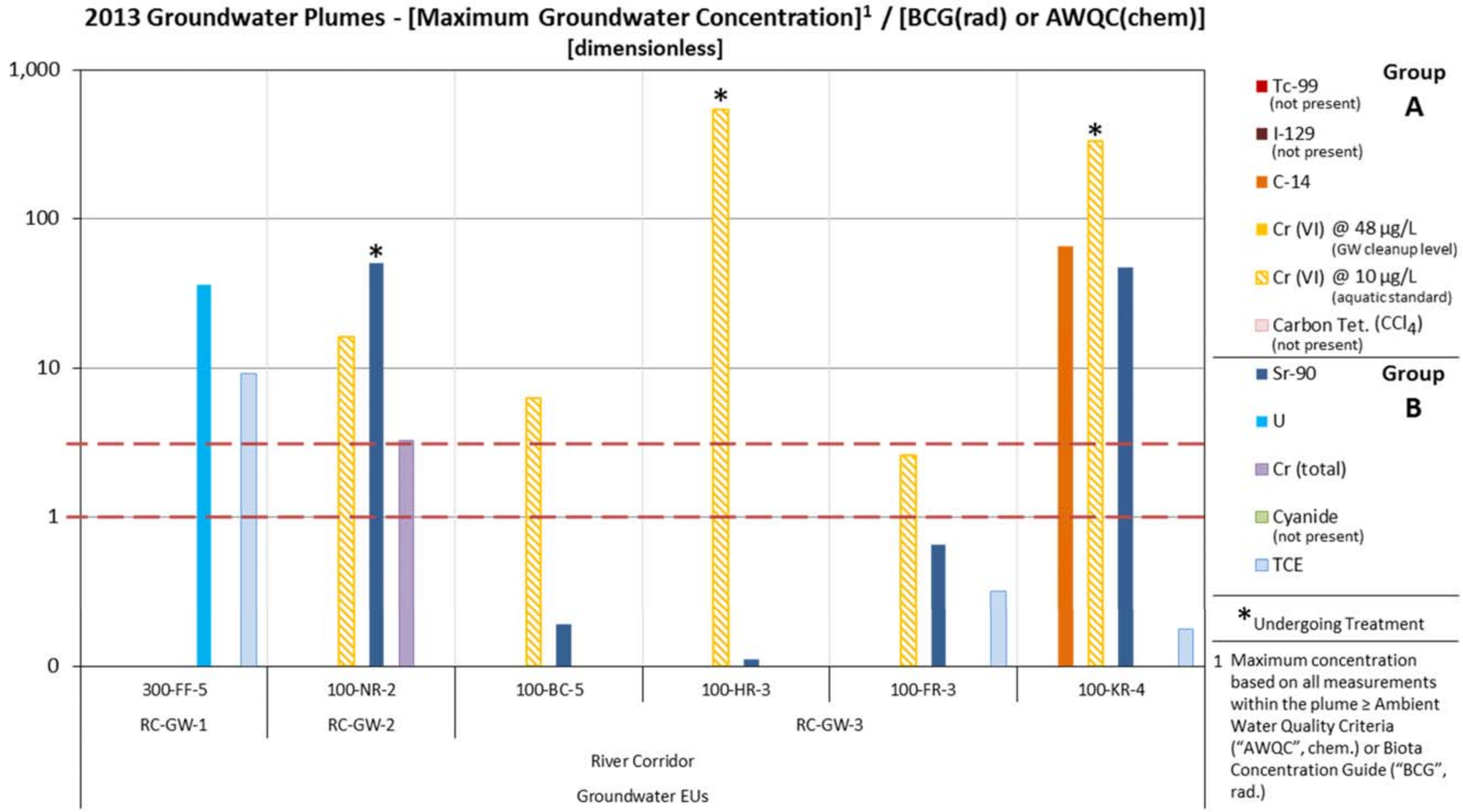


Figure 3-40. Calculated values of the ratio R1 for the River Corridor EUs using the 2013 groundwater monitoring data.

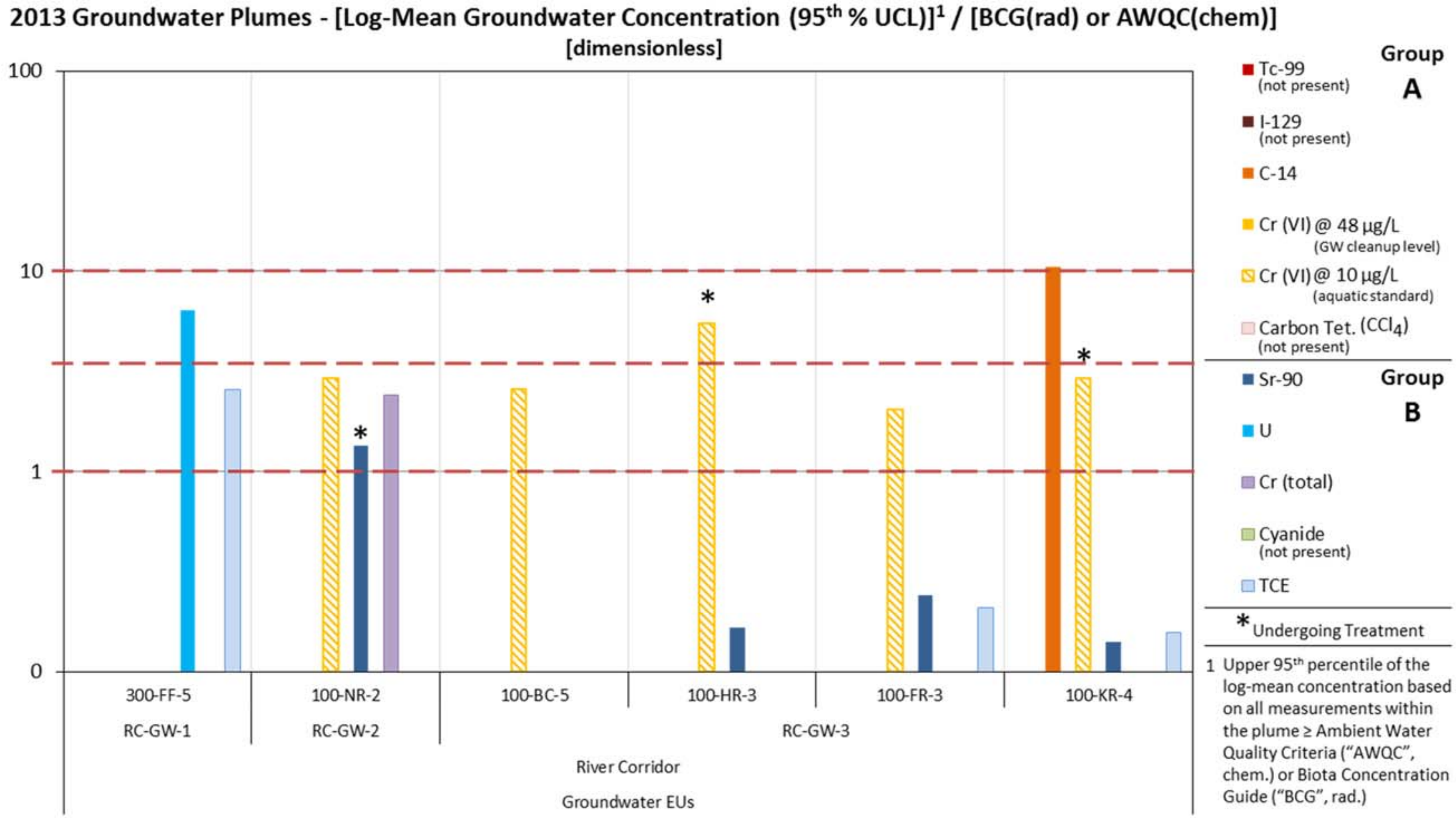


Figure 3-41. Calculated values of the ratio R2 for the River Corridor EUs using the 2013 groundwater monitoring data.

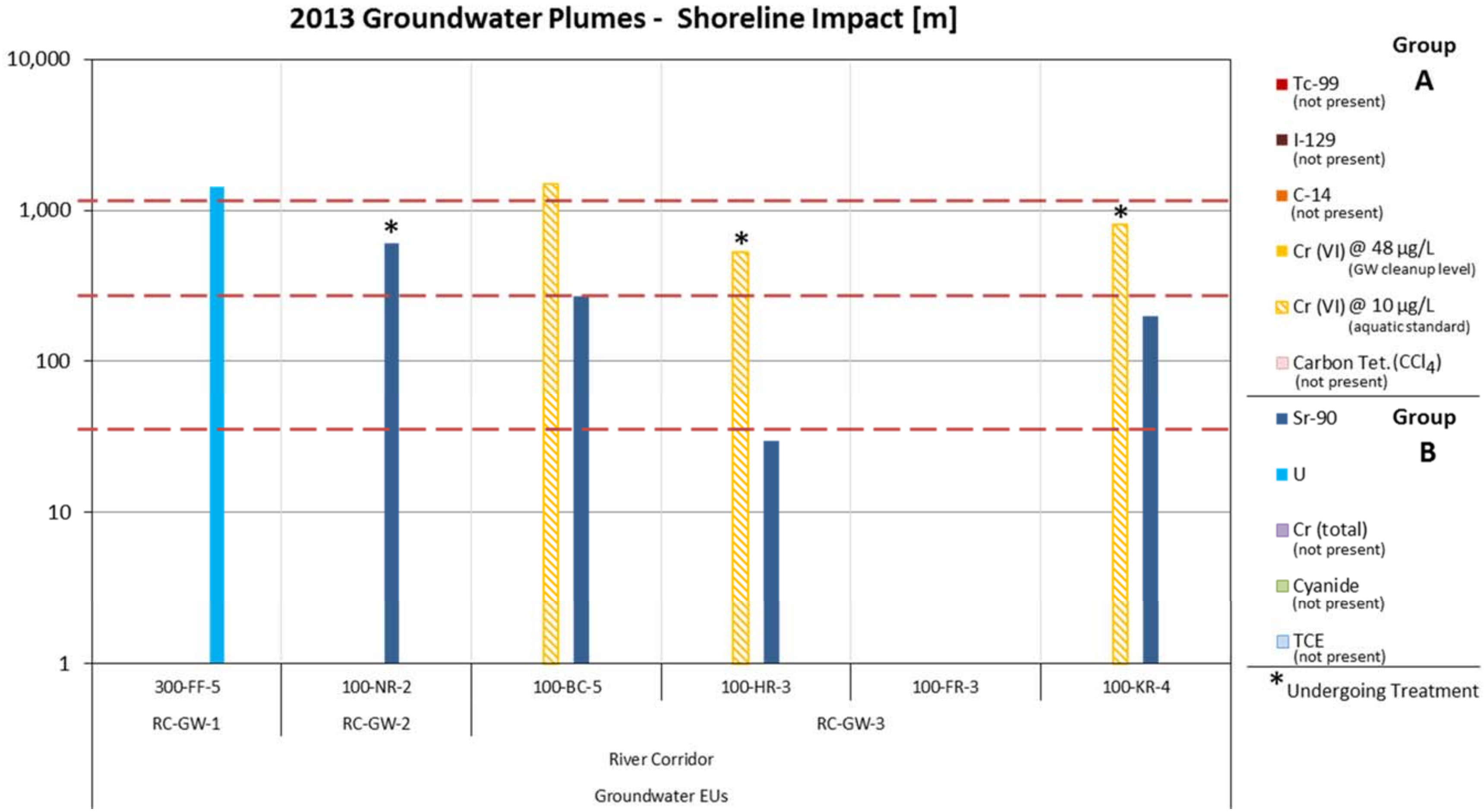


Figure 3-42. Estimated extent of shoreline impact (i.e., river reach) by the groundwater plumes in the River Corridor based on 2013 groundwater monitoring data.

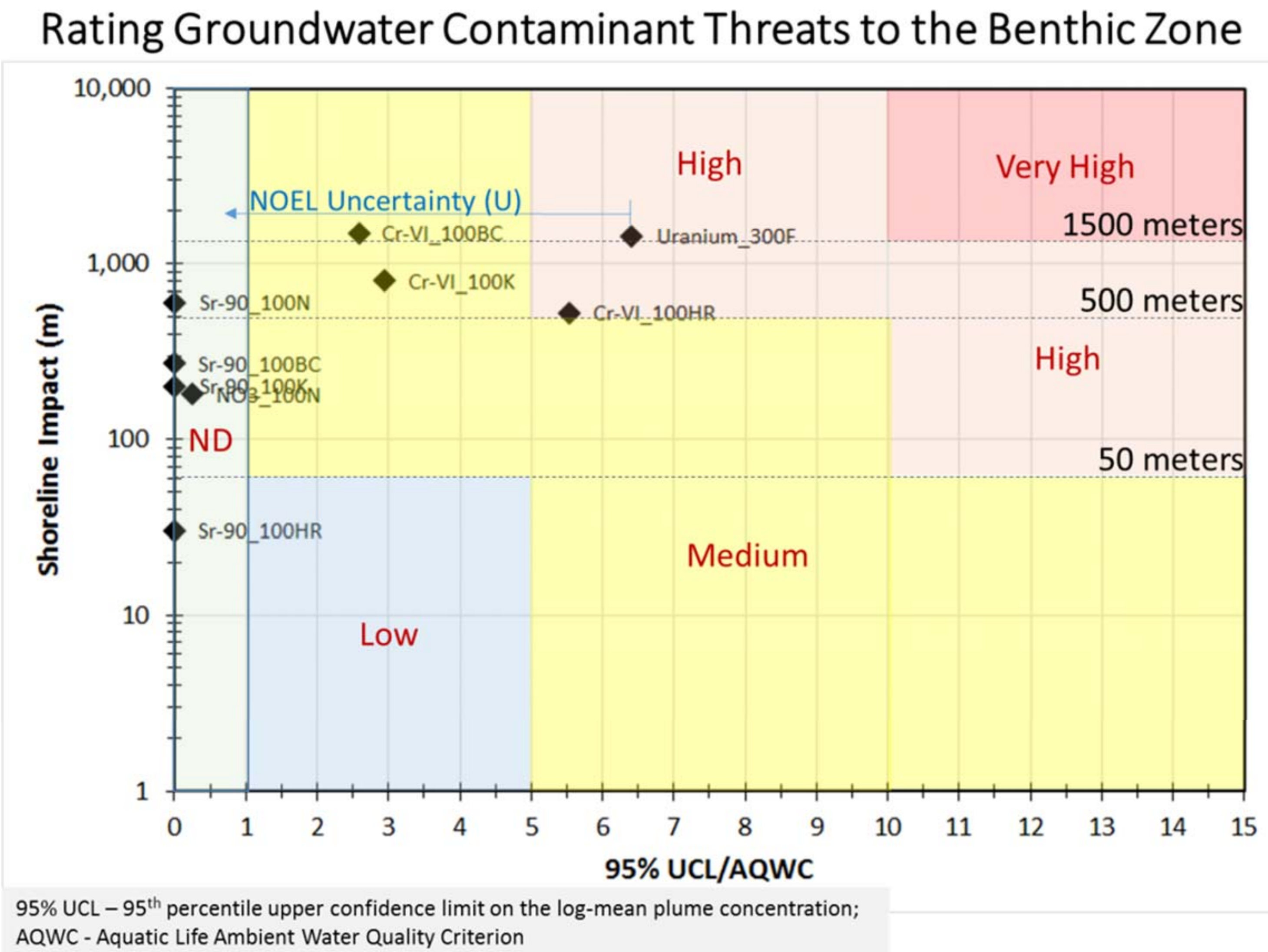


Figure 3-43. Risk Review Project ratings for groundwater contaminant threats to the benthic zone for River Corridor EUs.

Threats to the Columbia River Riparian Zone Ecology from Contaminants

The rating process for the riparian zone (Figure 2-11) proceeds along the same lines as the rating process for benthic receptors with the exception that if the ratio R2 exceeds unity, then the final step in the threat assessment process is

- If the ratio R2 > 1, then the matrix represented in Table 2-7 is used to determine the rating based on the ratio R2 and the Riparian Zone impact area.[78] The riparian zone area impacted by each of the River Corridor groundwater plumes was estimated based on habitat definition along the river and the intersection with the groundwater plumes greater than the screening threshold (Figure 3-44).

Results of the rating process for each River Corridor groundwater plume are presented in Figure 3-45.

[78] 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-2014-32, Rev. 0).

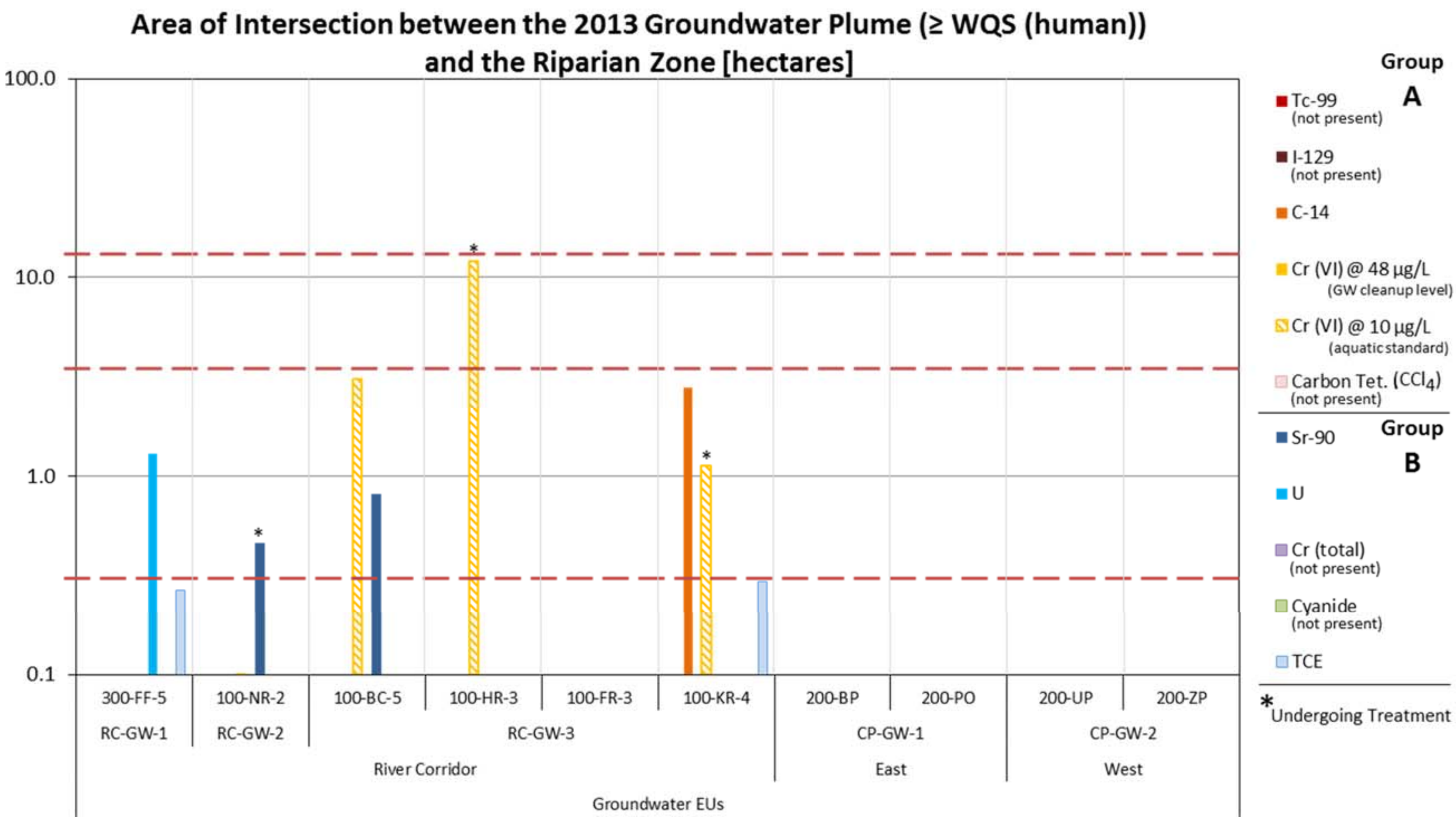
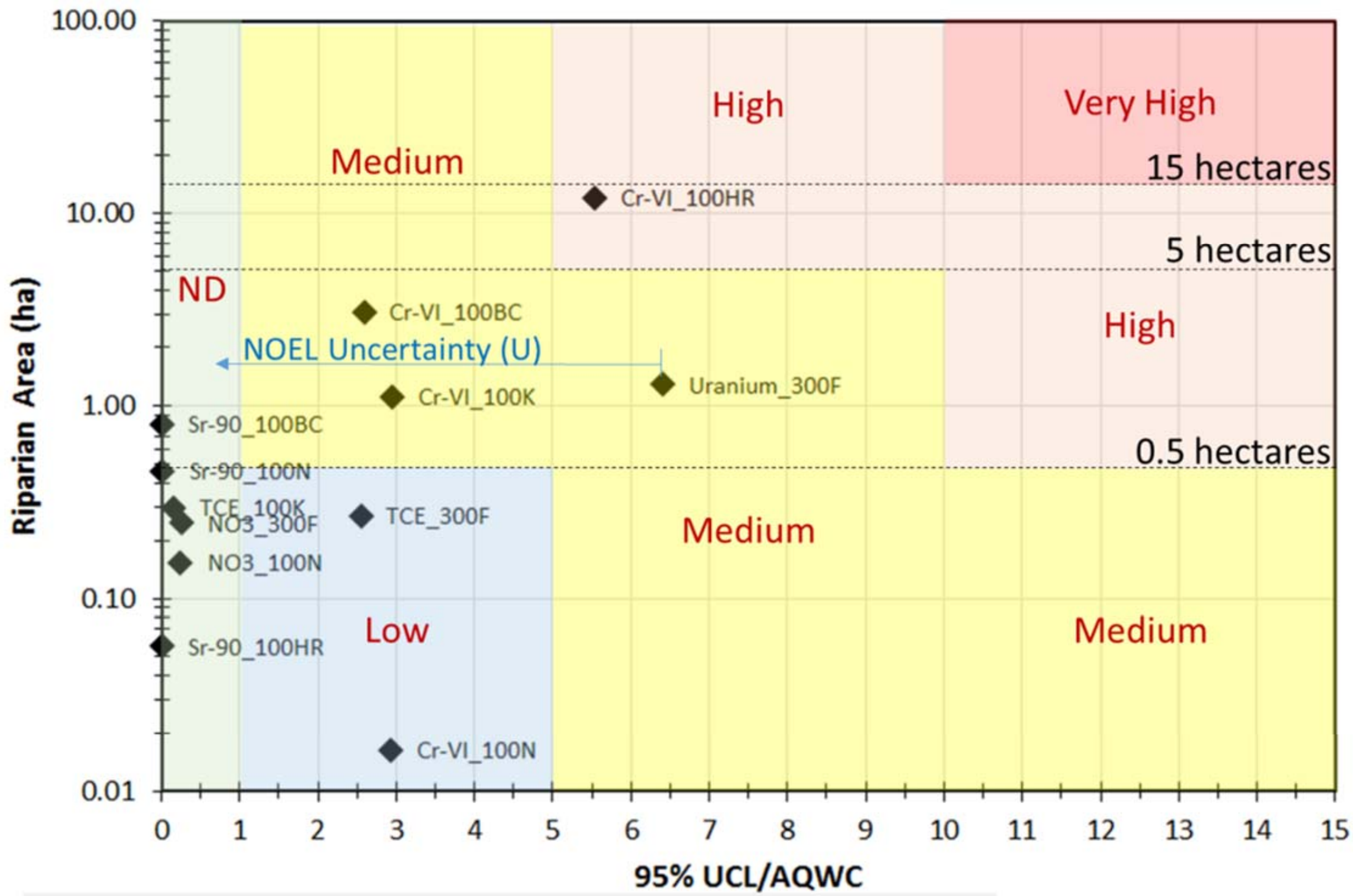


Figure 3-44. Area of intersection between the 2013 groundwater plumes along the River Corridor and the riparian zone.



95% UCL – 95th percentile upper confidence limit on the log-mean plume concentration;
AQWC - Aquatic Life Ambient Water Quality Criterion

Figure 3-45. Risk Review Project ratings for groundwater contaminant threats to the riparian zone for River Corridor EUs.

Threats to the Columbia River Free-flowing Ecology

The threat determination process for the free-flowing river ecology was evaluated in a manner similar to that described above for benthic receptors (Figure 2-11). However, because of the Columbia River's large dilution effect of on the contamination from the seeps and groundwater upwellings,[79] 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. If additional information becomes available (e.g., based on concentration measurements or bioaccumulation in certain areas of the Hanford Reach) that would lead to significant differentiation among EUs based on potential free-flowing river impacts, then the framework will be revised for the Hanford Risk Review Project final report.

SUMMARY OF RISK RATINGS

A summary of all groundwater EU risk ratings is provided in Chapter 4.3 (see Table 4-5).

3.4. DEACTIVATION, DECOMMISIONING, DECONTAMINATION, AND DEMOLITION OF FACILITIES (D4) EVALUATION UNITS

The Hanford Site contains seven major surplus facilities that are currently or will be undergoing one or more of deactivation, decommissioning, decontamination, and demolition (D4) phases. Final disposition will be burial of the demolition debris at ERDF or WIPP for plutonium/TRU contaminants, or the placement of an engineered barrier over the partially demolished structure along with maintenance of institutional controls, post-closure monitoring and caretaking. In addition, the K-Reactor ancillary buildings are currently undergoing D4, and the two reactor core buildings will be cocooned for interim safe storage until these two reactors and the other reactors along the Columbia River undergo final demolition and burial at ERDF.

An evaluation has been completed on the current condition and proposed D4 actions on three of the seven major D4 facilities, Building 324, PUREX, and the K Reactors, and the findings are compared below.

Figure 3-46 is a map of the Hanford Site showing the location of each D4 facility, with green stars identifying the three EUs included in this report and red stars identifying the EUs remaining to be evaluated as part of the final report. The K Reactors are identified with both colored stars, with the green star noting the current interim safe storage evaluation included in this report and the red star noting the final disposition in about 50 years to be evaluated as part of the final report.

[79] "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-2014-32, Rev. 0)." This represents a dilution effect of more than eight orders of magnitude (a dilution factor of greater than 100 million).

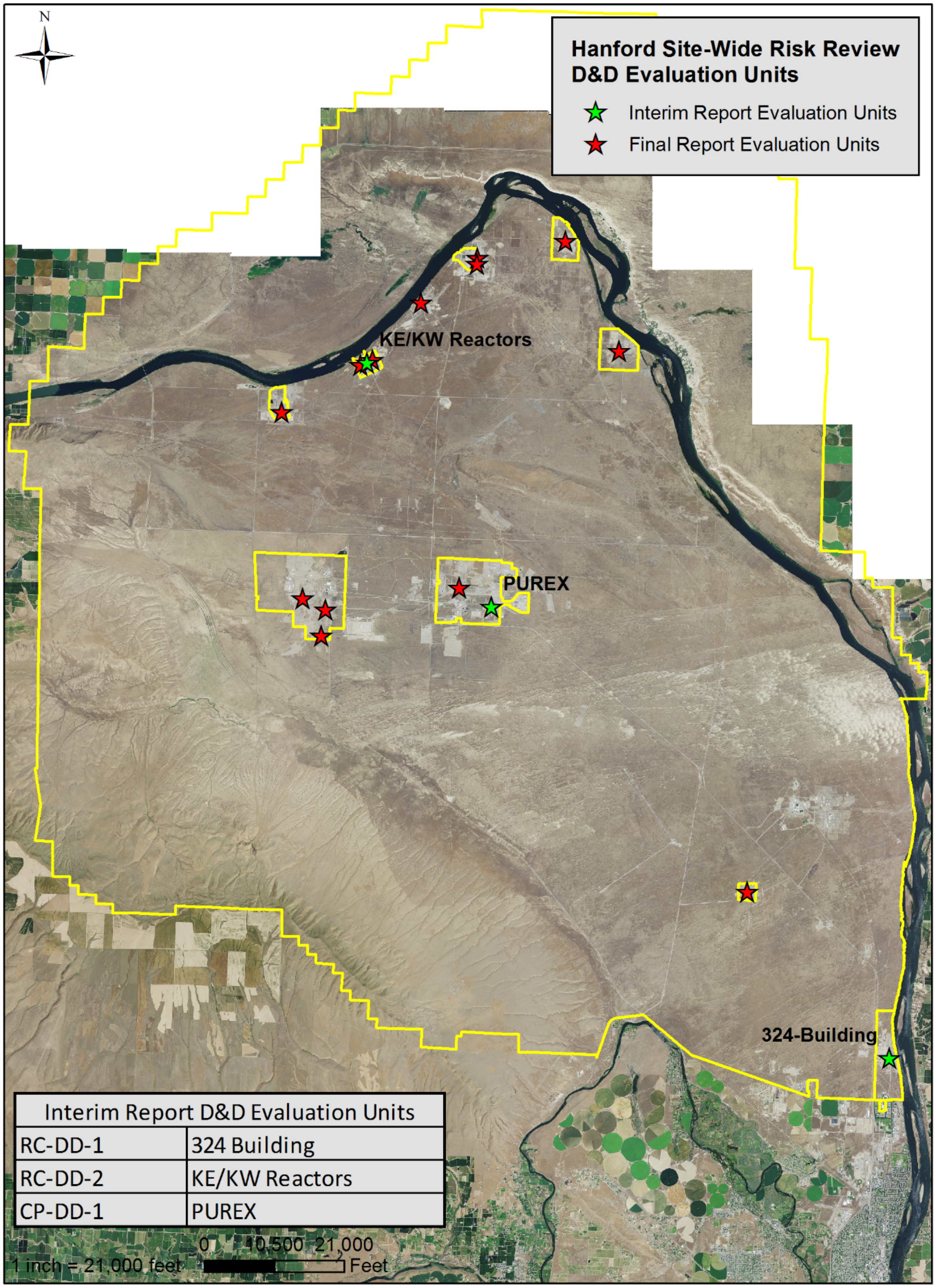


Figure 3-46. Map of D4 evaluation unit locations.

DESCRIPTION OF D4 EVALUATION UNITS

The following are short overview summaries of the Hanford D4 group of evaluation units:

- Building 324 (RC-DD-1)
- K-East, K-West Reactors (RC-DD-2)
- Plutonium-Uranium Extraction Facility (PUREX) (CP-DD-1)

Building 324 (RC-DD-1)

Figure 3-47. Aerial view of Building 324.

The 324 Chemical and Materials Engineering Laboratory (Figure 3-47), a Hazard Category 2 nonreactor nuclear facility, was constructed in 1965 as a dual-purpose facility that contained both radiochemical and radiometallurgical hot cells and laboratories. Located approximately 1000 ft from the Columbia River, the facility was operated by PNNL until 1996, although it continued limited operations in the 324 Building until October 1998, when it was transferred to B&W Hanford Company.

In 2009, a breach in the B-Cell liner was discovered during grout removal in the trench and sump. Investigations determined that a spill of approximately 510 L of a highly radioactive waste stream (approximately 1.3 million curies) containing Cs-137 and Sr-90 occurred in the B-Cell in October 1986. High radiation levels at the failed liner locations led to concerns that contamination had spread to the soil beneath the cell. In 2010, eight closed casings (geoprobes) were installed beneath B-Cell, which indicated contamination up to 8900 rad/hr in the soil. Modeling by PNNL estimated that the contamination had migrated to as much as 13 ft below B-Cell due to continuing amounts of water seeping through the hole until it was plugged up in 1992. In October 2014, nine new geoprobes were inserted by Washington Closure Hanford (WCH) below the floor that enabled the measurement of exposure rates along the length of the housing. These exposure rates were then converted to activity rates (curies) at 1 ft increments. The modeling[80] of this data indicates a contaminant plume, extending down to the cobble layer 4 ft below the B-Cell footings that spread out horizontally with increasing depth, that contains an estimated 224,100 Ci of activity. A maximum reading of 11,700 rad/hr was recorded by one of the probes. The more recent analysis indicates that the contamination has migrated down less than initial estimated but also horizontally to outside the boundaries of the building foundation.

[80] Washington Closure Hanford 2011, *Characterization of the Soil Contamination Under 324 B-Cell*, Calculation Sheet Project 618-10FR, Job No. 14655, Calc. No. 0300X-CA-N0140, Rev. 2, February 18, 2015.

Current Status: AREVA was awarded a $19 million contract in January 2014 to design, construct, and operate a pilot project designed as "proof of concept" for the remote retrieval of these highly contaminated soils through the floor of B-Cell. They are constructing a full-scale mockup of B-Cell and associated hot cells, and expect to have tested and documented the proposed removal process by September 2015. This might be delayed by the new and different data developed on the location of the soils that will need to be remediated. Building 324 currently is being maintained in a safe surveillance and maintenance mode pending completion and evaluation of the AREVA pilot project results and decision to proceed with soil remediation.

Contaminants: A recent analysis[81] indicates that an estimated 23,000 Ci of Sr-90 and 42,000 Ci of Cs-137 are primarily located in the building's A- and B-Cells and the High-Level Vault and Low-Level Vault tanks. Modeling of data from 9 probes inserted under the B-Cell in 2014 estimated a contaminate plume of 155,700 Ci of Cs-137 and 68,420 curies of Sr-90 extending down to the cobble layer 4 ft below the B-Cell footings that has spread out horizontally with increasing depth. Two hydraulic hammer unit penetrometers that were inserted at an angle into the cobble layer showed that the level of contamination below the cobble layer is negligible compared to the level of contamination immediately below B-Cell. There has been no indication of Cs-137 or Sr-90 migration from the soils underlying the building to the groundwater or the Columbia River. An important consideration with respect to prevention of Cs-137 and Sr-90 migration is prevention of water infiltration into the contaminated soils. Pending remediation of the soils, the greatest risk of water infiltration is from a leak or pipe rupture of the water supply main that runs close to the building. However, the very large quantities of Cs-137 and Sr-90 in the soil directly underlying the 324 building will remain a large near-surface hazard well past the 150 year evaluation period, and will require interim measures to prevent accidental water intrusion (through a water main break or building decay) and either long-term immobilization (e.g., grout and capping) or removal.

Final Cleanup and Disposition: One of the biggest challenges facing DOE is how to safely remove or contain the highly radioactive soils beneath the building's B-Cell. The current plan is to extract the soil up through the B-Cell floor, mix with grout and transfer to the C and D hot cells. The outer shell of Building 324 would be demolished, and the hot cells would be cut into monoliths and transported to ERDF for disposal. This process involves technical uncertainty that WCH is seeking to resolve through a $19 million contract with AREVA to design, construct, and operate a pilot project designed as "proof of concept" for the remote retrieval of these highly contaminated soils. An earlier estimate was for the soil mitigation work to be completed sometime around the fall of 2016, followed by demolition of the building and removal and transport of the hot cells by about mid-2020. Results of the AREVA study will not be available before September 2015, although this might be delayed by the release in February 2015 of new and different data on the location of the soils that will need to be remediated.

An alternative evaluated by WCH (Washington Closure Hanford 2014, Washington Closure Hanford 2011) was deemed safer and more feasible than the above method. However, DOE believes that this method is inconsistent with the RTD requirements of the *Interim Action Record of Decision for the 300-FF-2 Operable Unit, Hanford Site* (EPA 2001) and CERCLA documentation for the 300 Area. It involves stabilizing the contamination in place by injecting a grout or polymer into and/or under the waste matrix to stabilize and prevent its migration to groundwater, and leaving the contamination in situ with an engineered cap over the site. If the proposed remote retrieval prove technically infeasible, approaches

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[81] Washington Closure Hanford 2014, *324 Building Basis for Interim Operation*, River Corridor Closure Contract: WCH-140 Rev. 7, May 2014

that allow for immobilization and in situ decay of the soil contaminants (Cs-137, Sr-90) warrant further consideration.

Primary Risks: Building 324 is currently maintained in a safe surveillance and maintenance mode with minimal worker activities. The primary future risks to facility workers, co-located workers, and the public are associated with the significant radiological residual contaminates in the B hot cell and other hot cells. Any one of several worker-related accidents during future stabilization and deactivation activities could release high radiological doses to each because of the short distances from the building to offsite and public areas. The soils beneath the B-Cell represent the highest risk to workers and possibly co-located persons, but only if they are excavated and contaminants are released into the environment. The public, in the form of users of water from the Columbia River, are at risk only if the soil contaminants reach groundwater through a large infusion of water to the surface, such as the rupture of the aging high-pressure fire suppression water line system located above the contaminant area.

K-East, K-West Reactors (RC-DD-2)

The K Reactors were two (K-West, K-East) (Figure 3-48) third-generation-design plutonium production reactors. Construction of K-West began in 1952, with the initial startup of the reactor occurring on January 4, 1955. The final shutdown of the reactor occurred on February 1, 1970. Construction of K-East began in 1953, with the initial startup of the reactor occurring on April 17, 1955. The final shutdown of the reactor occurred on January 28, 1971. During final shutdown of the reactor buildings, extensive procedures were performed to safely shut down the entire facility and contain contamination within the reactor block.

Figure 3-48. Aerial view of K-East, K-West reactors

Current Status and Interim Cleanup: The K-East Reactor building achieved Cold and Dark status (electrical and mechanical systems air-gapped to eliminate potential external energy sources) in February 2010. The K-West Reactor building is currently managed as less than a Hazard Category 3 for authorized surveillance and maintenance activities. D&D of buildings and structures ancillary to the reactor core building will begin when the contaminated sludge is removed from the K-West fuel basin. The K-West fuel storage basin and sludge treatment project is addressed as a separate EU, as is the cleanup of the waste sites at the K-West area.

Pending funds availability, work will proceed to put both reactor buildings into interim safe storage until approximately the year 2068, followed by deferred demolition of the buildings and transporting the reactor cores to ERDF for disposition. Interim safe storage consists of demolishing part of the reactor building, constructing a safe storage enclosure (SSE) around the reactor block ("cocooning" the reactor building), and providing long-term monitoring. The SSE will be a structurally independent building supported on a newly poured concrete foundation.

Although DOE is currently following a remediation path of temporarily cocooning the two reactor buildings as selected in the 1993 NEPA ROD[82] and applied to the other Hanford surplus reactors, it has broadened its decommissioning approach by retaining the immediate one-piece removal alternative that was deemed equally favorable based solely on the evaluation of environmental impacts. An EIS supplemental analysis (DOE/EIS-0119F-SA-01) prepared in July 2010 addresses a proposed action to pursue accelerated dismantlement, removal, and disposal of all eight surplus reactor facilities on the Hanford Site, with an initial focus on the K-East Reactor as a demonstration of capabilities to accelerate the dismantlement, removal, and disposal of the remaining seven surplus production reactors. In April 2011, DOE advised the Hanford Advisory Board that it was no longer pursuing this option and was proceeding with construction of SSEs for both reactor buildings.

The existing soil grading exposes the exterior of the K-East Reactor building to a depth of approximately 16 to 21 ft below grade on three sides. The floor of the basin excavation pit on the north side is covered with approximately 2 ft of clean overburden for radiation shielding and to reduce contamination levels when backfill is resumed. A delay may require temporary filling of these areas to retain structural stability of the exposed building. Long delays in constructing the SSEs over each of the K-East and K-West Reactor buildings could cause the building envelope to lose integrity such that precipitation and animals can infiltrate. There is also the potential for building decay and spread of hazardous materials such as contamination that could complicate further cleanup.

Contaminants: The reactor blocks each contain approximately 18,000 Ci of radionuclides, with the primary contaminants within the reactor building based on curies being H-3, C-14, Ni-63, Co-60, Cl-36 and Cs-137. The block is located near the center of the building, and consists of a graphite moderator stack (41 ft wide by 41 ft high by 33.5 ft deep) encased in a cast iron thermal shield (10 in. thick) and a biological shield consisting of high-density aggregate concrete (45 to 83 in. thick). The entire block rests on a massive concrete foundation. The reactor block, including the foundation, weighs approximately 12,100 tons. A cast iron thermal shield surrounding the graphite stack isolates the biological (radiation) shield from the core (Figure 3-49).

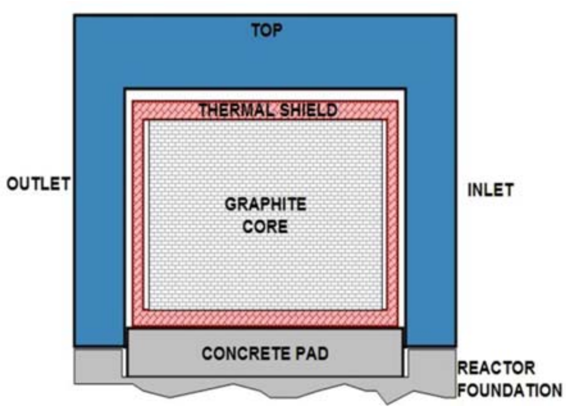

Figure 3-49. Schematic reactor cross-section.

In addition, about 187 tons of lead (in 1993[83]) exists in surface coatings (i.e., lead-based paint), plumbing, and as radiological shielding (e.g., lead shot, brick, sheet, and cast-lead forms) inside some of the 100-K Area facilities. About 926 yd^3 (in 1993) of asbestos-containing material is located in and around the facilities and may exist as vessel or piping insulation, floor tiles, transite wall coverings or panels, sheetrock, electrical wire insulation, and ducting. PCBs are identified as potential contaminants in the 100-K Area facilities and PCB-contaminated waste will likely be generated.

In addition, there is a fixed radionuclide contamination area on the lower part of the north exterior wall of the K-East Reactor building of

[82] 58 FR 48509

[83] Referenced in: Bechtel Hanford, Inc., *Surplus Reactor Auditable Safety Analysis, BHI-01172, Rev. 3.,* for U.S. Department of Energy, Richland Operations Office. August 19, 2004

approximately 864 ft^2 that was caused by openings between the chute feeding the fuel basin and the reactor building. It has been covered with Polymeric Barrier System fixative.

Hexavalent chromium is the primary groundwater contaminant underlying the 100-K Area (100-KR-3 and 100-KR-4 OUs), and the potential exists for high concentrations of chromium in the soils underlying the reactor building and related facilities.

Final Cleanup and Disposition: In or about 2068, DOE has proposed to demolish the two SSEs and the remaining reactor shell around the reactor block, followed by a one-piece removal of the reactor block that would be transported to ERDF for permanent disposal. The reactor block includes the graphite core, the thermal and biological shields, and the concrete base. The site would be backfilled, graded, revegetated, and released for other DOE use. This process is expected to take about 3 years for each reactor.

Interim safe storage of the two reactor buildings is expected to last until approximately 2068. The reactor block, including the thermal and biological shields, is of robust construction and has shown little degradation after 50 years. However, as noted above, long delays in constructing the SSEs over each of the K-East and K-West Reactor buildings could cause the building envelope to lose integrity such that precipitation and animals can infiltrate. Once constructed, the SSE will protect the reactor block from the elements, it is reasonable to expect that the reactor will remain structurally sound for the duration of interim safe storage. It is therefore highly unlikely that the co-located person or public would be at more than a Low risk of radiological exposure throughout this period.

Primary Risks: The K Reactors represent an ND to Low risk to a facility worker, co-located person, or the public because the primary contaminants are decaying inside a reactor core that can withstand a design basis seismic event.

PUREX (CP-DD-1)

The PUREX Plant complex (Figure 3-50) is a nuclear fuel processing facility that was constructed between 1953 and 1955 and was operated until 1990 to chemically separate plutonium, uranium, and neptunium from Hanford Site nuclear reactor fuel elements. Plutonium was recovered as an acidic solution of plutonium nitrate or was converted to plutonium oxide in N-cell. Nearly 70% of Hanford's uranium was reprocessed through PUREX. The original plant was a concrete rectangle 1005 ft long, 104 ft high (with approximately 40 ft below grade), and 61.5 ft wide.

The PUREX Plant incorporated a unique feature for disposing of large pieces of radioactive solid waste, such as failed or worn equipment. A 500 ft rail extension running southward was built onto the single-track rail tunnel that was used to bring irradiated slugs to the east end of the PUREX building. The tunnel's rectangular walls and ceiling are primarily constructed of 12 in. by 14 in. creosoted timbers arranged side by side with the 12 in. face exposed. Between June 1960 and January 1965, eight railcars with radioactive equipment were pushed into the tunnel by a remote controlled electric engine. In 1964, a 1700 ft tunnel was constructed to provide storage space for 40 railcars after the first tunnel had become full and was sealed. Its semicircular walls are supported by internal steel I-beams attached to externally constructed 3-foot-thick reinforced concrete arches, with a bituminous coated steel liner on the interior. It currently contains 28 railcars of radioactively contaminated equipment.

Figure 3-50. Aerial view of PUREX.

Between 1995 and 1997 the PUREX Plant was brought to a safe, low-cost, low-maintenance deactivation status. As part of the deactivation, the water-fillable doors of both tunnels and the outer PUREX railroad tunnel door were sealed. The current scope of work includes surveillance and maintenance that maintains confinement of hazardous wastes and protects the worker. This work scope includes pre-approved activities for surveillance of the facility, preventative maintenance of selected equipment, and incidental storage of necessary supplies and equipment.

Contaminants: The radioactive material inventory remaining at the end of deactivation in 1995 through 1997 was primarily in the form of contaminated equipment and surfaces, dust, and debris, with some remaining plutonium and oxide dust stabilized in gloveboxes (total of about 29,000 Ci). Various pieces of dangerous debris and equipment containing or contaminated with dangerous/mixed waste stored on the PUREX Canyon Deck were removed and placed in PUREX Storage Tunnel #2. In total, it contains more than 400,000 Ci of Cs-137 and Sr-90, as well as about 7200 Ci of total Pu. The PUREX Building and two tunnels are classified as nuclear Hazard Category 2 facilities (potential for significant onsite consequences). Other hazardous materials that remain are a relatively minor risk, as there are no substantial volatile, caustic, or reactive materials remaining.

Final Cleanup and Disposition: Final D&D of the PUREX building is expected to be similar to the "Close in Place-Partially Demolished Structure" alternative chosen for the 221-U Plant. There are several D&D options for the rail cars and equipment in the two tunnels, including injecting grout and close in-place or removal, treatment, and onsite or offsite disposal. The Tri-Party Agreement requires DOE to submit a change package by September 30, 2015 to establish a schedule for submittal of the remedial investigation/feasibility study work plans for PUREX and other 200 Area canyon facilities.

Primary Risks: The primary risks at PUREX are largely linked to a seismic or other natural phenomenon event that would cause structural failure of the 202-A Building or tunnels and would release much of the dispersible radiological contaminants. An additional primary risk is a fire in Tunnel #1 that would result in a similar release.

COMPARISON OF INVENTORIES AND PHYSICAL/CHEMICAL STATES OF WASTES AND CONTAMINANTS, BARRIERS

There are significant differences in the primary radiological inventories currently present at these three D4 EUs, as well as the long-term integrity of current barriers to release or allow dispersion of the contaminants (Table 3-19) and the potential unmitigated radiological dose impact to the co-located person and the public (Table 3-20). The K Reactors (excluding consideration of the K-West Basins) are Hazard Category 3 facilities. The radiologic inventory in each reactor is less than about 18,000 Ci, much of which is tritium that has a half-life of 12.3 years (7010 Ci), and the contaminants are located within a concrete and steel reinforced reactor block (Figure 3-50) that is sufficient to withstand a design basis seismic event.

Table 3-19. Summary of major radiological primary contaminant inventories, form, and barriers to release.

	Primary Contaminants (Ci)					
Evaluation Unit	**Cs^{137}**	**Sr^{90}**	**Pu (total)**	**Am^{241}**	**Form**	**Containment/ Barriers**
BUILDING 324 (RC-DD-1):[a]						
Building	42,000	23,000	NP	NP	Fixed and dispersible	Concrete walled A- and B-Cells and room containing High-Level Vault and Low-Level Vault tanks.
Soils	460,000	200,000	NP	NP	Mobile	Plume located between B-Cell footings and cobble layer 4 ft below[84]
K REACTORS (RC-DD-2):						
Reactors	35	12	7.4	<1	Fixed and dispersible	Concrete and cast iron reactor block
Building Exterior	0.75	0.34	0.033	0.033		
PUREX (CP-DD-1):[b]						
202-A Building	11,000	8,900	8,100	1,200	Fixed and dispersible	Concrete walled canyon
Tunnel #1	10,000	8,200	2,500	440	Fixed and dispersible	Wood tunnel walls covered by 8 ft of soil
Tunnel #2	330,000	170,000	7,200	330	Fixed and dispersible	Concrete/metal tunnel walls covered by 8 ft of soil
Soils	1.1	1.2	0.034	0.0037		

a. The Building 324 EU source sites also contain 1000 kg of chromium and 10,000 kg of total uranium.
b. The PUREX EU source sites also contain 3300 kg of total uranium, 47,000 kg of nitrate, 42 Ci of tritium, and minor quantities of other PCs.

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84 Washington Closure Hanford 2011, *Characterization of the Soil Contamination Under 324 B-Cell*, Calculation Sheet Project 618-10FR, Job No. 14655, Calc. No. 0300X-CA-N0140, Rev. 2, February 18, 2015.

Table 3-20. Unmitigated radiological dose (rem) impacts to co-located person and public.

	PUREX and Tunnels		Building 324		K Reactors	
Accident/Event Scenario	**Co-located Person**	**Public**	**Co-located Person**	**Public**	**Co-located Person**	**Public**
Seismic (0.2g)	250	0.170	11	3	Reactor blocks are stable and inventory would not be released	
Partial building collapse	25	<0.02	NA	NA	NA	NA
Crane Drop - Tunnel #2	14	<0.01	NA	NA	NA	NA
Waste Handling Accidents	4	<0.01	268	79	NA	NA
Fires	14-70	<0.05	4	1	External fire K-East: low consequences	
Explosions	NA	NA	24	7	NA	NA

Table 3-21. Unmitigated dose impacts to co-located person and public.

	PUREX and Tunnels		Building 324		K Reactors	
Accident/Event Scenario	**Co-located Person**	**Public**	**Co-located Person**	**Public**	**Co-located Person**	**Public**
Seismic (0.2g)	High	Low	Medium	Medium	Reactor blocks are stable and inventory would not be released	
Partial building collapse	Medium	ND	NA	NA	NA	NA
Crane Drop - Tunnel #2	Medium	ND	NA	NA	NA	NA
Waste Handling Accidents	Low	ND	High	High	NA	NA
Fires	Med-High	ND	Low	Low	External fire K-East: low consequences	
Explosions	NA	NA	Medium	High	NA	NA

CONSIDERATIONS FOR TIMING OF THE CLEANUP ACTIONS

A delay in initiating and completing D4 activities would have different potential impacts on the co-located person and public/MOI at each of these three D4 sites. With the K Reactors, physical maintenance of the building structures will become a priority if there is long delay in constructing the safe storage enclosures (holes in roof, etc.). The timing of construction of the K-East SSE is partially linked to the desire to work on the K-West Reactor building around the same time to make efficient use of personnel and other resources; however, a long-term delay could cause residual contaminants in exposed soils to migrate toward groundwater. D4 and waste site cleanup work on K-West cannot begin until the sludge is removed from the K-West used fuel basin and the fuel basins demolished, which is a separate project.

Delays in completing the proposed "Close in Place-Partially Demolish Structure" type D4 action on the PUREX 202-A canyon building and some type of grout in place and more permanent sealing of the two tunnels will leave the potential for the several natural phenomena hazard events and accidents mentioned earlier to occur, with resulting large aerial releases of contaminants. The timber walls and ceiling of Tunnel #1 will also continue to weaken and possibly collapse causing a similar release of contaminants.

There is not a short-term threat of the Cs-137 and Sr-90 contaminants beneath Building 324's B-Cell migrating to groundwater levels based on current extent of radionuclide migration (over 30 years), but that could change if a driving force such as a large source of water (e.g., from a water main break) pushes the contamination lower. Conversely, there are potential benefits to near-term measures that prevent infiltration to the soils (e.g., covers or in situ grouting) and allow time for an order of magnitude decrease in radiation levels due to natural decay (ca. 90 years) or allowing natural attenuation to achieve long-term environmental safety. Many of the exposure risks from waste handling accidents inside the building will be alleviated by completion of the stabilization, deactivation, decontamination, decommissioning of equipment and systems work.

COMPARATIVE SUMMARY

Although DOE and its contractors employ active and passive safety class and safety significant systems and controls to mitigate the potential adverse impacts of virtually all but some natural phenomena events, identifying differences between the three D4 EUs requires consideration of the unlikely but possible failure of one or more of these controls and thus the unmitigated radiological dose exposures to onsite and offsite persons as represented by a hypothetical individual located 100 m from the EU boundary (co-located person) and another individual located at Hanford Site controlled access boundary (public or MOI). As revealed by the comparison of these three D4 sites, human health risks are driven by the following factors:

- Quantity (in Ci) of the contaminant
- Form of the contaminant (fixed, dispersible, mobile)
- Integrity of its containment (concrete canyon or reactor walls, tunnel, soils)
- Whether cleanup work is going on that could cause accidents
- For the public or MOI, the distance between the initiating event and the Hanford boundary

As noted earlier, the K Reactors represent the lowest risk among the three EUs. The amount of radiological contaminants is smaller and contained in the most stable structure, and no work is going on that would cause an accident that might release the contaminants.

The PUREX 202-A canyon building and two adjacent tunnels contain the largest quantities of radiological contaminants that could be dispersed in the air, but the current surveillance and maintenance work offers little or no opportunity for an accident that might release them into the air. A seismic-caused collapse of the building and tunnels or a fire in Tunnel #1 represent high exposure risks to humans near the facilities, but the 8.5 mile distance to the closest Hanford boundary significantly reduces exposure risks to the public/MOI.

Building 324 represents the highest risk to human exposure among these three EUs. This is largely because the stabilization, deactivation, decontamination, decommissioning of equipment and systems work inside the building could cause accidents that release large amounts of radiological contaminants that adversely impact facility workers and co-located persons, as well as the public/MOI because of the relatively short distance between the building and the Columbia River Hanford Site boundary. In addition, although the building's foundation and structure is effectively containing a significant amount of Cs-137 and Sr-90 located in soils below the B-Cell by preventing any large infusion of rain, snow melt, or other water from reaching the contaminants, a worker-related fire inside the building could cause a fire protection water line on the building exterior to rupture and sufficient influx of water to the soil to cause the contaminants to migrate toward groundwater.

3.5. OPERATING FACILITY EVALUATION UNITS

The Hanford Site contains many facilities that are currently in active operations. These facilities are spread across the site and include many facilities to aid in the site cleanup, including both storage and treatment operations. Other types of onsite operating facilities are used to conduct research and testing for DOE programs.

An evaluation has been completed on the current condition and proposed actions of four of these facilities: the WESF, the ERDF, the K-West Basin Sludge Project, and the CWC. A summary of the findings from the review of these four facilities follows.

Figure 3-51 is a map of the Hanford Site showing the location of each of these facilities, with green stars identifying the three EUs included in this report and red stars identifying the EUs remaining to be evaluated as part of the final report.

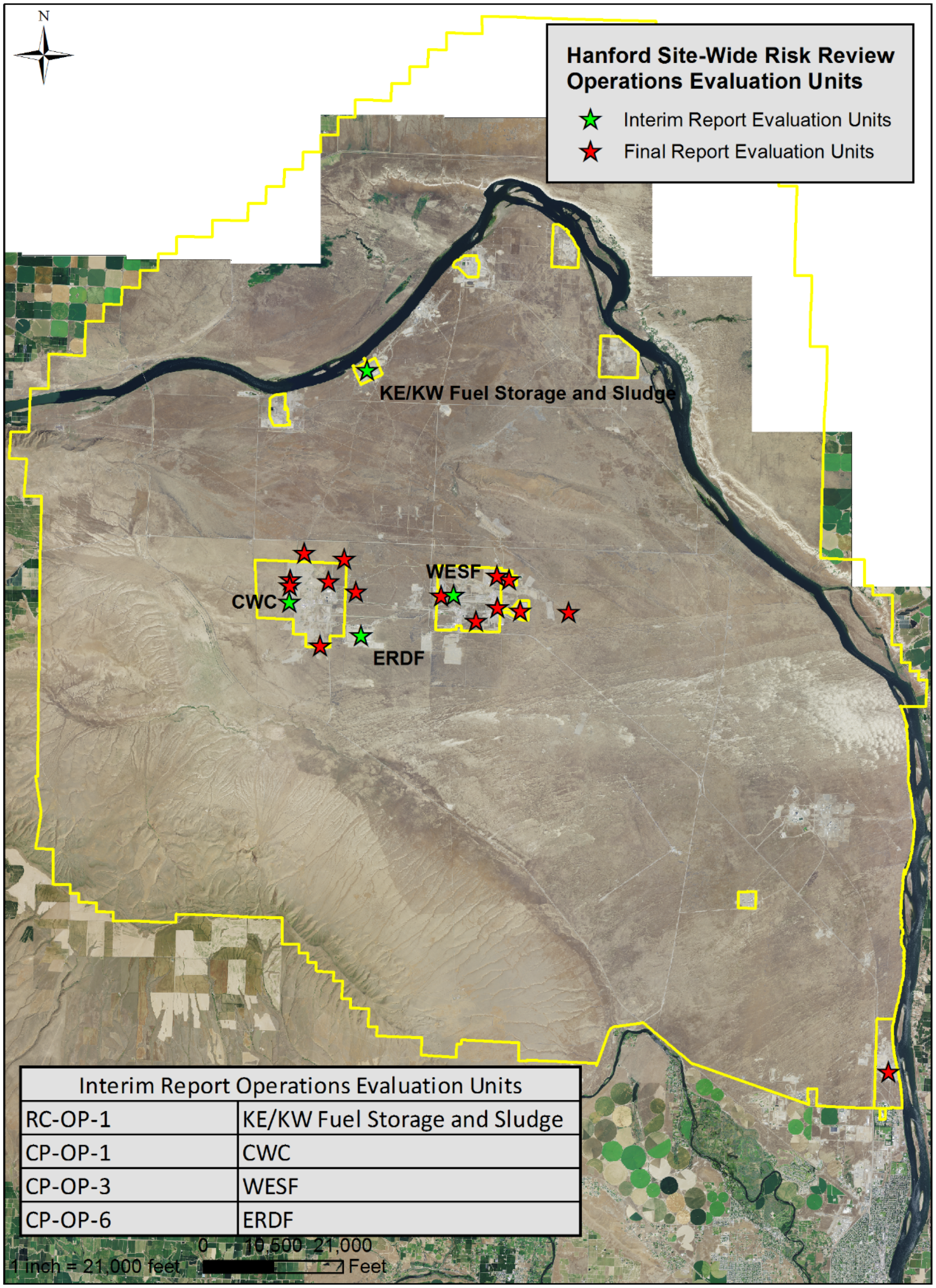

Figure 3-51. Map of operating facilities with Hanford.

Description of Operating facilities

The following are short overview summaries of the Hanford operating facility group of EU:

- WESF (CP-OP-3)
- ERDF (CP-OP-6)
- K-West Basin Sludge (RC-OP-1)
- CWC (CP-OP-1)

Waste Encapsulation and Storage Facility

The WESF (Figure 3-52) was designed and constructed to process, encapsulate, and store Sr-90 and Cs-137 separated from wastes generated during the chemical processing of used fuel on the Hanford Site. Hanford produced 1577 cesium capsules and 640 strontium capsules for a total of 2217 capsules. However, during the years since their production some capsules have been removed from WESF and sent elsewhere for a range of purposes under a range of conditions. The capsules that have been returned are in storage currently (1959 total capsules). A total of 187 capsules were not returned to WESF and were deconstructed and placed into glass logs, and the remaining 71 capsules were destructively examined.

Figure 3-52. Waste Encapsulation Storage Facility.

The construction of WESF lasted from 1971 to 1973. Cesium processing was shut down in October 1983 and strontium processing was shut down in January 1985. Final overall process shutdown was accomplished in September 1985.

Current Status: Current WESF operations consist of essentially one task: safely storing cesium and strontium capsules within a series of interconnected pools within the WESF building. The current scope of the WESF mission is limited to facility maintenance activities: inspection, decontamination, and movement of capsules; and storage and surveillance of capsules.

Contaminants: Table 3-22 provides the currently estimated primary radiological contaminates at WESF (in curies). The majority of radioactive material (cesium chloride and strontium fluoride) at WESF is confined in doubly encapsulated stainless steel capsules. WESF currently stores 1335 cesium capsules, 23 of which are single-contained Type W overpack capsules, and 601 strontium capsules in pool cells located in the 225-B building. The radioactivity level contained within the Cs capsules is approximately 68 MCi (34 MCi of Cs-137 and 34 MCi of Ba-137m). The radioactivity level contained within the Sr capsules is approximately 30 MCi (15 MCi of Sr-90 and 15 MCi of Y-90). Contamination within the hot cells and connecting ventilation is approximately 300 kCi. The hot cells A through F (G is clean) contain around 55 kCi of Cs and 43 kCi of Sr. The connecting ventilation and ductwork to the hot cells contain around 2,800 Ci of Cs and 107,500 Ci of Sr.

Table 3-22. WESF (CP-OP-3) radionuclide inventory.

Radionuclides	Group	Cs/Sr Capsules, Ci	Hot Cells, Ducts, Ci
Americium-241	D	NP	NP
Carbon-14	A	NP	NP
Chlorine-36	A	NP	NP
Cobalt-60	C	NP	NP
Cesium-137	D	34,000,000	57,000
Europium-152	D	NP	NP
Europium-154	D	NP	NP
Tritium	C	NP	NP
Iodine-129	A	NP	NP
Nickel-59	D	NP	NP
Nickel-63	D	NP	NP
Plutonium-Total Rad[(a)]	D	NP	NP
Strontium-90	B	15,000,000	150,000
Technetium-99	A	NP	NP
Uranium- Total Rad[(b)]	B	NP	NP

a. Sum of plutonium isotopes 238, 239, 240, 241, and 242
b. Sum of uranium isotopes 232, 233, 234, 235, 236, and 238

Primary Risks: The primary current risk is that the safe containment of the cesium chloride and strontium fluoride within the capsules could be compromised under design basis accident and beyond design basis accident conditions if the pool cells were to lose water. The second most potentially significant event that could impact human health is a hydrogen explosion in hot cell G and the connecting K3 duct that releases contamination from the hot cells and connecting contaminated ventilation ducts, thereby releasing contaminants that become airborne and also cause external gamma radiation doses.

Final Cleanup and Disposition: Future plans are divided into two phases. The first phase is to upgrade the ventilation system and stabilize the hot cell contaminants. The long-term, tentative plan is to remove the Cs and Sr capsules from the pools by packaging the capsules into dry storage overpacks and storing them on the Hanford Site. This movement into dry storage will allow the adjacent building (B-Plant) to proceed with D&D plans tied to a TPA milestone.

Environmental Restoration and Disposal Facility (CP-OP-6)

The ERDF (Figure 3-53) is composite-lined waste disposal facility located on the Central Plateau area of the Hanford Site between the 200 West and 200 East Areas.[85] ERDF was constructed to permanently dispose of all wastes generated by remediation of Hanford Site past-practice and CERCLA waste sites in an environmentally protective manner. Waste disposal at ERDF predominantly consists of high-volume slightly contaminated soils and debris delivered by truck from remediation sites that are spreading in ERDF cells and compacted to minimize void space and limit future waste volume subsidence. However, other demolition wastes are also placed in ERDF, and when necessary, wastes are grouted to fill void spaces that could lead to compression and settlement over the long term.

Figure 3-53. Aerial view of ERDF.

ERDF is lined with a state-of-the-art double composite barrier system that has been shown to transmit virtually no leakage. The final cover proposed for ERDF also employs a composite barrier and an overlying water balance cover that will result in de minimis percolation. This high level of containment is complemented by a thick vadose zone (geologic zone above the water table) that is 80 to 100 m thick and provides the greatest possible distance to the water table compared to other Hanford waste sites. In addition, because ERDF is located in the middle of the Central Plateau, ERDF has largest distance practical for contaminant migration to the Columbia River from the Hanford Site.

Current Status: ERDF was constructed in a modular fashion so that additional disposal space can be built as needed. The first eight disposal cells were built in pairs located at the west end of the site. Each cell is approximately 152 m by 152 m at the bottom, approximately 21 m deep, and has a 3:1 (horizontal to vertical ratio) side slope that extends 64 m horizontally from the base of the cells. The latest cell construction toward the east (supercells 9 and 10) combines the cell pairings into larger cells, approximately the same size as each two-cell pair. Cells 1 through 4 have been filled, cells 5 through 8 are nearly filled, and supercells 9 and 10 are receiving waste. As of July 2013, approximately 13.6 million metric tons of waste has been disposed at ERDF since the facility started operations in July 1996 (an average of 800,000 metric tons per year).

Contaminants: Table 3-23 includes the currently estimated primary radiological contaminants at ERDF (in curies) and total uranium (in kg).

[85] ERDF is constructed to RCRA sub-title C design standards but is permitted under CERCLA as a corrective action management unit.

Table 3-23. ERDF (CP-OP-6) radionuclide inventory (2014) and projected at closure.

Radionuclides	Group	Curies (Ci) - 2014	Curies (Ci) – at closure
Americium-241	D	540	
Carbon-14	A	1,900	< 45,000
Chlorine-36	A	NP	< 300
Cobalt-60	C	5400	< 30,000
Cesium-137	D	15,000	< 2,000,000
Europium-152	D	4,800	
Europium-154	D	1,400	
Tritium	C	7,800	< 160,000
Iodine-129	A	0.019	
Nickel-59	D	190	
Nickel-63	D	15,000	< 110,000
Plutonium-Total Rad[(a)]	D	5,500	
Strontium-90	B	11,000	< 1,200,000
Technetium-99	A	21	< 860
Uranium- Total	B	200,000 kg	< 870,000 kg

a. Sum of plutonium isotopes 238, 239, 240, 241, and 242

Primary Risks: The primary risks at ERDF are associated with radiation exposure through worker contact with waste of much higher activity than expected when unloading trucks and placing waste in the disposal cell, and physical accidents associated with trucks and machinery within or entering/exiting the ERDF area.

Final Cleanup and Disposition: ERDF is intended for permanent disposal and isolation of wastes. No cleanup approaches are needed after the facility is filled and the final cover is installed. The only “clean up” activity is installation of the final cover.

K-West Basin Sludge (RC-OP-1)

Figure 3-54. K-West Basin sludge.

The K-East and K-West Basins (Figure 3-54) were constructed in the early 1950s to support K-Reactor operations. After irradiation, fuel was pushed from the horizontal fuel channels in the reactors into the discharge chutes and then sorted, canned, and queued underwater in the basins. This allowed for decay of radionuclides with short half-lives prior to reprocessing the fuel at either the 202-S REDOX or the 202-A PUREX facilities for plutonium and uranium recovery. The basins originally had a 20-year design life and were deactivated when the K-West and K-East Reactors were shut down. The K-West Basin was reactivated later as supplemental storage for irradiated N Reactor fuel. The basin superstructures are not sealed from the environment, which allowed sand, dirt, and organic material (weeds, bugs, etc.) to be deposited in the basins.

Current Status and Interim Cleanup: The present condition of the K-West Basin Sludge Project is safe storage of K-West and K-East sludge in engineered containers in the K-West Basin. Typical operations in the basin include the operation of the water treatment system; management of fuel fragments; retrieval, storage, movement and containerization of sludge; sorting and removal of debris (e.g., dust and sand); removal and disposition of equipment no longer in use; handling and interim storage of waste; and the construction of the K-West Basin Annex, which will house the Engineered Container Removal and Transfer System (ECRTS), the next phase of the K-West Basin Sludge Project.

Contaminants: The sludge in the K-West Basin is classified as remote handled TRU. This waste consists primarily of sludge retrieved from the K-East Basin and contains aluminum cladding shards, oxidized fuel, and metal fuel particles as well as windblown sand and environmental debris, spalled concrete from the basin walls, iron and aluminum corrosion products, and ion exchange resin beads. Sludge retrieved from the K-West Basin floor and the pit sludge stream prior to the retrieval and packaging of spent nuclear fuel for its removal, iron and aluminum corrosion products, flexible graphite [GrafoilTM1], limited amounts of uranium oxides, and uranium fuel particles.

Primary Risks: The primary or highest risks to workers and co-located persons at the K Basins during the current phase are (1) deflagration of accumulated hydrogen that has been generated through radiolysis and fuel corrosion accumulating in the headspace of the annular filter vessel while the Integrated Water Treatment System is out of service for an extended period (a leak allows air to enter, and a deflagration results); (2) industrial accidents that might cause a fire. The hazardous operations study for the ECRTS phase identified 13 events that are anticipated and have High consequences, including uncontrolled releases from initiating events.

Final Cleanup and Disposition: Cleanup of the K-West Basin Sludge Project involves closing several facilities: K-West Basin, K Basin Modified Annex, T Plant, and the future sludge treatment system facility.

In terms of the K-West Basin, the removal sludge is integral to the D&D process. When the sludge has been removed from the K-West Basin, the K-East and K-West Basins will continue with D&D procedures including the K Basin Modified Annex.

At the conclusion of the ECRTS activities, the sludge will be stored in T Plant in the sludge transportation and storage containers. These will eventually be removed from T Plant for Phase 2 of sludge processing, from which point the treated and packaged sludge will be stored and eventually shipped to WIPP. The emptied remaining sludge transportation and storage containers will be disposed of at a location TBD.

Central Waste Complex (CP-OP-1)

Current Status and Interim Cleanup: The CWC (Figure 3-55) provides storage, inspection (as required), limited processing, and staging for waste containers that are awaiting waste processing operations or disposal at other waste management facilities. The CWC receives waste from both onsite and offsite generators. Four types of waste are processed or stored at the CWC: low-level radioactive waste; mixed, low-level radioactive waste, TRU waste; and TRU mixed waste. The CWC can receive, as necessary, unvented containers from retrieval operations for staging prior to venting (for example, at T Plant).

Personnel receive and inspect waste packages at the Waste Receiving and Staging Area. In accordance with all applicable procedures, transport offloading operations are performed using handtrucks, forklifts, or cranes operated by qualified personnel. Packages are transferred from the offloading area to the appropriate CWC storage building or other storage area. Alternatively, waste packages may be received, inspected, and unloaded at the specific CWC building or storage area where the waste would be stored. Typical stored waste packages include 208-liter (55-gallon) drums; 322-liter (85-gallon) overpacks; and fiberglass-reinforced plywood, plywood, or metal boxes. Atypical packages include, but are not limited to, radioisotopic thermoelectric generators, vault tank filter assemblies, blanked-off gloveboxes, overpacks, and pipe overpacks in 208-liter (55-gallon) drums.

Figure 3-55. Central Waste Complex.

Contaminants: In the Master Documented Safety Analysis for Solid Waste Operations Complex (HNF-14741), the bounding drum and array analysis assumptions of the DOE-STD-3009-2014 and SARAH (HNF-8739) are used. In that bounding drum, the radionuclides are assumed to be Pu-238, Pu-239 (more than 80% by activity), Pu-240, Pu-241, and Pu-242, along with the Pu decay product Am-241. Debris from D&D and operational wastes, notably from PNNL and tank farms, WRAP, Low Level Burial Grounds, and T Plant also contain fission products (Cs-137, Sr-90). However, majority of presently stored waste is classified as remote handled or contact handled TRU. The waste also contains some RCRA-classified dangerous waste as well as pyrophoric materials including sodium.

Primary Risks: The primary hazards at the CWC are radiological and chemical hazards to the workers, both remediation and co-located, as well as the environment, including near-surface soils and groundwater. Several waste containers at the facility have been determined to have leaks or have the potential to develop leaks in the near future. Leaking waste containers are the primary source of the hazards described above. Along with potential leaks, there is an exposure pathway for some radiation to workers performing daily activities around the waste. Accident scenarios with High consequences to co-located workers had an unlikely frequency. These included two fire scenarios (small inside fire, small outside fire) and a seismic building collapse (design basis seismic event).

Final Cleanup and Disposition: Addendum H of the RCRA Permit for the CWC outlines closure activities as follows: (1) remove waste inventory, (2) decontaminate structural surfaces and equipment, (3) analyze decontamination waste to determine proper methods of treatment/disposal, and (4) dispose of decontamination waste based on results of waste analysis. The cleanup phase is expected to take 180 days. The DSA states that D&D and cleanup activities have yet to be planned. Future uses would await post-D&D condition assessment; however, CWC is located on the Central Plateau, an area presently scheduled for continued federal custody.

COMPARISON OF RADIOLOGICAL INVENTORIES, CONTAINMENT, AND POTENTIAL IMPACTS

Table 3-24 summarizes the radiological inventories associated with each operating facility EU. Table 3-25 compares the estimated unmitigated doses to a co-located person from postulated event scenarios.

Table 3-24. Radiological inventories, form, and barriers to release for operating facility EUs.

Operating Facility EU Name (Barrier Type) [Contaminant: Fixed (F), Dispersible (D), Mobile(M)]	Cs-137 [Ci]	Sr-90 [Ci]	Tc-99 [Ci]	H-3 [Ci]	Pu (total) [Ci]	U (total) [Ci]	Sum of all other radio-nuclides [Ci]	Isotope Names
KW Sludge Treatment Project (b) [F and D]	13,000	17,000	9		15,000	17		
Central Waste Complex (e) [F and D]					53,000			
WESF (Cs/Sr capsules) (b) [F and D]	34,000,000	15,000,000					49,000,000	Ba-137m, Y-90
WESF (Hot Cells, Ducts) (b) [F and D]	57,000	150,000						
ERDF (CY2014) (d) [F]	15,000	11,000	21	7,800	5,500	200,000 kg	15,000	C-14, Co-60, Ni-63
ERDF (Closure) (d) [F]	<2,000,000	<1,200,000	<860	<160,000		<870,000 kg	<190,000	C-14, Co-60, Ni-63

Notes: If there is a blank cell, then values are not available. Barrier type indicated by letter within parentheses after operating facility EU name: (a) None, (b) Bldg. & Engr. System, (c) Soil Cover & Veg., (d) Liner, (e) Packaging, (f) Packaging post-2004, (g) Tank Constr. (Single Shell Tank), (h) Tank Constr. (Double Shell Tank), (i) Remedial Process in Place.

Table 3-25. Unmitigated radiological dose (rem) impacts to co-located person and public.

Accident/Event Scenario	CWC		K Basins Sludge		WESF[(a)]		ERDF	
	Co-located Person	Public	Co-located Person	Public	Co-located Person	Public	Co-located Person	Public
Seismic (0.2g)	285	0.75	NA	NA	21	0.006	NA	NA
Loss of Water	NA	NA	0.0044	0.0002	277	0.21	NA	NA
Water Release (Spray)	NA	NA	0.68	0.033	3.1	0.0028	NA	NA
Waste Handling Accidents	53.5	0.05	13.4	1.23	NA	NA	<1	NA
Fires	770	0.73	5.7	0.28	7.8	0.006	NA	NA
Explosions	NA	NA	3.2	0.15	102	0.031	NA	NA

a. The beyond design basis event earthquake is not evaluated in the DSA, but a separate analysis was performed, titled *WESF Beyond Design Basis Accident Conditions and Plans* (CHPRC-02047, Rev. 0). The unmitigated doses were estimated to be 380 rem for the co-located person (380 rem) and 0.24 rem for a member of the public. Note that the design basis earthquake cannot cause the loss of pool cell water by itself; a combination of operational (human-caused) errors and conditions is required that is, in effect, a ***beyond*** design basis event. The difference is that the design basis earthquake only releases material from the hot cells and connecting ventilation system and the beyond design basis event earthquake releases material from the capsules stored in the pool cells at WESF.

Table 3-26. Unmitigated radiological risk rating impacts to co-located person and public.

Accident/Event Scenario	CWC		K Basins Sludge		WESF		ERDF	
	Co-located Person	Public	Co-located Person	Public	Co-located Person	Public	Co-located Person	Public
Seismic (0.2g)	High	Low	NA	NA	Medium	ND	NA	NA
Loss of Water	NA	NA	ND	ND	High	Low	NA	NA
Water Release (Spray)	NA	NA	Low	ND	Low	ND	NA	NA
Waste Handling Accidents	High	ND	Medium	Medium	NA	NA	Low	NA
Fires	High	Low	Medium	Low	Medium	ND	NA	NA
Explosions	NA	NA	Low	Low	High	ND	NA	NA

DEPENDENCE ON OTHER FACILITIES AND CONSIDERATIONS FOR TIMING OF THE CLEANUP ACTIONS

The K-West Basin Sludge Treatment Project has direct ties to several other facilities and processes, including the D&D of the K-West Reactor facility, and an interim period of operations at T Plant. The project also involves a future facility to treat the sludge, the location of which has yet to be determined.

The K-West Basin Sludge Treatment Project is multi-phase, and delay would have different impacts, depending on when it occurred. These will be addressed in chronological order:

1. *Delay in removing the sludge from the K-West Basin* – The sludge stored in engineered containers at the K-West Basin is the last significant quantity of nuclear material in the K Area. Transportation of this material out of the K Area to T Plant is on the critical path to enable completion of environmental restoration activities on the K Area.
2. *Delay in design and construction of the Phase 2 Sludge Treatment System* – T Plant is intended to be only an interim stop for the sludge material from K Basins. CH2M Hill Plateau Remediation Company (CHPRC) has completed alternatives analysis and recommended a warm water oxidation system to stabilize the remaining uranium in the sludge (along with some limited development of backup/enhancement technologies). The DOE Richland Operations Office has approved this path forward and CHPRC has developed a preliminary technology development plan to mature the technologies to support design of the Phase 2 treatment system. Delays in design and construction of the Phase 2 treatment system, or the technology development program to support it, would result in the sludge being stored for longer than currently planned in T Plant. Such a delay could make retrieval of the sludge for processing problematic. (Note: The aging properties of the sludge materials while in storage at T Plant is a line of inquiry in the technology development planning.)

The CWC has ties to WRAP, the Low Level Burial Grounds, and T Plant. For the CWC there are two foreseeable delays: (1) overall delays that that result in the risks and hazards of the operating facility continuing as they are, without moving into a cleanup phase; (2) problems with WIPP or other long-term storage that would require the CWC to remain available to store TRU for an extended period, which would result in the continuation of operating risks and hazards.

WESF is a multi-phase project and delay would have different impacts, depending on when it occurred. These impacts are addressed below:

4. *Delay in completion of the WESF Stabilization and Ventilation Modification Project* – This will result in a longer period in which (1) a substantial (~300,000 Ci) source term is available for potential dispersion during a beyond design basis event, and (2) the ventilation system at WESF is not in compliance with requirement for confinement ventilation systems, thus increasing the potential for an inadequately filtered release from WESF.
5. *Delay in removal of the Cs and Sr capsules* - The Waste Management EIS mentions two potential options for addressing the HLW present in the capsules at WESF: (1) designing and building a facility that would be an adjunct to the WTP, which would allow the capsules to be opened, prepared, and fed to the HLW vitrification melter; and (2) more recently, due to the age of WESF and schedule challenges at WTP, the retrieval of the capsules from the storage pool in WESF and placement in dry cask storage, similar to commercial spent nuclear fuel, to await disposition in a geologic repository. Both options require the design and construction of new facilities. Delay in either option results in extended storage of the capsules in the 40-year-old WESF.
6. *Continued need to perform surveillance and maintenance on WESF systems and Cs and Sr capsules*. – The timeliness of moving capsules out of WESF does impact the progress of the D&D timeline of B Plant and milestone TPA M-092-05 (Ecology, EPA, and DOE 1998).

ERDF provides the end-state from other projects on site, and the activities at ERDF can scale up or down depending on the level of activity at the projects that supply waste. ERDF will continue to operate until all other projects at Hanford are complete, and then will undergo final closure as the last active construction-related project at Hanford.

CLARIFICATION OF STAGES FOR EACH FACILITY

The Sludge Treatment Project consists of three phases, two of which are discussed in this report: (1) storage and transfer of sludge from K-West Basin to T Plant and (2) treatment of sludge and shipment for disposal. Each phase has several stages. Phase 1 stages include (1) storage of sludge in K-West Basin, (2) the Engineered Container Removal and Transfer System (ECRTS); and (3) storage of sludge in T Plant. Phase 2 stages include sludge treatment. A third phase, processing of knock out pot material, has been completed and will not be discussed in this review.

The CWC does not have several operational phases; however, the D&D processes and ultimate disposition of the land will involve processes that are yet to be determined.

Future plans for WESF are divided into two phases. The first phase is to upgrade the ventilation system and stabilize the hot cell contaminants. The long-term, tentative plan is to remove the Cs and Sr capsules from the pools by packaging the capsules into dry storage overpacks and storing them on the Hanford Site. This movement into dry storage will allow the adjacent building (B Plant) to proceed with D&D plans that are tied to a Tri-Party Agreement milestone.

ERDF has three stages: filling, final closure, and long-term surveillance. ERDF is currently in the filling stage. During filling, additional cells are constructed to support disposal at the Hanford Site. Ten cells currently exist, with expansion possible for two more cells. However, given the available space surrounding ERDF, much more expansion beyond 12 cells could be provided. New cells are added as existing cells are filled and demand exists for more disposal volume. Once filling is complete, the final closure stage will be undertaken, followed by long-term surveillance.

COMPARATIVE SUMMARY

Although DOE and its contractors employ active and passive safety class and safety significant systems and controls to mitigate the potential adverse impacts of virtually all but some natural phenomena events, identifying differences between the four operating facilities EUs requires consideration of the unlikely but possible failure of one or more of these controls and thus the unmitigated radiological dose exposures to onsite and offsite persons as represented by a hypothetical individual located 100 m from the EU boundary (co-located person) and another individual located at Hanford Site controlled access boundary (public or MOI). As revealed by the comparison of these four operating facility sites, human health risks are driven by the following factors:

- Quantity (in Ci) of the contaminant
- Form of the contaminant (fixed, dispersible, mobile)
- Whether cleanup work is going on that could cause accidents
- For the public or MOI, the distance between the initiating event and the Hanford boundary

The WESF operating facility contains the highest level of radioactivity contained within capsules but it is beyond extremely unlikely that an initiating event would cause a release from the capsules. The integrity of the capsules is tested regularly and the structural analysis of the pool cell concrete has estimated that even with a very conservative estimate of 50% concrete strength degradation, the pool cell structure would still survive a design basis earthquake.

By far, the highest unmitigated dose to the co-located person (770 rem) is associated with a fire in the CWC. The second highest unmitigated dose to the co-located person (285 rem) is associated with the design basis event for the CWC. The third highest unmitigated dose to the co-located person (277 rem) is associated with the loss of all pool cell water resulting from a combination of external events and human response failures at WESF.

The highest unmitigated dose to a member of the public (1.23 rem) is associated with a waste handling accident at the K Basins Sludge facility. The second highest unmitigated dose to a member of the public (0.75 rem) is associated with a design basis earthquake affecting the CWC. A fire at the CWC would result with the third highest unmitigated dose to the member of the public (0.73 rem). Interestingly, WESF unmitigated doses to the hypothetical member of the public at Hanford's site boundary are much lower for other operating facility EUs.

The only potential hazard to the co-located person or the public at the ERDF site is associated with a waste handling accident (radiological or non-radiological, although the former is dominant). Such accidents are considered as anticipated but unlikely and would have a Low consequence to the co-located person 100 m from the ERDF boundary.

CHAPTER 4. RESULTS FROM REVIEW FOR EACH RECEPTOR CATEGORY

4.1. INVENTORIES

Figure 4-1 through Figure 4-4 summarize the inventories of selected radionuclides and chemical contaminants for comparison across EUs. On a total curie basis, Cs-137 and Sr-90 dominate the total inventory of radionuclides across all EUs evaluated. The largest inventories of Cs-139 and Sr-90 are in the WESF capsules, 200 East DSTs, and the S-SX and A-AX tank waste and farm EUs (Figure 4-1). The sum of all other radionuclides for WESF (representing decay products) are of the same order of magnitude as the inventory in the Cs-137 and Sr-90 capsules. However, the inventory of all radionuclides in the Energy Northwest Columbia Generating Station, which are present in current and used fuel (including fission products), is much greater than the Hanford inventories examined. The Cs-137 and Sr-90 inventory in the soils underlying Building 324 is the dominant contributor to the overall Building 324 EU and PUREX Tunnel #2 is the dominant contributor to the overall PUREX EU.

Pu (total) is primarily in the CWC (packaged wastes), tank wastes, PUREX (distributed between the 202-A Building and the tunnels) and the Pu-contaminated waste sites EUs (Figure 4-2). U (total) is primarily associated with the tank waste and farms EUs, with smaller amounts present in PUREX and anticipated to be in ERDF at the time of closure (based on permit specifications).

Tc-99 and I-129 are primarily associated with the tank waste and farms EUs and legacy disposal practices at BC Cribs and Trenches, and also are anticipated to be in ERDF at the time of closure (Figure 4-3).

For chemical contaminants (Figure 4-4), substantial inventories of total chromium are associated with the tank waste and farm EUs, BC Cribs and Trenches, and similar inventories associated with the subsurface at 200 East and 200 West Areas. Carbon tetrachloride is primarily associated with legacy disposal practices that originated in the Pu-contaminated waste sites but then migrated in the groundwater in the 200 West Area. Significant quantities of TCE are only present in one of the River Corridor EUs.

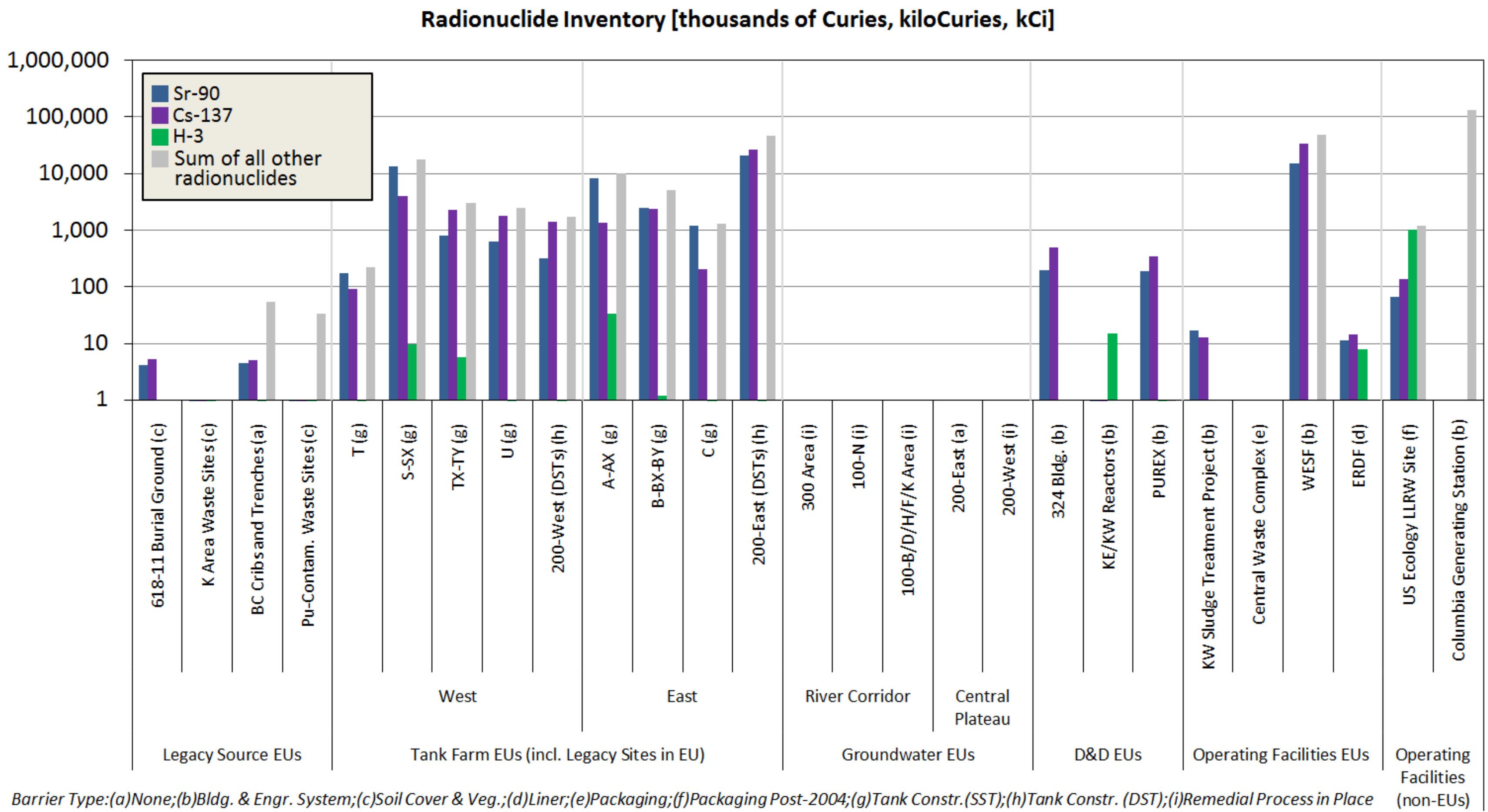

Figure 4-1. Radionuclide inventories – Sr-90, Cs-137, tritium (H-3): Comparison of inventories for each EU.

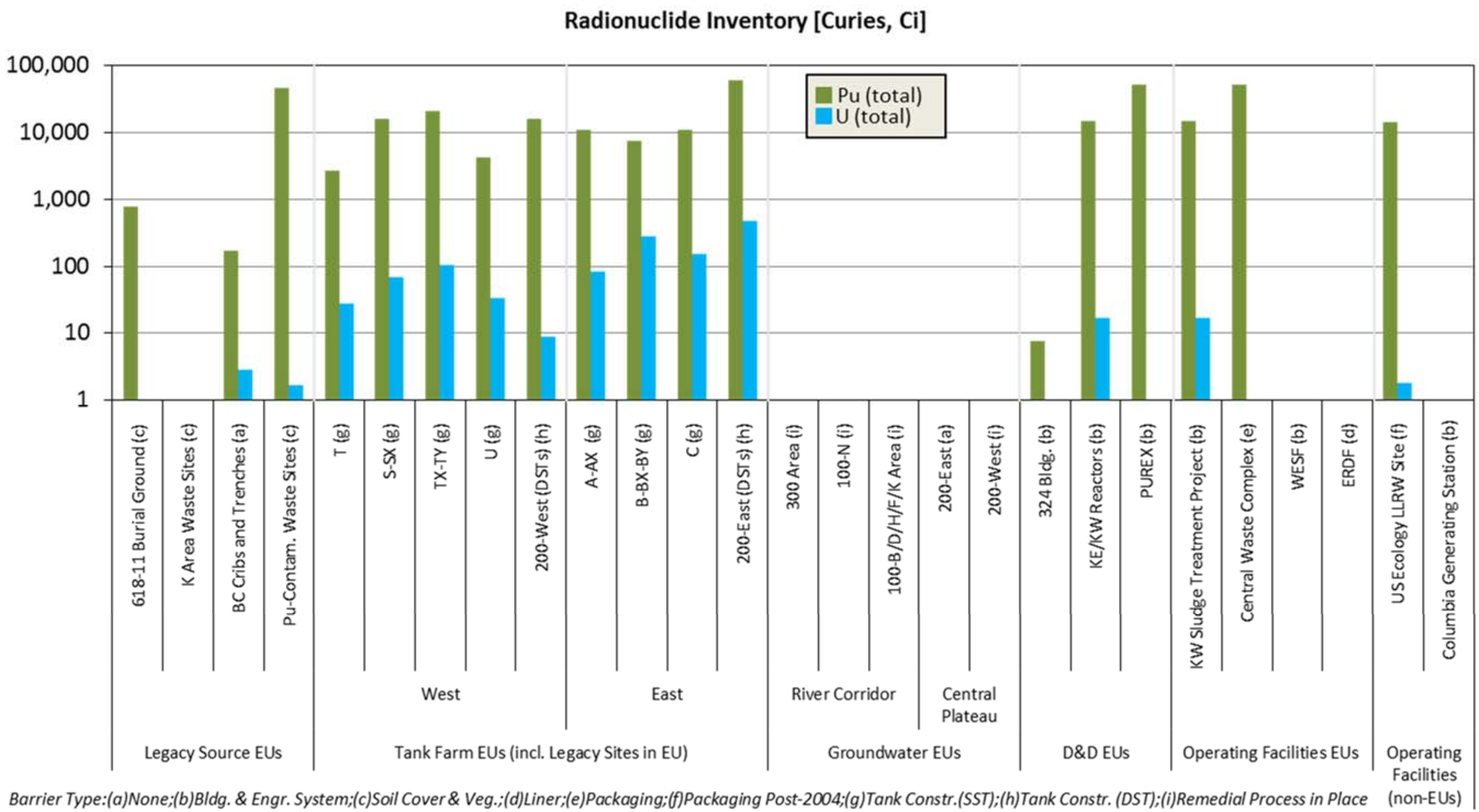

Figure 4-2. Radionuclide inventories – Pu (total) and U (total): Comparison of inventories for each EU.

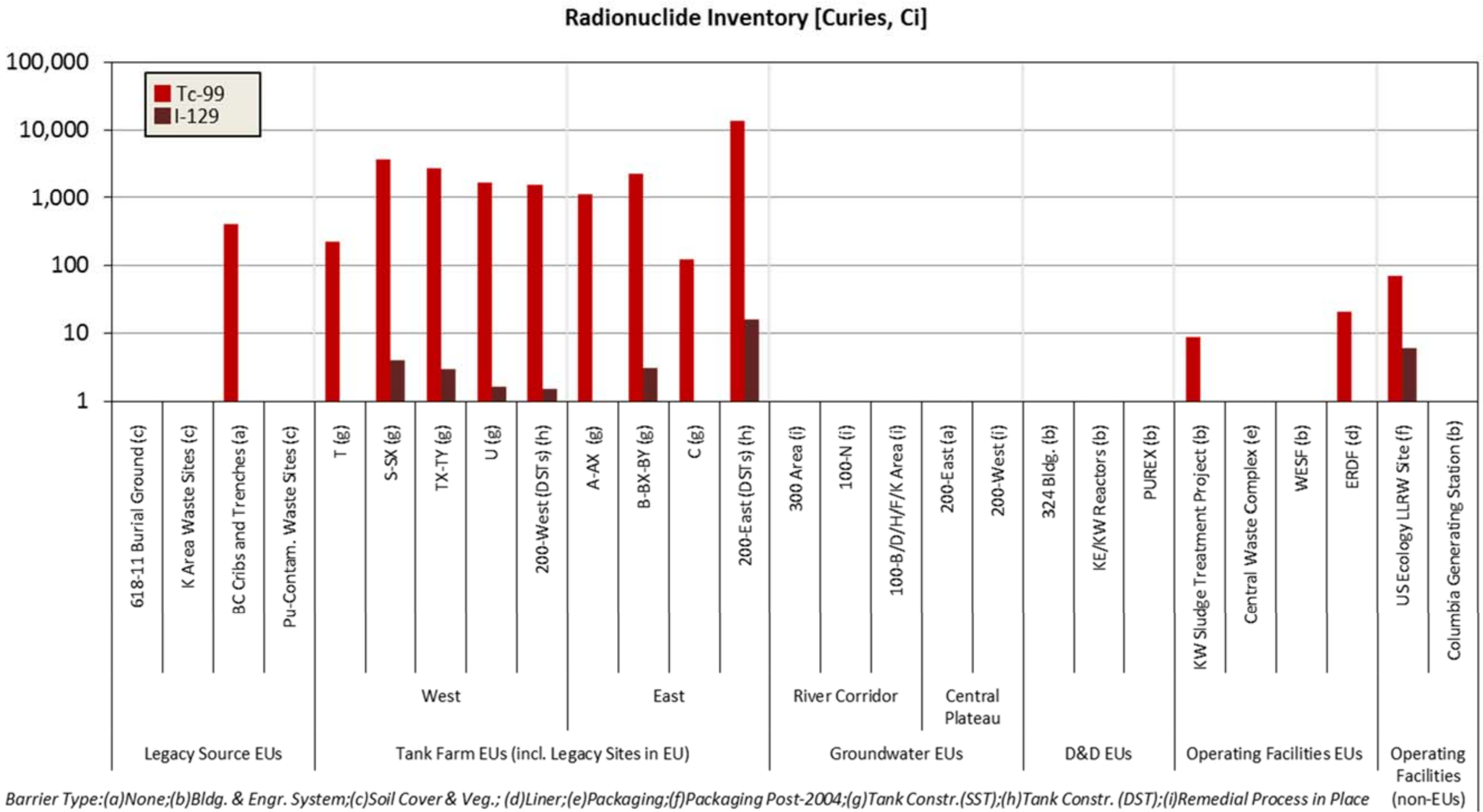

Figure 4-3. Radionuclide inventories – Tc-99 and I-129: Comparison of inventories for each EU.

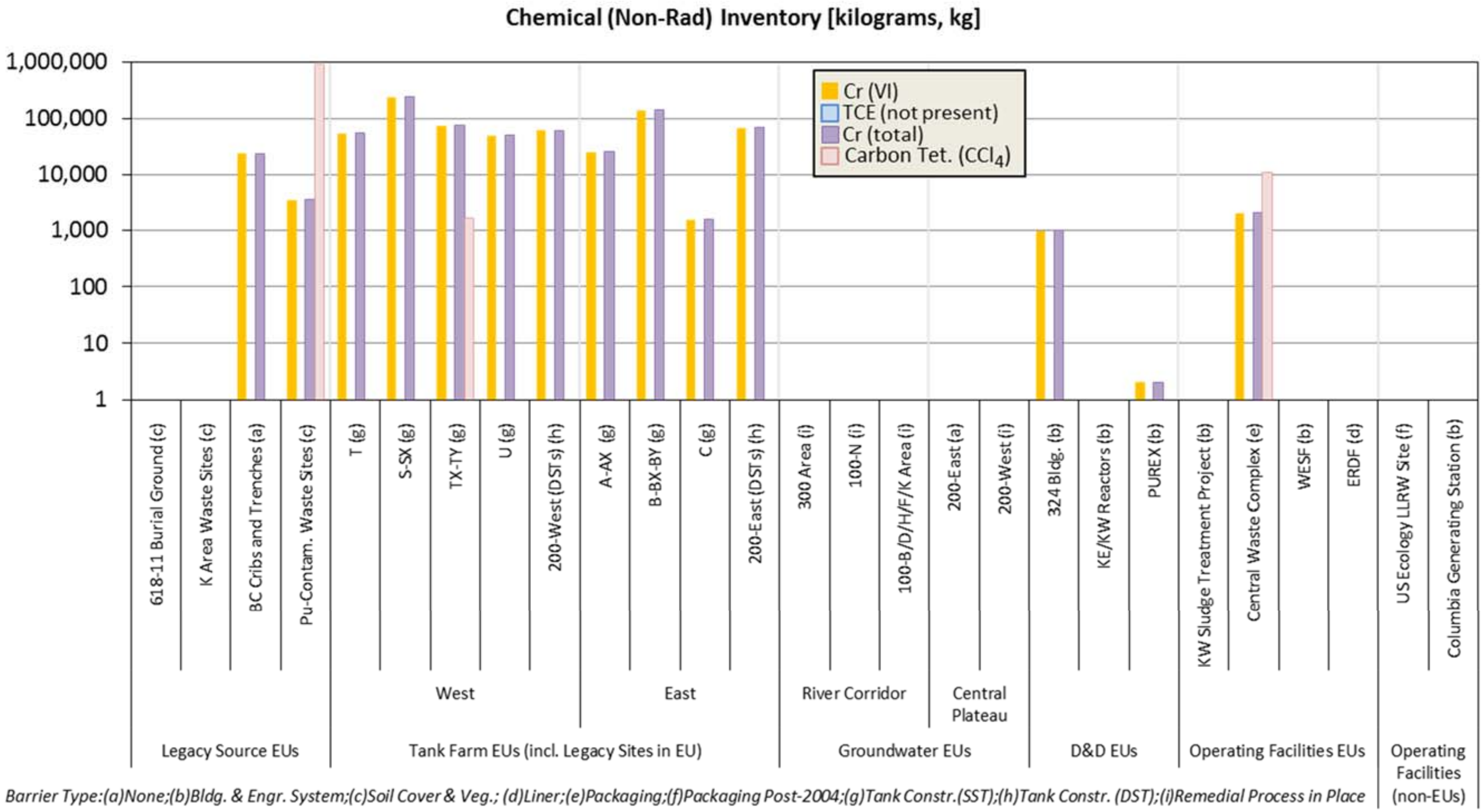

Figure 4-4. Chemical inventories – Cr(VI), Cr(total), TCE, and carbon tetrachloride: Comparison of inventories for each EU.

4.2. HUMAN HEALTH (MITIGATED AND UNMITIGATED)

Figure 4-5 compares estimated unmitigated doses to the co-located person for the highest dose scenarios associated with each EU. Significant potential doses from operational accidents are associated with the 324 Building, the CWC, WESF ducts, PUREX, and 618-11 Burial Grounds. Estimated doses from natural phenomenon and external events are as a consequence of a severe seismic, fire, or loss of active controls (e.g., ventilation or cooling water) associated with an extended period of loss of power. Further discussion of each of these scenarios can be found in the related appendices that provide the Evaluation Template for each facility.

Table 4-1 through Table 4-9 provide the summary ratings for each EU with respect to human health. Ratings for facility workers are first by Type 1 (acute threats from sudden events or nuclear safety accident scenarios), Type 2 (acute threats from sudden events or nuclear safety accident scenarios), and Type 3 (threats from industrial accidents (heat stress, physical trauma, etc.)) events and accidents that threaten worker safety. Review of these ratings clearly indicates worker safety threats are predominantly from the cleanup activities, although some worker safety threats are present from maintenance and monitoring activities both before and after cleanup. Furthermore, nuclear safety event scenarios are the most important differentiator between ratings of specific EUs, followed by the type of EU (e.g., legacy sites vs. D4 EUs).

For threats to public health, operational accidents at the legacy waste site 618-11 and the D4 EU Building 324 are the only cases where the Risk Review Project ratings are higher than low.

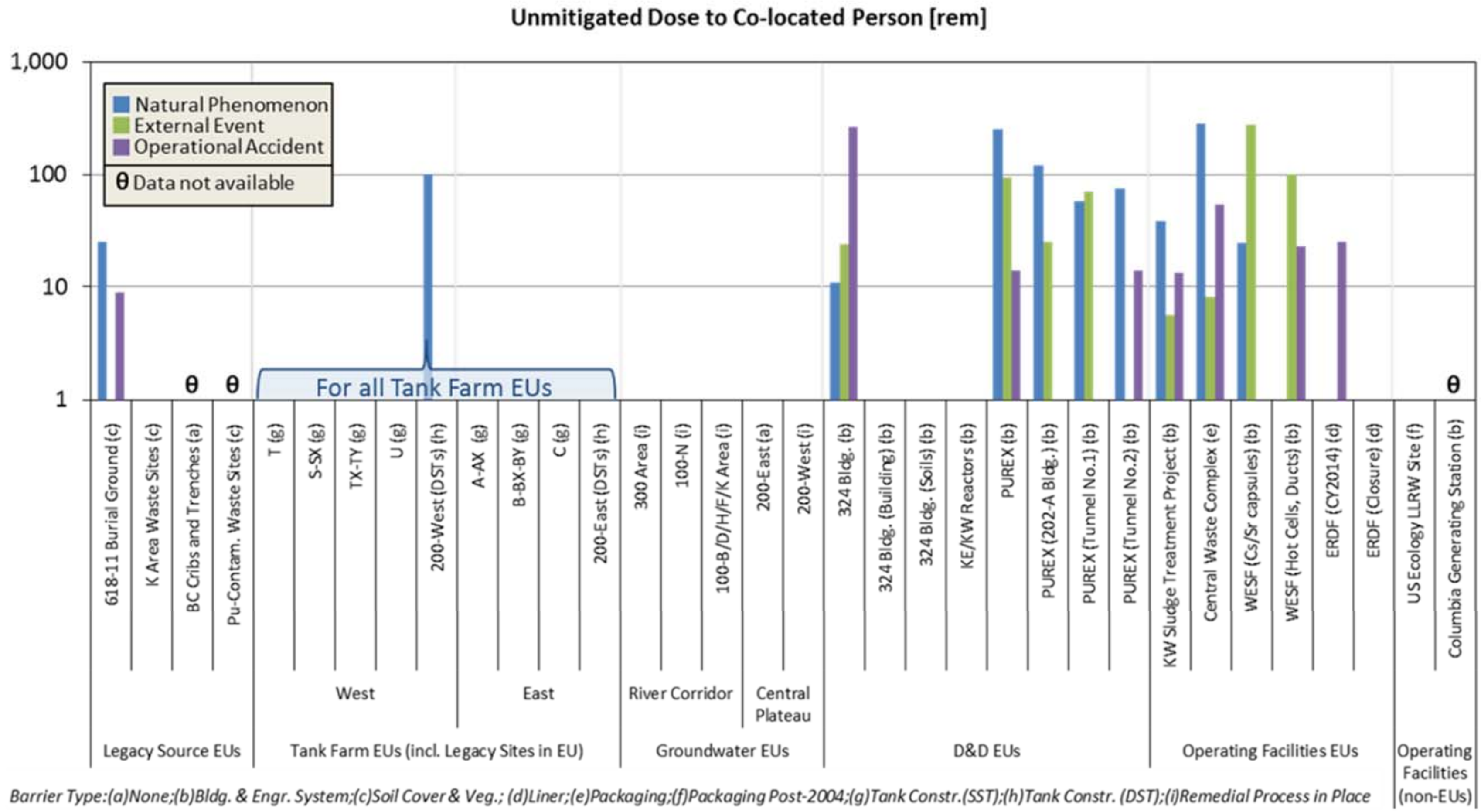

Figure 4-5. Unmitigated dose to co-located person (rem): Comparison of event types and dose estimates for each EU.

Table 4-1. Summary of Risk Review Project ratings: facility worker Type 1, 2, and 3 worker safety events and accidents. (See symbology legend p. xxv)

EU Name	EU #	Type 1 - Acute threats from sudden events or nuclear safety accident scenarios	Type 2 - Subacute or chronic threats from occupational exposures to chemicals or radiation	Type 3 - Threats from industrial accidents (heat stress, physical trauma, etc.)
Legacy Sites				
618-11 Burial Grounds	RC-LS-1	Low to Med	ND to Low	Low
K –Area Waste Sites	RC-LS-2	Low	ND to Low	Low
BC Cribs and Trenches	CP-LS-1	Med	ND to Low	Low to Med
Pu-Contaminated Waste Sites	CP-LS-2	Low to Med	ND to Low	Low to Med
Tank Farms				
T Tank Farm	CP-TF-1	High	Low to Med	Low to Med
S-SX Tank Farms	CP-TF-2	High	Low to Med	Low to Med
TX-TY Tank Farms	CP-TF-3	High	Low to Med	Low to Med
U Tank Farm	CP-TF-4	High	Low to Med	Low to Med
A-AX Tank Farms	CP-TF-5	High	Low to Med	Low to Med
B-BX-BY Tank Farms	CP-TF-6	High	Low to Med	Low to Med
C Tank Farms	CP-TF-7	High	Low to Med	Low to Med
200 East (DSTs)	CP-TF-8	High	Low to Med	Low to Med
200 West (DSTs)	CP-TF-9	High	Low to Med	Low to Med
Groundwater				
300 Area GW Plumes	RC-GW-1	ND to Low	ND to Low	Low
100-N GW Plumes	RC-GW-2	ND to Low	ND to Low	Low
00-B/D/H/F/K Area GW Plumes	RC-GW-3	ND	ND to Low	Low
200 East Groundwater	CP-GW-1	ND to Low	ND to Low	Low
200 West Groundwater	CP-GW-2	ND to Low	ND to Low	Low
D&D				
324 Building	RC-DD-1	Med to High	ND to Low	Low to Med
KE/KW Reactors	RC-DD-1	ND to Low	ND	Med to High
PUREX	CP-DD-1	Med to High	Low to Med	Low to Med
Operating Facilities				

EU Name	EU #	Type 1 - Acute threats from sudden events or nuclear safety accident scenarios	Type 2 - Subacute or chronic threats from occupational exposures to chemicals or radiation	Type 3 - Threats from industrial accidents (heat stress, physical trauma, etc.)
KW Basin Sludge	RC-OP-1	Med to High	ND to Low	Low to Med
CWC	CP-OP-1	Med to High	ND to Low	ND to Low
WESF	CP-OP-3	Med to High	ND to Low	Low to Med
ERDF	CP-OP-6	Low to Med	Low to Med	Low to Med

Table 4-2. Summary of Risk Review Project ratings: human health: facility worker. (See symbology legend p. xxv)

EU Name	EU #	Current	Active Cleanup	Near-Term Post-Cleanup
Legacy Sites				
618-11 Burial Grounds	RC-LS-1	ND	Med[a]	Low
K-Area Waste Sites	RC-LS-2	Low	Low	ND to Low
BC Cribs and Trenches	CP-LS-1	Low	Low to High[b]	Low
Pu-Contaminated Waste Sites	CP-LS-2	ND to Low	Low to Med[c]	ND to Low
Tank Farms				
T Tank Farm	CP-TF-1	Low to High	High	Low
S-SX Tank Farms	CP-TF-2	Low to High	High	Low
TX-TY Tank Farms	CP-TF-3	Low to High	High	Low
U Tank Farm	CP-TF-4	Low to High	High	Low
A-AX Tank Farms	CP-TF-5	Low to High	High	Low
B-BX-BY Tank Farms	CP-TF-6	Low to High	High	Low
C Tank Farms	CP-TF-7	Low to High	High	Low
200 East (DSTs)	CP-TF-8	Low to High	High	Low
200 West (DSTs)	CP-TF-9	Low to High	High	Low
Groundwater				
300 Area Groundwater Plumes	RC-GW-1	Low	Low	Low
100-N GW Plumes	RC-GW-2	Low	Low	Low
00-B/D/H/F/K Area Groundwater Plumes	RC-GW-3	Low to Med	Low to Med	Low
200 East Groundwater	CP-GW-1	Low to Med	Low to Med	Low
200 West Groundwater	CP-GW-2	Low to Med	Low to Med	Low
D&D				
324 Building	RC-DD-1	High[d]	High[d]	ND
KE/KW Reactors	RC-DD-1	Low	Low	ND to Low
PUREX	CP-DD-1	High[e]	High[e]	ND to Low
Operating Facilities				
KW Basin Sludge	RC-OP-1	Med	High[f]	NA[g]
CWC	CP-OP-1	High[h]	NA[i]	NA[9]

EU Name	EU #	Current	Active Cleanup	Near-Term Post-Cleanup
WESF	CP-OP-3	High[j]	High[j]	IS[k]
ERDF	CP-OP-6	Med[l]	Med[l]	ND

a. 618-11 Burial - Medium for sampling pit accident
b. BC Cribs - High for significant action associated with removal treatment and disposal
c. Pu-Contaminated - Medium for removal of heavily Pu contaminated soils
d. Building 324 - High for waste handling accident, Hydrogen deflagration, and seismic events
e. PUREX - High for seismic caused collapse of Building 202-A and fire in Tunnel #1
f. K-West Basin Sludge - High in phase 2 (ECRTS) under multiple scenarios
g. K-West Basin - D&D to be done with K-West Reactor
h. CWC - High for fire scenarios and seismic event
i. D&D of facility not yet planned
j. WESF - High for loss of pool cell water, hydrogen explosion in hot cell G or K3 duct, hydrogen explosion in ion exchange module (WIXM) and design basis seismic event
k. WESF - Insufficient information
l. ERDF - Medium for contact with waste of much higher activity than expected

Table 4-3. Summary of Risk Review Project ratings: human health: co-located person. (See symbology legend p. xxv)

EU Name	EU #	Current	Active Cleanup	Near-Term Post-Cleanup
Legacy Sites				
618-11 Burial Grounds	RC-LS-1	ND	Med[a]	ND
K –Area Waste Sites	RC-LS-2	Low	Low	ND
BC Cribs and Trenches	CP-LS-1	ND to Low	Low to Med[b]	Low
Pu-Contaminated Waste Sites	CP-LS-2	ND to Low	Low	ND
Tank Farms				
T Tank Farm	CP-TF-1	Low to Med	Low to Med	Low
S-SX Tank Farms	CP-TF-2	Low to Med	Low to Med	Low
TX-TY Tank Farms	CP-TF-3	Low to Med	Low to Med	Low
U Tank Farm	CP-TF-4	Low to Med	Low to Med	Low
A-AX Tank Farms	CP-TF-5	Low to Med	Low to Med	Low
B-BX-BY Tank Farms	CP-TF-6	Low to Med	Low to Med	Low
C Tank Farms	CP-TF-7	Low to Med	Low to Med	Low
200 East (DSTs)	CP-TF-8	Low to Med	Low to Med	Low
200 West (DSTs)	CP-TF-9	Low to Med	Low to Med	Low
Groundwater				
300 Area GW Plumes	RC-GW-1	Low	Low	Low
100-N GW Plumes	RC-GW-2	Low	Low	ND
00-B/D/H/F/K Area GW Plumes	RC-GW-3	Low to Med	Low to Med	ND to Low
200 East Groundwater	CP-GW-1	Low to Med	Low to Med	ND to Low
200 West Groundwater	CP-GW-2	Low to Med	Low to Med	ND
D&D				
324 Building	RC-DD-1	High[c]	High[c]	ND
KE/KW Reactors	RC-DD-1	Low	Low	ND
PUREX	CP-DD-1	High[d]	Med[d]	ND

Operating Facilities				
KW Basin Sludge	RC-OP-1	Med	High[e]	NA[f]
CWC	CP-OP-1	High[g]	NA[h]	NA[h]
WESF	CP-OP-3	High[i]	Med[j]	IS[k]
ERDF	CP-OP-6	Low[l]	Low[l]	ND

a. 618-11 Burial - Medium for Sampling Pit accident
b. BC Cribs - High for significant action associated with removal treatment and disposal
c. Building 324 - High for waste handling accident
d. PUREX - High for seismic caused collapse of Building 202-A and fire in Tunnel #1
e. KW Basin Sludge - High in phase 2 (ECRTS) under multiple scenarios
f. KW Basin - D&D to be done with K-West Reactor
g. CWC - High for fire scenarios and seismic event
h. D&D of facility not yet planned
i. WESF - High for loss of pool cell water and hydrogen explosion in hot cell G or K3 duct
j. WESF - Medium for design basis seismic event, crane drop through roof and hydrogen explosion K3 filter
k. WESF - Insufficient information
l. ERDF - Medium for contact with waste of much higher activity than expected

Table 4-4. Summary of Risk Review Project ratings: human health: public. (See symbology legend p. xxv)

EU Name	EU #	Current	Active Cleanup	Near-term Post-cleanup
Legacy Sites				
618-11 Burial Grounds	RC-LS-1	ND	Med	ND
K-Area Waste Sites	RC-LS-2	Low	Low	ND
BC Cribs and Trenches	CP-LS-1	ND	ND to Low	ND
Pu-Contaminated Waste Sites	CP-LS-2	ND	ND	ND
Tank Farms				
T Tank Farm	CP-TF-1	Low	Low	ND
S-SX Tank Farms	CP-TF-2	Low	Low	ND
TX-TY Tank Farms	CP-TF-3	Low	Low	ND
U Tank Farm	CP-TF-4	Low	Low	ND
A-AX Tank Farms	CP-TF-5	Low	Low	ND
B-BX-BY Tank Farms	CP-TF-6	Low	Low	ND
C Tank Farms	CP-TF-7	Low	Low	ND
200 East (DSTs)	CP-TF-8	Low	Low	ND
200 West (DSTs)	CP-TF-9	Low	Low	ND
Groundwater				
300 Area GW Plumes	RC-GW-1	ND	ND	ND
100-N GW Plumes	RC-GW-2	ND	ND	ND
00-B/D/H/F/K Area GW Plumes	RC-GW-3	ND to Low	ND to Low	ND
200 East Groundwater	CP-GW-1	ND to Low	ND to Low	ND
200 West Groundwater	CP-GW-2	ND to Low	ND to Low	ND
D&D				
324 Building	RC-DD-1	High[(a)]	High[(b)]	ND
KE/KW Reactors	RC-DD-1	Low	Low	ND-Low
PUREX	CP-DD-1	ND to Low	ND to Low	ND-Low

Operating Facilities				
KW Basin Sludge	RC-OP-1	Low	Low	NA[c]
CWC	CP-OP-1	Low	NA[d]	NA[d]
WESF	CP-OP-3	Low	Low	IS[e]
ERDF	CP-OP-6	ND to Low	ND to Low	ND

a. 618-11 – Med for sampling and retrieval accident, including impacts at Energy Northwest Columbia Generating Station
b. Building 324 - High for waste handling accident
c. K-West Basin - D&D to be done with K-West Reactor
d. D&D of facility not yet planned
e. WESF - Insufficient information

4.3. GROUNDWATER AND COLUMBIA RIVER

Many of the EUs being considered involve discharges of contaminants into the environment that either have resulted in current groundwater contamination or may in the future impact groundwater. In addition, groundwater may serve as a contaminant transport pathway for threats to the Columbia River. Table 4-5 through Table 4-7 provide the Risk Review Project ratings related to current and potential future groundwater contamination. Threats to groundwater evaluated are:

1. Groundwater currently contaminated and the potential for increased extent of contaminated groundwater from the spread of contaminants already in groundwater (Table 4-5)
2. The potential for existing environmental contamination in the near surface or vadose zone to increase the extent of contaminated groundwater (Table 4-6)
3. The potential for contaminants currently in engineered facilities (i.e., tank wastes) to increase the extent of contaminated groundwater.

The primary focus was on Group A and Group B primary contaminants because of their persistence and mobility.

Threats considered to the Columbia River from discharges of contaminated groundwater through springs and upwellings are (Table 4-7):

1. Threats to the riparian zone ecology
2. Threats to the Columbia River benthic zone ecology
3. Threats to the free stream ecology

Current threats to human health from groundwater are non-discernible because contaminated groundwater is not currently being used. The most sensitive receptors are (1) groundwater (as a protected resource) because of the large volumes of groundwater currently contaminated above resource protection thresholds, and (2) the riparian zone as part of the rating of threats to the Columbia River because of elevated contaminant concentrations in an area of sensitive ecosystems. Most of the groundwater EUs with elevated Risk Review Project ratings (in the River Corridor and the Central Plateau) are currently being treated, with the notable exception of groundwater and vadose contamination in the 200 East Area. The current state of groundwater contamination in the River Corridor suggests that current active treatment actions (e.g., groundwater pump and treat) should be evaluated for optimization and consideration of appropriate end-points.

Table 4-5. Summary of Risk Review Project ratings: threats to groundwater as a resource from existing groundwater contamination. (See symbology legend p. xxv)

EU Name	EU #	Risk Driver	Current	Active Cleanup	Near-Term Post-Cleanup
Groundwater					
300 Area GW Plumes	RC-GW-1	U-Total	Low	ND	ND
100-N GW Plumes	RC-GW-2	Sr-90	Medium	Medium	Medium
100-B/D/H/F/K Area GW Plumes	RC-GW-3	Cr-VI	Medium	Medium	Medium
200 East Groundwater	CP-GW-1	I-129	Very High	Very High	Very High
200 West Groundwater	CP-GW-2		Very High (CCl4)	Very High (CCL4)	High (I-129)

Table 4-6. Summary of Risk Review Project ratings threats to groundwater from contaminants currently in the vadose zone (includes current vadose zone inventory in Tank Farm and Waste EUs but not inventory within the tanks themselves). (See symbology legend p. xxv)

EU Name	EU	Risk Driver	Current	Risk Driver	Active Cleanup	Risk Driver	Near-term Post-cleanup
Legacy Site EUs							
618-11 Burial Grounds	RC-LS-1	Sr-90	Low	Sr-90	Low	Sr-90	ND
K–Area Waste Sites	RC-LS-2	C-14	Medium	C-14	Medium	C-14	Medium
BC Cribs and Trenches	CP-LS-1	I-129, Tc-99, Cr[(a)]	High	I-129, Tc-99, Cr[(a)]	High	I-129, Tc-99, Cr[(a)]	High
Pu-Contam-inated Waste Sites	CP-LS-2	CCl4	Very High	CCl4	Very High	CCl4	Very High
Tank Waste and Farms							
T Tank Farm	CP-TF-1	Cr[(a)]	High	Cr[(a)]	High	Cr[(a)]	High
S-SX Tank Farms	CP-TF-2	Cr[(a)]	High	Cr[(a)]	High	Cr[(a)]	High
TX-TY Tank Farms	CP-TF-3	Tc-99, CCl4, Cr[(a)]	High	Tc-99, CCl4, Cr[(a)]	High	Tc-99, CCl4, Cr[(a)]	High
U Tank Farm	CP-TF-4	Various[(b)]	Low	Various[(b)]	Low	Various[(b)]	Low

EU Name	EU	Risk Driver	Current	Risk Driver	Active Cleanup	Risk Driver	Near-term Post-cleanup
A-AX Tank Farms	CP-TF-5	Cr[(a)]	Medium	Cr[(a)]	Medium	Cr[(a)]	Medium
B-BX-BY Tank Farms	CP-TF-6	I-129, Tc-99, Cr[(a)]	High	I-129, Tc-99, Cr[(a)]	High	I-129, Tc-99, Cr[(a)]	High
C Tank Farms	CP-TF-7	I-129	Medium	I-129	Medium	I-129	Medium
200 East (DSTs)	CP-TF-8	Various[(b)]	Low	Various[(b)]	Low	Various[(b)]	Low
200 West (DSTs)	CP-TF-9		ND		ND		ND
D4							
324 Building	RC-DD-1	Sr-90	Low	Sr-90	Low		ND
KE/KW Reactors	RC-DD-2		ND		ND		ND
PUREX	CP-DD-1	Various[(c)]	Low	Various[(c)]	Low	Various[(c)]	Low
Operating Facilities							
KW Basin Sludge	RC-OP-1		ND		ND		ND
CWC	CP-OP-1		ND		ND		ND
WESF	CP-OP-3		ND		ND		ND
ERDF	CP-OP-6		ND		ND		Low

a. Cr represents both total and hexavalent chromium
b. The various non-zero inventory PCs are C-14, I-129, Sr-90, Tc-99, Cr[(a)], U-Total
c. The various non-zero inventory PCs are C-14, I-129, Tc-99, Cr[(a)]
d. 618-11 – Med for sampling and retrieval accident, including impacts at Energy Northwest Columbia Generating Station
e. Building 324 - High for waste handling accident
f. K-West Basin - D&D to be done with K-West Reactor
g. D&D of facility not yet planned
h. WESF - Insufficient information

Table 4-7. Summary of Risk Review Project ratings: threats to the Columbia River through groundwater contaminant transport. (See symbology legend p. xxv)

EU Name	EU	Receptor	Current	Active Cleanup	Near-Term Post-Cleanup
Groundwater (from existing groundwater contamination)					
300 Area GW Plumes	RC-GW-1	Benthic (all)	High[a]	ND	ND
		Riparian (all)	Medium	ND	ND
		Free-flowing (all)	ND	ND	ND
100-N GW Plumes	RC-GW-2	Benthic (all)	Medium (Sr-90)	Medium (Sr-90)	Medium (Sr-90)
		Riparian (all)	Low (Sr-90, Cr-VI)	Low (Sr-90, Cr-VI)	Low (Sr-90, Cr-VI)
		Free-flowing (all)	ND	ND	ND
100-B/D/H/F/K Area GW Plumes	RC-GW-3	Benthic (all)	High (Cr-VI)	Medium (Cr-VI)	Medium (Cr-VI)
		Riparian (all)	High (Cr-VI)	Medium (Cr-VI)	Medium (Cr-VI)
		Free-flowing (all)	ND	ND	ND
200 East Groundwater	CP-GW-1	Benthic (all)	ND	ND	ND
		Riparian (all)	ND	ND	ND
		Free-flowing (all)	ND	ND	ND
200 West Groundwater	CP-GW-2	Benthic (all)	ND	ND	ND
		Riparian (all)	ND	ND	ND
		Free-flowing (all)	ND	ND	ND
Legacy Site EUs					
618-11 Burial Grounds	RC-LS-1	Benthic (all)	ND	ND	ND
		Riparian (all)	ND	ND	ND
		Free-flowing (all)	ND	ND	ND
K–Area Waste Sites	RC-LS-2	Benthic (all)	ND	Low (C-14)	Low (C-14)
		Riparian (all)	ND	Low (C-14)	Low (C-14)
		Free-flowing (all)	ND	Low (C-14)	Low (C-14)
BC Cribs and Trenches	CP-LS-1	Benthic –			
		(radionuclides)	ND	ND	ND
		(chemicals)	ND	ND	ND

EU Name	EU	Receptor	Current		Active Cleanup		Near-Term Post-Cleanup	
		Riparian –						
		(radionuclides)	ND	○	ND	[○]	ND	◎
		(chemicals)	ND	○	ND	[○]	ND	◎
		Free-flowing (all)	ND	○	ND	[○]	ND	◎
Pu-Cont'd Sites	CP-LS-2	Benthic (all)	ND	○	ND	[○]	ND	◎
		Riparian (all)	ND	○	ND	[○]	ND	◎
		Free-flowing (all)	ND	○	ND	[○]	ND	◎
Tank Waste and Farms								
200-West SSTs								
T Tank Farm	CP-TF-1	Benthic (all)	ND	○ ǂ	ND	○ ǂ	ND	◎
		Riparian (all)	ND	○ ǂ	ND	○ ǂ	ND	◎
		Free-flowing (all)	ND	○ ǂ	ND	○ ǂ	ND	◎
S-SX Tank Farms TX-TY Tank Farms U Tank Farm	CP-TF-2 CP-TF-3 CP-TF-4	Benthic (all)	ND	◎ (dashed) ǂ	ND	[◎ (dashed)] ǂ	ND	◎
		Riparian (all)	ND	◎ (dashed) ǂ	ND	[◎ (dashed)] ǂ	ND	◎
		Free-flowing (all)	ND	◎ (dashed) ǂ	ND	[◎ (dashed)] ǂ	ND	◎
200-East SSTs								
A-AX Tank Farms B-BX-BY Tank Farms	CP-TF-5 CP-TF-6	Benthic –						
		(radionuclides)	ND	◎ (dashed) ǂ	ND	[◎ (dashed)] ǂ	ND	◎
		(chemicals[b])	ND	◎ (dashed) ǂ	ND	[◎ (dashed)] ǂ	Low	◔
		Riparian –						
		(radionuclides)	ND	◎ (dashed) ǂ	ND	[◎ (dashed)] ǂ	ND	◎
		(chemicals)	ND	◎ (dashed) ǂ	ND	[◎ (dashed)] ǂ	ND	◎
		Free-flowing (all)	ND	◎ (dashed) ǂ	ND	[◎ (dashed)] ǂ	ND	◎
C Tank Farms	CP-TF-7	Benthic –						
		(radionuclides)	ND	[◎ (dashed)] ǂ	ND	[◎ (dashed)] ǂ	ND	◎
		(chemicals)	ND	[◎ (dashed)] ǂ	ND	[◎ (dashed)] ǂ	ND	◎
		Riparian –						
		(radionuclides)	ND	[◎ (dashed)] ǂ	ND	[◎ (dashed)] ǂ	ND	◎
		(chemicals)	ND	[◎ (dashed)] ǂ	ND	[◎ (dashed)] ǂ	ND	◎
		Free-flowing (all)	ND	[◎ (dashed)] ǂ	ND	[◎ (dashed)] ǂ	ND	◎
	CP-TF-8	Benthic (all)	ND	◎ (triple)	ND	[◎ (triple)]	ND	◎ (triple)

EU Name	EU	Receptor	Current		Active Cleanup		Near-Term Post-Cleanup	
200 East DSTs		Riparian (all)	ND	◎	ND	[◎]	ND	◎
		Free-flowing (all)	ND	◎	ND	[◎]	ND	◎
200 West DSTs	CP-TF-9	Benthic (all)	ND	◎	ND	[◎]	ND	◎
		Riparian (all)	ND	◎	ND	[◎]	ND	◎
		Free-flowing (all)	ND	◎	ND	[◎]	ND	◎
D4								
324 Building	RC-DD-1	Benthic (all)	ND	◎	ND	[◎]	ND	◎
		Riparian (all)	ND	◎	ND	[◎]	ND	◎
		Free-flowing (all)	ND	◎	ND	[◎]	ND	◎
KE/KW Reactors	RC-DD-2	Benthic (all)	ND	◎	ND	[◎]	ND	○
		Riparian (all)	ND	◎	ND	[◎]	ND	○
		Free-flowing (all)	ND	◎	ND	[◎]	ND	○
PUREX	CP-DD-1	Benthic (all)	ND	◎	ND	[◎]	ND	◎
		Riparian (all)	ND	◎	ND	[◎]	ND	◎
		Free-flowing (all)	ND	◎	ND	[◎]	ND	◎
Operating Facilities								
KW Basin Sludge	RC-OP-1	Benthic (all)	ND	◎	ND	◎	ND	○
		Riparian (all)	ND	◎	ND	◎	ND	○
		Free-flowing (all)	ND	◎	ND	◎	ND	○
CWC	CP-OP-1	Benthic (all)	ND	◎	ND	◎	ND	◎
		Riparian (all)	ND	◎	ND	◎	ND	◎
		Free-flowing (all)	ND	◎	ND	◎	ND	◎
WESF	CP-OP-3	Benthic (all)	ND	◎	ND	◎	ND	◎
		Riparian (all)	ND	◎	ND	◎	ND	◎
		Free-flowing (all)	ND	◎	ND	◎	ND	◎
ERDF	CP-OP-6	Benthic (all)	ND	◎	ND	◎	ND	◎
		Riparian (all)	ND	◎	ND	◎	ND	◎
		Free-flowing (all)	ND	◎	ND	◎	ND	◎

4.4. ECOLOGICAL RESOURCES

Plants and animals belong to communities and ecosystems, which in turn are part of larger geographical units or ecoregions. The value of ecological resources depends not only on resources at a specific site, but on their relationship to adjacent areas, the region, and the greater ecoregion, as well as to human communities. For this Risk Review Project, ecological resources at Hanford were evaluated relative to three landscape scales: (1) the Columbia Basin Ecoregion, (2) Hanford-wide, and (3) site-specific with respect to EUs and their buffer.

In general, the habitats most at risk are those that currently are in short supply both at Hanford Site and in the Columbia Basin Ecoregion, as well as those habitats that have been declining most rapidly on site or in the ecoregion. Bluebunch Wheatgrass is a unique habitat that increased on Hanford over the last centuries, but decreased markedly in the ecoregion (see Chapter 7 of the methodology report (CRESP 2015)). Big Sagebrush steppe is also of concern because Hanford has a significant component of this habitat in the ecoregion, and it has decreased both at Hanford and in the ecoregion (although it is still the dominant and largest habitat on the Hanford Site). Sagebrush is a priority habitat in the State of Washington.

On the Hanford Site, Big Sagebrush habitats are considered at risk even though they are common, partly because large areas of sagebrush can be destroyed by fire, reducing its availability for decades. Further, the value of a habitat type increases with the size of the patch; many small, separate sagebrush patches are of less value than single patch that has similar amount of sagebrush. Large patches have less edge to interior and are less likely to be invaded by non-native, noxious species. Aquatic habitats embedded within the terrestrial environment at the Hanford Site are critical because they are so limited in space, and act as habitat islands for many species. That is, some species are limited to these regions, and the dry steppe habitat that surrounds them serves as a barrier to movement. Sensitive and irreplaceable habitats on the Hanford Site include cliffs, lithosols, dune fields, ephemeral streams and vernal ponds, and fall Chinook salmon and steelhead spawning areas (DOE/RL-96-32 2013, Chapter 7 of the methodology report (CRESP 2015)).

The most highly valued habitats on the Hanford Site are in the riparian zone along the Columbia River (DOE/RL-96-32 2013, Chapter 7 of the methodology report (CRESP 2015)). The riparian zone (1) is in short supply and occurs only in a narrow band along the Columbia River; (2) is the interface zone between land and water, and biota living there have adapted to that narrow habitat band; (3) is a zone of relatively high species diversity; (4) has plants that can withstand inundation by flood waters, and dry out during low water; (5) is vulnerable to stressors from both the land and Columbia River; (6) is vulnerable to disturbance because of the vertical gradient sloping down to the Columbia River; (7) provides the exposure pathway from land to the Columbia River to physical, biological, and chemical/radiological contamination stressors; and (8) is the region most used by humans for thousands of years because of its proximity to the Columbia River. Thus, the resources in the riparian zone are critical and highly valued (Level 5 resources, DOE/RL-96-32 2013, Chapter 7 of the methodology report (CRESP 2015)) by the State of Washington.

There are three federally endangered/threatened species, and four Washington State endangered (threatened) species on the Hanford Site (reviewed in Chapter 7 of the methodology report (CRESP 2015)). The federally endangered fish are spring chinook salmon (spring run), and threatened fish are steelhead and bull trout. Although bull trout have been reported on the Hanford Reach, their natural habitat is mountain streams. Although many species are being monitored or are of special concern, few are actually listed as endangered or threatened by the U.S. Fish and Wildlife Service or Washington State at any one time.

The most critical component of determining risk to ecological resources is the evaluation of the EUs and their buffer areas (defined as 1X the greatest diameter of the EU, Chapter 7 of the methodology report (CRESP 2015)). Twenty-five EUs were evaluated. The ecological evaluation of EUs and their buffer involved using GIS-based data, previous resource level designations (DOE/RL-96-32 2013), field data collected in 2014 and 2015 (Appendix J), a table of disposition options (Appendix B), and a risk rating for each EU (see Chapter 7 of the methodology report (CRESP 2015)).

There were five levels of ecological resources (DOE/RL-96-32, 2013), described briefly below (see Chapter 7 of the methodology report (CRESP 2015) for a full description).

Levels of Ecological Resources (DOE/RL-96-32, 2013)

Level 5 = Irreplaceable habitat or federal threatened and endangered species (including proposed species, and species that are new to science or unique to Washington state).

Level 4 = Essential habitat for important species.

Level 3 = Important habitat.

Level 2 = Habitat with high potential for restoration (ecologically, not legally)

Level 1 = Industrial or developed.

Level 0 = Non-native plants and animals.

Three caveats: (1) many of these resources have not been evaluated for a decade or more (and so may have changed), (2) no invasive species inventory has been completed, and (3) while much of the site was evaluated for resource level, not all sites were evaluated; thus, evaluations are valid where given. If a site is blank on the resource map, it may not indicate lack of a value, but rather that it was not surveyed. This is another reason for the field evaluations (see below).

The Risk Review Project uses the following five risk ratings. Full definitions and explanations can be found in Chapter 7 of the methodology report (CRESP 2015).

ND = Not discernible from the surrounding conditions; not additional risk

Low = Little risk to disrupt or impact level 3-5 ecological resources.

Medium = Potential to disrupt or impair level 3-5 ecological resources, but the remedial action is not expected to disrupt communities permanently.

High = Likely to disrupt and impair level 3-5 ecological resources of high value or resources that have restoration potential, and can cause permanent disruption.

Very High = Very high probability of impairing (or destroying) ecological resources of high value (levels 3-5) that have typical (and healthy) shrub-steppe species, low percent of exotic species, and may have federally listed species. The remediation likely results in permanent destruction or degradation of habitat.

The lowest risk ratings are self-explanatory, but High and Very High require some comment. High is applied when there are high-level resources (Levels 3 to 5) that can be disrupted permanently. Very High is reserved for EUs where there is high probability of impairing or destroying resources of very high value. This is especially true of Level 5 resources. For example, all of the riparian zone along the Columbia River was designated as Level 5 resources because the riparian zone is limited and was rated the highest value resource on the Hanford Site (DOE/RL-96-32, 2013). Thus, if there is currently, or could be as a result of remediation, degradation to the riparian zone along the Columbia River, the rating would be Very High.

The risk ratings for the 25 EUs, along with brief comments, can be found in Table 4-10. Below is a summary table for each EU (Table 4-8).

Table 4-8. Summary of risk ratings for ecological resources. (See symbology legend p. xxv)

EU Name	EU #	Current	Active Cleanup	Near-Term Post-Cleanup
Legacy Site EUs				
618-11 Burial Grounds	RC-LS-1	ND	Low to Med	Low
K-Area Waste Sites	RC-LS-2	ND to Low	ND to Med	Low to Med
BC Cribs and Trenches	CP-LS-1	ND to Low	Low to Med	ND to Low
Pu-Contaminated Waste Sites	CP-LS-2	ND to Low	Low to Med	Low
Tank Waste and Farms				
T Tank Farm	CP-TF-1	ND to Low	Low to Med	ND to Low
S-SX Tank Farms	CP-TF-2	ND to Low	Low to Med	ND to Low
TX-TY Tank Farms	CP-TF-3	ND to Low	Low to Med	ND to Low
U Tank Farm	CP-TF-4	ND to Low	Low to Med	ND to Low
A-AX Tank Farms	CP-TF-5	ND to Low	Low to Med	ND to Low
B-BX-BY Tank Farms	CP-TF-6	ND to Low	Low to Med	ND to Low
C Tank Farms	CP-TF-7	ND	ND to Med	ND to Low
200 East (DSTs)	CP-TF-8	ND	ND to Med	ND to Low
200 West (DSTs)	CP-TF-9	ND	ND to Med	ND to Low
Groundwater				
300 Area GW Plumes	RC-GW-1	Low to Med	Very High	Low to Med
100-N GW Plumes	RC-GW-2	Low to Med	Very High	Low to Med
00-B/D/H/F/K Area GW Plumes	RC-GW-3	Low to Very High	Very High	Low to Med
200 East Groundwater	CP-GW-1	Low	Very High	Low
200 West Groundwater	CP-GW-2	ND to Low	ND to Low	ND to Low
D4				
324 Building	RC-DD-1	ND	ND	ND to Low
KE/KW Reactors	RC-DD-2	ND	ND	ND to Low
PUREX	CP-DD-1	ND to Low	Low to Med	ND to Low
Operating Facilities				

EU Name	EU #	Current	Active Cleanup	Near-Term Post-Cleanup
KW Basin Sludge	RC-OP-1	ND	ND	ND to Low
CWC	CP-OP-1	ND	ND to Low	ND to Low
WESF	CP-OP-3	ND	ND	ND
ERDF	CP-OP-6	Low to Med	ND to High	ND to Low

A compilation of the risk ratings follows (Table 4-9). The number of EUs in each category is summed in each source category by evaluation period (current, active cleanup, near-term post cleanup). Ratings given are the highest for that period; if the rating is ND to Medium, it is categorized in the Medium risk rating category. Variations in the ratings are due to potential differences in remediation options.

Table 4-9. Summary of risk ratings for ecological resources on EUs as a function of source type.

EUs	ND	Low	Medium	High	Very High
Current					
Legacy Sites	1	3			
Tank Farms	3	6			
Groundwater		2	2		1
D&D	2	1			
Operating Facilities	3		1		
Totals (%)	9 (36%)	12 (48%)	3 (12%)		1 (4%)
Active Cleanup					
Legacy Sites			4		
Tank Farms			9		
Groundwater		1			4
D&D		2	1		
Operating Facilities	2	1		1	
Totals (%)	2 (8%)	4 (16%)	14 (56%)	1 (4%)	4 (16%)
Near-Term Post-Cleanup					
Legacy Sites		3	1		
Tank Farms		9			
Groundwater		2	3		
D&D		3			
Operating Facilities	1	3			
Totals (%)	1 (4 %)	20 (80%)	4 (16%)		

Several observations are clear from the data (tables above and Table 4-10 at end of this section):

1. Risk to ecological receptors is highest during cleanup, intermediate before cleanup, and lowest after.
2. The greatest risk before cleanup (current condition) is for the groundwater EUs, largely because of risk to the riparian zone and the Columbia River.
3. The highest risk to ecological receptors during remediation is for the groundwater EUs, followed by the tank farms and legacy sites.
4. After remediation (near-term post-cleanup), the greatest risk to ecological receptors is for the groundwater sites.
5. Variability in cleanup options is expressed as variation in the risk ratings. The percent of EUs with a range of risk ratings (e.g. ND to Medium, ND to Low) was 56% currently, 68 % during active clean-up, and 80% in the near-term post-cleanup. Since the table reflects the highest range given, the risk may be lower (depending upon cleanup method selected during active clean-up, and restoration after active clean up).
6. For some EUs, the risk rating is higher in the near-term post cleanup period because during clean up, many sites will undergo restoration. This is the effect of creating higher resource level than existed there before. In other words, DOE has improved the habitat, allowing there to be a higher risk to those new resources than existed when the site had no ecological resources.

A summary of the ratings for each of the EUs is given in Table 4-10.

Summary of Risk Rating for Ecological Resources

Overall, the risks to ecological resources range from ND to Very High currently, partly due to the high value resources in the riparian zone that are vulnerable to both contamination and physical disruption. Ecological resources are most vulnerable during active cleanup, when the risk is Medium to High for 76 % of the EUs. After active cleanup, only 16 % have a Medium risk, and are mainly the groundwater sites because of revegetation in areas surrounded by Level 3 and 4 resources, and the continued potential for disruption and disturbance (especially in the riparian zone).

The change in risk for the 25 EUs is illustrated in Figure 4-6. It summarizes the ratings for the three evaluation periods. It is critical to note the hatched part of each bar. This indicates the EUs that had a ND rating before cleanup (e.g., current condition) and a higher risk rating after cleanup. The reason for this change is that currently there are NO resources on the site (e.g., it is gravel or entirely buildings), but during cleanup restoration of native vegetation to the site will occur. This vegetation (not currently present) could then be at risk if the site is exposed to continued monitoring or other activities during the near-term post cleanup period. It is thus an indication of additional habitat created by DOE during the cleanup phase.

At the other end, the high risks currently or during cleanup are all reduced in the near-term post cleanup period. Thus, risk to ecological resources is highest during cleanup, and decreases after cleanup. And, DOE will have created new ecological resources on some EUs due to restoration during cleanup.

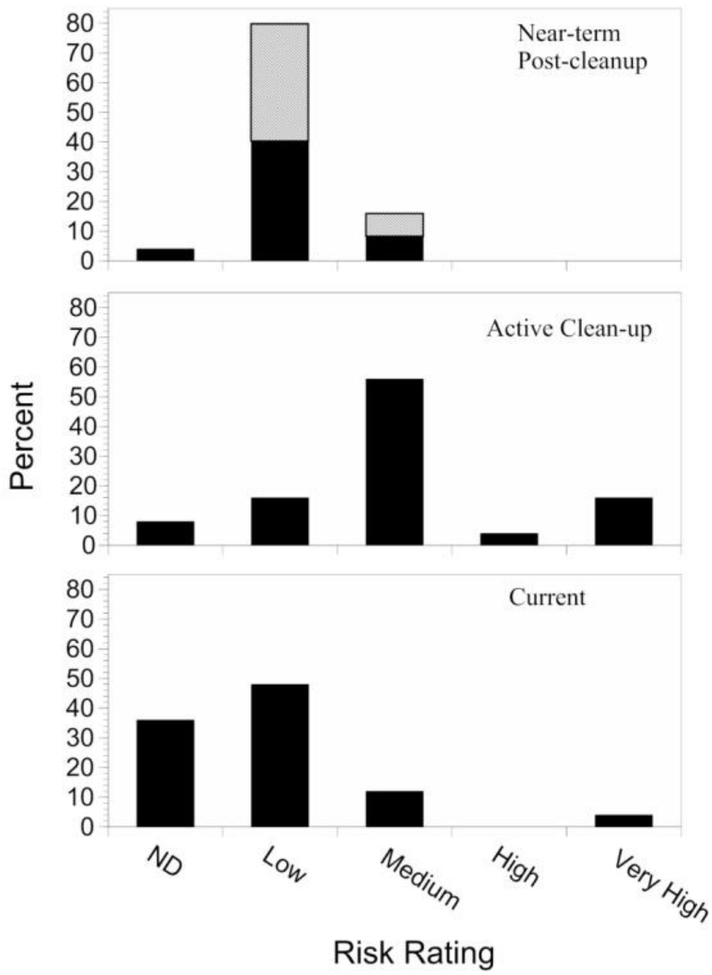

Figure 4-6. Summary of risk to ecological resources during the different evaluation periods (current, active cleanup, near-term post-cleanup).

The ratings for the different evaluation periods are shown in Table 4-10 for all the EUs completed so far, along with a brief explanation of the ratings. Full explanations can be found in the individual EU templates.

Table 4-10. Risk and potential impacts ratings for ecological summary.

Active cleanup refers to the period of 50 years or until 2064; near-term post-cleanup is from 2064 to 2164. High-level or high-quality resources are resource levels 3 to 5.

EU Name	EU ID	Evaluation Period	Potential Risk or Impact Rating	Comments
618-11 Burial Grounds	RC-LS-1	Current	ND	ND because currently there is no disturbance to site, although 10% of EU consists of Level 3 resources and over half of buffer area consists of Level 4 resources
		Active Cleanup	Low to Medium	Low in EU because only about 10% consists of Level 3 resources (none higher), but Low to Medium in buffer zone because 65% consists of Level 3 and 4 resources. Disturbance could result during soil removal.
		Near-Term Post-Cleanup	Low to Medium	Revegetation in EU will potentially place additional Level 3 and 4 resources at risk because of disturbance, especially from invasive species and change of species composition. Similar effects in buffer zone.
K Areas Waste Sites	RC-LS-2	Current	ND to Low	Most of the EU is non-vegetated, but risk is Low (rather than ND) because part of the EU falls in an eagle roosting area, which is a species of concern, and 8% consists of Level 4 resources.
		Active Cleanup	ND to Medium	ND to Low in EU because of eagle roosting, but Low to Medium in buffer because of high percent of Level 3 and 4 resources (78% consists of Level 3 and 4 resources), and it is close to the riparian habitat (all of which is Level 5 habitat). Removal of dirt will result in disturbance and disruption.
		Near-Term Post-Cleanup	Low to Medium	Revegetation 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. Similar effects in buffer zone.
BC Cribs And Trenches	CP-LS-1	Current	ND to Low	ND to Low in EU because nearly 30% is Level 3 and 4 resources, along with the buffer area. There is the potential for disturbance and invasion of exotic species in both EU and buffer area.
		Active Cleanup	Low to Medium	Depending on remediation option, could result in disturbance and disruption to Level 3 and 4 resources (30% of EU and 77% of buffer), including increases in exotic species and changes in species composition of native species.

EU Name	EU ID	Evaluation Period	Potential Risk or Impact Rating	Comments
		Near-Term Post-Cleanup	ND to Medium	Depending on remediation options, it could be ND, but it may be Medium in both EU and buffer areas because of high percent of Level 3 and 4 resources, uncertainty about remediation options, disturbance, and potential for invasion by exotic species, changes in species composition of native species.
Plutonium Cont. Waste Sites	CP-LS-2	Current	ND to LOW	ND to Low in the EU due to low resource value (only 5% Level 3 resources), but Low in buffer area because there is a small finger with 3% Level 3 vegetation, which could be disturbed by traffic.
		Active Cleanup	Low to Medium	The risk depends on the importance of some of the Level 3 habitat in buffer area (5% of EU). The range of remediation options being considered results in both activity and potential of disruptive activity, changing species composition of vegetation in EU and buffer.
		Near-Term Post-Cleanup	Low to Medium	There are two waste sites with contamination in place, which will have continued monitoring, which leads to disturbance, and the potential for exotic species to invade and disrupt native habitat.
T Tank Farm	CP-TF-1	Current	ND to Low	Little habitat in EU (>1% Level 3 resources), but over 10% in buffer area consists of Level 3 resources. Effect ND in EU, but may be up to Low in buffer due to truck disturbance.
		Active Cleanup	Low to Medium	Effects to resources are due to increased disturbance and potential for contaminant release, increases in exotic species, and potential loss of some nesting habitat in buffer area, run over lizards and other wildlife during cleanup.
		Near-Term Post-Cleanup	ND to Low	Continued monitoring could result in some disturbance to EU, and buffer lands. Remediation may improve habitat through revegetation (and increased monitoring may lead to increases in exotic species, and changes in species composition).
S-SX Tank Farms	CP-TF-2	Current	ND to Low	Little habitat in EU (Level 2 only), but over 10% in buffer consists of Level 3 resources. ND in buffer, unless there are trucks in the buffer, then it is Low
		Active Cleanup	Low to Medium	Effects due to increased disturbance and potential for contaminant release, increases in exotic species, and could lose some nesting habitat, run over lizards and other wildlife during cleanup.

EU Name	EU ID	Evaluation Period	Potential Risk or Impact Rating	Comments
		Near-Term Post-Cleanup	ND to Low	Continued monitoring could result in some disturbance to EU and buffer lands. Remediation may improve habitat (and increased monitoring may lead to increases in exotic species, changes in species composition).
TX-TY Tank Farms	CP-TF-3	Current	ND to Low	Some Level 3 resources in EU (4%) and in buffer area (9%). People and trucks are present, which could lead to increases in exotic species and changes in species diversity in Level 3 resource areas of EU and buffer.
		Active Cleanup	Low to Medium	Potential for continual disturbance levels with increasing number of trucks, which may cause changes in abundance and diversity in Level 3 resources in EU and buffer.
		Near-Term Post-Cleanup	ND to Low	It will be capped, which results in less frequent monitoring, but monitoring activities can cause some disruption and disturbance to EU and buffer areas. Remediation may improve habitat through revegetation (and increased monitoring may lead to increases in exotic species, and changes in species composition).
U TANK FARM	CP-TF-4	Current	ND to Low	Some Level 3 resources in EU (16%) and in buffer area (18%). People and trucks are present, which could lead to increases in exotic species and changes in species diversity in Level 3 resource areas of EU and buffer.
		Active Cleanup	Low to Medium	Potential for continual disturbance levels with increasing number of trucks, results may cause changes in abundance and diversity in Level 3 resource areas.
		Near-Term Post-Cleanup	ND to Low	It will be capped, which results in less frequent monitoring, but monitoring activities can cause some disruption and disturbance to EU and buffer resources. Remediation may improve habitat through revegetation.
A-AX Tank Farms	CP-TF-5	Current	ND to Low	High-quality habitat (22% Level 3) in EU, and 27% Level 3 and 4 in buffer suggests potential for disturbance even though truck traffic is low. Trucks can bring in seeds of exotic species, changing species composition. There is some nice sagebrush habitat on EU.

EU Name	EU ID	Evaluation Period	Potential Risk or Impact Rating	Comments
		Active Cleanup	Low to Medium	Remediation may result in some destruction of Level 3 habitat in EU (with sagebrush habitat); intense activity will result in loss of resources to EU and potentially buffer area (with 27% Level 3 and 4 resources).
		Near-Term Post-Cleanup	ND to Low	If capped and monitored, there could be some disturbance to EU and buffer habitat, but revegetation may increase resource value.
B-BX-BY Tank Farms	CP-TF-6	Current	ND to Low	Little habitat in EU, but over 10% in buffer consists of Level 3 resources. ND in buffer, unless there are trucks in the buffer, then it is Low. Habitat is fragmented, which increases disturbance and increases exotic species and potentially changes in species composition of vegetation.
		Active Cleanup	Low to Medium	Effects due to increased disturbance and potential for contaminant release, increases in exotic species, and could lose some nesting habitat, trucks could run over lizards and other wildlife during cleanup.
		Near-Term Post-Cleanup	ND to Low	Continued monitoring could result in some disturbance to EU and buffer lands. Remediation may improve habitat (and increased monitoring may lead to increases in exotic species or changes in vegetation species composition).
C Tank Farm	CP-TF-7	Current	ND	No resources on site, but about 15% Level 3 resources on buffer. If no trucks, ND effects.
		Active Cleanup	ND to Medium	No resources on EU, but about 15% Level 3 resources on buffer area. Remediation could result in truck disturbance, increases in exotic species, and changes in species composition in buffer.
		Near-Term Post-Cleanup	ND to Low	Likely monitoring of caps, with potential for disruption due to monitoring. Revegetation could result in higher quality habitat on EU.
200 East DSTs	CP-TF-8	Current	ND	No resources on site, but about 5% Level 3 resources on buffer. Assuming no trucks in buffer, it is ND.
		Active Cleanup	ND to Medium	No resources on EU, but about 5% Level 3 resources on buffer. Remediation could result in truck disturbance, increases in exotic species, changes in species composition in buffer, and contamination of sensitive species.

EU Name	EU ID	Evaluation Period	Potential Risk or Impact Rating	Comments
		Near-Term Post-Cleanup	ND to Low	Likely monitoring of caps, with potential for disruption due to monitoring. Revegetation could result in higher quality habitat on EU, but there could be some residual contamination to sensitive resources.
200 West DSTs	CP-TF-9	Current	ND	No resources on site, but about 15% Level 3 resources on buffer. Assuming no trucks in buffer, it is ND.
		Active Cleanup	ND to Medium	No resources on EU, but about 7% Level 3 resources on buffer. Remediation could result in truck disturbance, increases in exotic species, changes in species composition in buffer, and contamination of sensitive species.
		Near-Term Post-Cleanup	ND to Low	Likely monitoring of caps, little disturbance, but potential for disruption due to monitoring, and some contamination of receptors. Revegetation could result in higher quality habitat on EU.
300 Area GW Plumes	RC-GW-1	Current	Low to Moderate	There are areas where groundwater plumes intersect the riparian vegetation. Monitoring shows concentrations of uranium 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.
		Active Cleanup	Very High	Remediation activities in the shoreline will need to be monitored to evaluate resources and seasonal use of shoreline.
		Near-Term Post-Cleanup	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. Revegetation 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.
100 N Area Groundwater Plumes	RC-GW-2	Current	Low to Moderate	There are areas where groundwater plumes intersect the riparian vegetation. Potential for contaminant uptake by terrestrial vegetation. Sensitive animals and bird species use region and may be at risk.

EU Name	EU ID	Evaluation Period	Potential Risk or Impact Rating	Comments
		Active Cleanup	Very High	Remediation activities in the shoreline will need to be monitored to evaluate resources and seasonal use of shoreline.
		Near-Term Post-Cleanup	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. Revegetation 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.
100 B/D/H/F/K Areas Groundwater Plumes	RC-GW-3	Current	Low to Very High	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.
		Active Cleanup	Very High	Remediation activities in the shoreline will need to be monitored to evaluate resources and seasonal use of shoreline.
		Near-Term Post-Cleanup	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. Revegetation 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.
200 East Groundwater Plumes	CP-GW-1	Current	Low	There are areas where groundwater plumes intersect the riparian vegetation. Monitoring does not show concentrations of plume contaminants 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.
		Active Cleanup	Very High	Remediation activities in the shoreline will need to be monitored to evaluate resources and seasonal use of shoreline.

EU Name	EU ID	Evaluation Period	Potential Risk or Impact Rating	Comments
		Near-Term Post-Cleanup	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. Revegetation 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.
200 West Groundwater Plumes	CP-GW-2	Current	ND to Low	Groundwater wells on Central Plateau are in sensitive ecological areas. There is the potential for disturbance and invasion of exotic species in EU. Ecological resources at locations of new wells are evaluated prior to activities to assess potential impacts.
		Active Cleanup	ND to Low	Remediation could degrade habitats, disturb wildlife and affect animal behavior, and introduce exotic plant species.
		Near-Term Post-Cleanup	ND to 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. Revegetation 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.
324 Building	RC-DD-1	Current	ND	Currently no ecological resources on EU or buffer area.
		Active Cleanup	ND	No ecological resources on EU or buffer area during active cleanup.
		Near-Term Post-Cleanup	ND to Low	Any risk depends on the quality and quantity of revegetation following remediation. Could be a risk from invasion of exotic species.
KE/KW Reactors	RC-DD-2	Current	ND	Currently no ecological resources on EU, and only 1 acre of Level 3 on buffer area.
		Active Cleanup	ND	No ecological resources on EU, and few on buffer.
		Near-Term Post-Cleanup	ND to Low	Any risk depends on the quality and quantity of revegetation following remediation. Could be a risk from invasion of exotic species.

EU Name	EU ID	Evaluation Period	Potential Risk or Impact Rating	Comments
PUREX	CP-DD-1	Current	ND to Low	Generally ND on EU because there are few ecological resources (5% Level 3 resources), Low because of possible contamination to ecological receptors on buffer area (31% Level 3 and 4 resources)
		Active Cleanup	Low to Medium	Few high-level resources in EU (5% Level 3 resources), but Low to Medium in buffer area because of high value resources (nearly a third of area has Level 3 and 4 resources).
		Near-Term Post-Cleanup	ND to Low	Remote chance of penetration of roots into contaminated site, allowing exposure to residual contamination.
KW Basin Sludge	RC-OP-1	Current	ND	Currently no ecological resources on EU, and only 1 acre of Level 3 on buffer area.
		Active Cleanup	ND	No ecological resources on EU, and few on buffer.
		Near-Term Post-Cleanup	ND to Low	Any risk depends on the quality and quantity of revegetation following remediation. Could be a risk from invasion of exotic species.
CWC	CP-OP-1	Current	ND	Little high quality resources on EU or on buffer.
		Active Cleanup	ND to Low	Little high quality resources on EU or on buffer, but remediation options unknown. Remediation options could result in contamination of the few resources on site (only 2% Level 3 resources in EU).
		Near-Term Post-Cleanup	ND to Low	Remediation options unknown, thus whether area with be revegetated is unknown. If revegetated, risk could be Low (rather than ND) due to presence of higher quality resources (e.g. Level 3 or 4) created by revegetation.
WESF	CP-OP-3	Current	ND	No resources on EU or buffer, mainly Level 2 or below.
		Active Cleanup	ND	No resources on EU or buffer to be disturbed during active cleanup.
		Near-Term Post-Cleanup	ND	Few ecological resources now, and likely none in the future. If there is revegetation, then continued activity and monitoring could result in minor disturbance in EU.

EU Name	EU ID	Evaluation Period	Potential Risk or Impact Rating	Comments
ERDF	CP-OP-6	Current	Low to Medium	Levels of frequent disturbance can result in increases in invasive species, particularly to high quality habitat in buffer (80% consists of Level 3-5 resources). ERDF is one of only two EUs in interim progress report with Level 5 resources (about 9% of buffer is Level 5 resources, 0 in EU)
		Active Cleanup	ND to High	Because of high quality of resources in buffer area (7% Level 3 resources in EU, 80% Level 3-5 in buffer), the potential for disturbance is Medium, which could disrupt native communities in buffer, and result in increases in exotic species. Continued dust suppression changes available water levels, which could affect native species diversity and abundance
		Near-Term Post-Cleanup	ND to Low	Because of low level of monitoring expected in the near-term post-cleanup period, effect may be ND, but risk will depend upon disturbance, which may adversely affect the 80% Level 3-5 resources in buffer area.

4.5. CULTURAL RESOURCES

An overall risk rating has not been completed for cultural resources because federal law requires that a review of cultural resources be completed in advance of any project or activity (16 U.S.C. 470 et. seq.). This means an evaluation must be completed by DOE regardless of any rating that may be provided under the Risk Review Project. While a rating has not been made, evaluations, nonetheless, have been completed. The objective was to determine whether a resource is or has been present within the unit being evaluated based on a thorough review of DOE and Washington State cultural resources records. The review was conducted by professional archaeologists. Afterward, a written report was prepared on the results of the literature review for each EU (Appendix K).

If the information gathered from the literature review established the presence of cultural resources, the impacts for the periods evaluated (current operations, during active cleanup, and during near-term post-cleanup) are considered known as shown in the table below. If the review revealed an uncertainty, the impacts are considered unknown. Finally, if the review established no presence of cultural resources, the impacts are considered none. Consideration was also given to the anticipated remediation option for that EU.

The analysis described above was made for all three cultural resources landscapes identified at the Hanford Site (Native American, Pre-Hanford Era, and Manhattan Project/Cold War Era), and for each landscape the same analysis was made to determine the direct and indirect impacts to cultural resources during the evaluation periods. As noted in this interim progress report and in Chapter 8 of the methodology document (CRESP 2015), direct effects or impacts are derived from regulatory requirements prescribed under the National Historic Preservation Act and relate to physical destruction (all or part) or alteration such as diminished integrity (16 U.S.C. 470 et.seq.,36 CFR 800 (2004)). Indirect effects or impacts under the regulations include, but are not limited to, the introduction of visual, atmospheric, or audible elements that diminish the cultural resource's significant, historic features. Direct and indirect impacts were determined based on the literature review and what is known about the remediation option for that EU (Evaluation Unit Disposition Table, Appendix B).

Table 4-11 summarizes the results for the 25 EUs evaluated using the cultural resources methodology (Chapter 8, methodology report (CRESP 2015)) and which are described in the Evaluation Templates completed for this interim progress report. Brief comments from the literature review also are included. For more information regarding a specific EU, refer to the completed template for that EU as well as the EU's literature review (Appendix K).

It should be noted that the assignation of known or unknown regarding direct impacts to cultural resources within the Native American and Pre-Hanford Era landscapes remains the same for current operations and near-term post-cleanup evaluation periods. Indirect effects could change from current operations to near-term post-cleanup depending, for example, on whether the view shed of a traditional cultural place considered and recognized as culturally important to living communities, including Native Americans, may be affected during active cleanup. Additionally, in those EUs where the remediation option is deactivation and demolition, the assignation provided assumes that deactivation and demolition will have been completed when the near-term post-cleanup period begins or in 2064. So, for the Manhattan Project/Cold War Era landscape, the assignation is "none" for the near-term post-cleanup evaluation period.

Table 4-11. Compilation of evaluations for cultural resources for EUs contained in the interim progress report.

EU Name	EU ID	Evaluation Period	Potential RISK OR IMPACT	Comments
618-11 Burial Grounds	RC-LS-1	Current	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: Known Manhattan/Cold War: Direct: Known Indirect: Unknown	There are no known recorded cultural resources located within or near this EU.
		Active Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Unknown	There are no known recorded cultural resources located within or near this EU. Surface and subsurface investigations may be necessary prior to ground disturbance.

EU Name	EU ID	Evaluation Period	Potential RISK OR IMPACT	Comments
		Near-Term Post-Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: None Indirect: None	No expectations for impacts to known cultural resources.
K Areas Waste Sites	RC-LS-2	Current	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Known Indirect: Known	Manhattan Project/Cold War significant resources have already been mitigated. Area within the EU is heavily disturbed, but the entire area is extremely culturally sensitive based on prehistoric, ethno-historic, and historic land use in the area. Traditional cultural places are known to be located in the vicinity as well as National Register eligible archaeological sites associated with all three landscapes.
		Active Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Known Indirect: Known	Due to high cultural sensitivity of area, consultation may need to occur. Archaeological investigations or monitoring may also need to occur. Direct and indirect effects are likely to archaeological sites and traditional cultural places.
		Near-Term Post-Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: None Indirect: None	Permanent direct and indirect effects are possible due to high sensitivity of area.
BC Cribs And Trenches	CP-LS-1	Current	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: None Manhattan/Cold War: Direct: Known Indirect: Unknown	There are unevaluated cultural resources located within this EU. Manhattan Project/Cold War significant resources have already been mitigated. Traditional cultural places in view shed.

EU Name	EU ID	Evaluation Period	Potential RISK OR IMPACT	Comments
		Active Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: None Manhattan/Cold War: Direct: Known Indirect: Unknown	There is one unevaluated (for National Register) cultural resource. Traditional cultural places in view shed. Indirect effects are possible from capping.
		Near-Term Post-Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: None Manhattan/Cold War: Direct: None Indirect: None	Permanent indirect effects to view shed are possible from capping. Permanent effects may be possible due to presence of contamination if capping occurs. No other expected cultural resources impacts.
Plutonium Contam-inated Waste Sites	CP-LS-2	Current	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Known Indirect: Unknown	Manhattan Project/Cold War significant resources have already been mitigated. Area is very disturbed and there are no known recorded archaeological resources within the EU. There is evidence of ethno-historic and historic land use near the EU.
		Active Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Known Indirect: Unknown	Due to proximity of historic and ethno-historic land use near this EU, consultation will be necessary. Very small potential for surface or subsurface archaeological material to be present in pockets of undisturbed ground, if any.
		Near-Term Post-Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: None Indirect: None	No expectations for impacts to known cultural resources.

EU Name	EU ID	Evaluation Period	Potential RISK OR IMPACT	Comments
T Tank Farm	CP-TF-1	Current	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: None Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Known	Historical evidence of National Register eligible historic trail through the EU, however, extensive disturbance in area indicates low likelihood of remaining archaeological resources. Manhattan Project/Cold War significant resources have already been mitigated. Area is very disturbed and there is no evidence of archaeological sites being recorded within the EU. There is evidence of ethno historic and historic land use within the EU that has been destroyed by the tank farms.
		Active Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: None Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Known	Due to presence of historic and ethno-historic land use within this EU, consultation will be necessary. Little to no potential for intact surface or subsurface archaeological material to be present due to heavy disturbance throughout EU.
		Near-Term Post-Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: None Indirect: Unknown Manhattan/Cold War: Direct: None Indirect: None	Indirect effects to trail may be permanent. Permanent indirect effects to view shed are possible from capping. Permanent effects may be possible due to presence of contamination if capping occurs.
S-SX Tank Farms	CP-TF-2	Current	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Unknown	Manhattan Project/Cold War significant resources have already been mitigated. Area is very disturbed and there are no known recorded archaeological resources within the EU. There is evidence of ethno-historic and historic land use.

EU Name	EU ID	Evaluation Period	Potential RISK OR IMPACT	Comments
		Active Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Unknown	Because area has not been investigated on the surface or subsurface, archaeological investigations may need to occur within pockets of undisturbed land if any prior to remediation. Potential for intact archaeological material to be present is very low.
		Near-Term Post-Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Unknown Manhattan/Cold War: Direct: None Indirect: None	Permanent indirect effects to view shed are possible from capping. Permanent effects may be possible due to presence of contamination if capping occurs. No other expected cultural resources impacts.
TX-TY Tank Farms	CP-TF-3	Current	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Known Indirect: Unknown	Manhattan Project/Cold War significant resources have already been mitigated. Area is very disturbed and there are no known recorded archaeological resources within the EU. Traditional cultural places are visible from EU.
		Active Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Known Indirect: Unknown	Because area has not been investigated on the surface or subsurface, archaeological investigations may need to occur within pockets of undisturbed land if any prior to remediation. Potential for intact archaeological material to be present is very low.
		Near-Term Post-Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: None Indirect: None	Permanent indirect effects to view shed are possible from capping. Permanent effects may be possible due to presence of contamination if capping occurs. No other expected cultural resources impacts.

EU Name	EU ID	Evaluation Period	Potential RISK OR IMPACT	Comments
U Tank Farms	CP-TF-4	Current	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Unknown	Manhattan Project/Cold War significant resources have already been mitigated. Area is very disturbed and there are no known recorded archaeological resources within the EU. Traditional cultural places are visible from EU.
		Active Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Unknown	Because area has not been investigated on the surface or subsurface, archaeological investigations may need to occur within pockets of undisturbed land if any prior to remediation. Potential for intact archaeological material to be present is very low.
		Near-Term Post-Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: None Indirect: None	Permanent indirect effects to view shed are possible from capping. Permanent effects may be possible due to presence of contamination if capping occurs. No other expected cultural resources impacts.
A-AX Tank Farms	CP-TF-5	Current	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Known	Manhattan Project/Cold War significant resources have already been mitigated. Area is very disturbed and there are no known recorded archaeological resources within the EU. Traditional cultural places are visible from EU.
		Active Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Known	Because area has not been investigated on the surface or subsurface, archaeological investigations may need to occur within pockets of undisturbed land if any prior to remediation. Potential for intact archaeological material to be present is very low.

EU Name	EU ID	Evaluation Period	Potential RISK OR IMPACT	Comments
		Near-Term Post-Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: None Indirect: None	Permanent indirect effects to view shed are possible from capping. Permanent effects may be possible due to presence of contamination if capping occurs. No other expected cultural resources impacts.
B-BX-BY Tank Farms	CP-TF-6	Current	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Known	Manhattan Project/Cold War significant resources have already been mitigated. Area is very disturbed and there are no known recorded archaeological resources within the EU. EU has not been investigated for archaeological resources (surface or subsurface). Traditional cultural places are visible from EU.
		Active Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Known	Because area has not been investigated on the surface or subsurface, archaeological investigations may need to occur within pockets of undisturbed land if any prior to remediation. Potential for intact archaeological material to be present is very low.
		Near-Term Post-Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Unknown Manhattan/Cold War: Direct: None Indirect: None	Permanent indirect effects to view shed are possible from capping. Permanent effects may be possible due to presence of contamination if capping occurs. No other expected cultural resources impacts.
C Tank Farm	CP-TF-7	Current	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Known	Manhattan Project/Cold War significant resources have already been mitigated. Area is very disturbed and there are no known recorded archaeological resources within the EU. Traditional cultural places are visible from EU.

EU Name	EU ID	Evaluation Period	Potential RISK OR IMPACT	Comments
		Active Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Known	Because area has not been investigated on the surface or subsurface, archaeological investigations may need to occur within pockets of undisturbed land if any prior to remediation. Potential for intact archaeological material to be present is very low.
		Near-Term Post-Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Unknown Manhattan/Cold War: Direct: None Indirect: None	Permanent indirect effects to view shed are possible from capping. Permanent effects may be possible due to presence of contamination if capping occurs. No other expected cultural resources impacts.
200 East DSTs	CP-TF-8	Current	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Known	Manhattan Project/Cold War significant resources have already been mitigated. Area is very disturbed and there are no known recorded archaeological resources within the EU. Traditional cultural places are visible from EU.
		Active Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Known	Because area has not been investigated on the surface or subsurface, archaeological investigations may need to occur within pockets of undisturbed land if any prior to remediation. Potential for intact archaeological material to be present is very low.
		Near-Term Post-Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: None Indirect: None	Permanent indirect effects to view shed are possible from capping. Permanent effects may be possible due to presence of contamination if capping occurs. No other expected cultural resources impacts.

EU Name	EU ID	Evaluation Period	Potential RISK OR IMPACT	Comments
200 West DSTs	CP-TF-9	Current	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Known	Manhattan Project/Cold War significant resources have already been mitigated. Area is very disturbed and there are no known recorded archaeological resources within the EU. Traditional cultural places are visible from EU.
		Active Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Known	Because area has not been investigated on the surface or subsurface, archaeological investigations may need to occur within pockets of undisturbed land if any prior to remediation. Potential for intact archaeological material to be present is very low.
		Near-Term Post-Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: None Indirect: None	Permanent indirect effects to view shed are possible from capping. Permanent effects may be possible due to presence of contamination if capping occurs. No other expected cultural resources impacts.
300 Area Ground-water Plumes	RC-GW-1	Current	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Known Indirect: Known	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 three landscapes.

EU Name	EU ID	Evaluation Period	Potential RISK OR IMPACT	Comments
		Active Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Known Indirect: Known	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 three landscapes.
		Near-Term Post-Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Unknown Indirect: Unknown	Assuming no long-term monitoring of groundwater wells, then no further impact to known cultural resources. Residual contamination in groundwater will likely be of concern for Native American landscape. Permanent direct and indirect effects are possible due to high sensitivity of area.
100-N Ground-water Plumes	RC-GW-2	Current	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Known Indirect: Known	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 three landscapes.
		Active Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Known Indirect: Known	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 three landscapes.

EU Name	EU ID	Evaluation Period	Potential RISK OR IMPACT	Comments
		Near-Term Post-Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Unknown Indirect: Unknown	Assuming no long-term monitoring of groundwater wells, then no further impact to known cultural resources. Residual contamination in groundwater will likely be of concern for Native American landscape. Permanent direct and indirect effects are possible due to high sensitivity of area.
100-B/D/H/F/K	RC-GW-3	Current	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Known Indirect: Known	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 three landscapes.
		Active Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Known Indirect: Known	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 three landscapes.
		Near-Term Post-Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Unknown Indirect: Unknown	Assuming no long-term monitoring of groundwater wells, then no further impact to known cultural resources. Residual contamination in groundwater will likely be of concern for Native American landscape. Permanent direct and indirect effects are possible due to high sensitivity of area.

EU Name	EU ID	Evaluation Period	Potential RISK OR IMPACT	Comments
200 East Area	CP-GW-1	Current	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Known Indirect: Known	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 three landscapes.
		Active Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Known Indirect: Known	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 three landscapes.
		Near-Term Post-Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Unknown Indirect: Unknown	Assuming no long-term monitoring of groundwater wells, then no further impact to known cultural resources. Residual contamination in groundwater will likely be of concern for Native American landscape. Permanent direct and indirect effects are possible due to high sensitivity of area.
200 West Area	CP-GW-2	Current	Native American: Direct: Unknown Indirect: Unknown Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: Unknown Indirect: Unknown	Groundwater plumes are not intercepting riparian areas; along river; vehicle traffic with monitoring and remediation wells could introduce exotic species that disrupt native communities, including biota of cultural importance.

EU Name	EU ID	Evaluation Period	Potential RISK OR IMPACT	Comments
		Active Cleanup	Native American: Direct: Unknown Indirect: Unknown Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: Unknown Indirect: Unknown	Groundwater plumes are not intercepting riparian areas; along river; vehicle traffic with monitoring and remediation wells could introduce exotic species that disrupt native communities, including biota of cultural importance.
		Near-Term Post-Cleanup	Native American: Direct: Unknown Indirect: Unknown Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: Unknown Indirect: Unknown	Assuming no long-term monitoring of groundwater wells, then no further impact to known cultural resources. Residual contamination in groundwater will likely be of concern for Native American landscape.
324 Building	RC-DD-1	Current	Native American: Direct: Known Indirect: Unknown Historic Pre-Hanford: Direct: Known Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: None	Very disturbed, but close to important resources (close proximity to river), Manhattan era significant facility has already been mitigated. There are no known recorded archaeological sites or traditional cultural places located within the 324 Building EU; there are five archaeological sites located within 500 m of the 324 Building EU.
		Active Cleanup	Native American: Direct: Known Indirect: Unknown Historic Pre-Hanford: Direct: Known Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: None	Very disturbed, but close to important resources (close to river).
		Near-Term Post-Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: None Manhattan/Cold War: Direct: None Indirect: None	No expectations for impacts to known cultural resources.

EU Name	EU ID	Evaluation Period	Potential RISK OR IMPACT	Comments
KE/KW Reactors	RC-DD-2	Current	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Known Indirect: Known	Manhattan Project/Cold War significant resources have already been mitigated. Area within the EU is heavily disturbed, but the entire area is extremely culturally sensitive based on prehistoric, ethno-historic, and historic land use in the area. Traditional cultural places are known to be located in the vicinity as well as National Register eligible archaeological sites associated with all three landscapes.
		Active Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Known Indirect: Known	Due to highly sensitive cultural resources in vicinity of the EU, consultation is needed. Archaeological investigations or monitoring may also need to occur. Direct and indirect effects are likely to archaeological sites and traditional cultural places in vicinity of EU.
		Near-Term Post-Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: None Indirect: None	Permanent direct and indirect effects are possible due to high sensitivity of area.
PUREX	CP-DD-1	Current	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: None Manhattan/Cold War: Direct: Known Indirect: None	Manhattan Project/Cold War significant resources have already been mitigated. Area is heavily disturbed and even thought the entire area has not been inventoried for archaeological resources, it has very low potential to contact intact archaeological resources on the surface or subsurface. Traditional cultural places are visible from EU.

EU Name	EU ID	Evaluation Period	Potential RISK OR IMPACT	Comments
		Active Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Unknown Indirect: None Manhattan/Cold War: Direct: Known Indirect: None	Area has not been investigated either on the surface or subsurface, archaeological investigations may need to occur within pockets of undisturbed land if any prior to remediation. Potential for intact archaeological material to be present is very low.
		Near-Term Post-Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: None Indirect: None Manhattan/Cold War: Direct: None Indirect: None	Permanent indirect effects to view shed are possible from capping. No other expected cultural resources impacts.
K Basin Sludge	RC-OP-1	Current	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Known Indirect: Known	Manhattan Project/Cold War significant resources have already been mitigated. Area within the EU is heavily disturbed, but the entire area is extremely culturally sensitive based on prehistoric, ethno-historic, and historic land use in the area. Traditional cultural places are known to be located in the vicinity as well as National Register eligible archaeological sites associated with all three landscapes.
		Active Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: Known Indirect: Known	Due to highly sensitive cultural resources in vicinity of the EU, consultation is needed. Archaeological investigations or monitoring may also need to occur. Direct and indirect effects are likely to archaeological sites and traditional cultural places in vicinity of EU.
		Near-Term Post-Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: None Indirect: None	Permanent direct and indirect effects are possible due to high sensitivity of area.

EU Name	EU ID	Evaluation Period	Potential RISK OR IMPACT	Comments
CWC	CP-OP-1	Current	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: None Indirect: None	National Register eligible historic trail runs through the EU. Two National Register ineligible sites/isolates are located within the EU. Potential for additional resources within pockets of undisturbed soil if it exists based on presence of Native American and Historic era resources within 500 m of EU. Traditional cultural places are visible from the EU.
		Active Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: None Indirect: None	Both direct and indirect effects are likely on National Register eligible trail. Other sites have been determined ineligible. Potential for additional archaeological resources where pockets of undisturbed soils exist.
		Near-Term Post-Cleanup	Native American: Direct: Known Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Known Manhattan/Cold War: Direct: None Indirect: None	Long-term protection measures may be in place to resolve adverse effects to National Register eligible trail. Permanent effects possible due to presence of contamination.
WESF	CP-OP-3	Current	Native American: Direct: Unknown Indirect: Unknown Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Known	This EU is located within a Manhattan Project/Cold War significant resource that has already been mitigated. There are no archaeological resources known to be located within this EU. Traditional cultural places are visible from this EU.
		Active Cleanup	Native American: Direct: Unknown Indirect: Unknown Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Known	Because no ground disturbance will occur, there should be no impact to archaeological resources.

EU Name	EU ID	Evaluation Period	Potential RISK OR IMPACT	Comments
		Near-Term Post-Cleanup	Native American: Direct: Unknown Indirect: Unknown Historic Pre-Hanford: Direct: Unknown Indirect: Unknown Manhattan/Cold War: Direct: None Indirect: None	No expectations for impacts to known cultural resources.
ERDF	CP-OP-6	Current	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Known	A few National Register ineligible archaeological sites and isolated finds were recorded before construction of ERDF within this EU. None are likely present due to construction of ERDF and were addressed under the National Historic Preservation Act, Section 106 Review completed prior to ERDF construction. A Manhattan Project/Cold War eligible site is recorded within 500 m of ERDF as well as several other archaeological sites associated with various landscapes. Traditional cultural places are visible from this EU.
		Active Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Unknown Manhattan/Cold War: Direct: Known Indirect: Known	All of the EU has been inventoried for archaeological resources on the surface. Because there are pockets of land where no disturbance has occurred, the potential for subsurface archaeological material to be present in these areas is moderate. Indirect effects to the Manhattan Project/Cold War eligible archaeological site are possible.
		Near-Term Post-Cleanup	Native American: Direct: Unknown Indirect: Known Historic Pre-Hanford: Direct: Known Indirect: Unknown Manhattan/Cold War: Direct: None Indirect: None	Permanent indirect effects to view shed are possible from capping. Permanent effects may be possible due to presence of contamination if capping occurs. No other expected cultural resources impacts.

CHAPTER 5. PROVIDING CONTEXT, SUMMARY DISCUSSION, AND INTERIM OBSERVATIONS

5.1. CONTEXT FOR THE RISK REVIEW PROJECT RESULTS

In January 2014, the Department of Energy (DOE) asked the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) to conduct an independent Hanford Site-wide evaluation of human health, nuclear safety, environmental and cultural resource risks (hereinafter referred to as the "Risk Review Project") associated with existing hazards, environmental contamination and remaining cleanup activities. The overarching goal of the Risk Review Project is to carry out a screening process for risks and impacts to human health and resources[86]. The results of the Risk Review Project are intended to provide the DOE, regulators, Tribal Nations and the public with a more comprehensive understanding of the remaining cleanup at the Hanford Site to help inform (1) decisions on sequencing of future cleanup activities, and (2) selection, planning and execution of specific cleanup actions, including which areas at the Hanford Site should be addressed earlier for additional characterization, analysis, and remediation[87]. DOE, the State of Washington, and EPA recognize that the Risk Review Project results, including evaluations of hazards and risks, are only one of many inputs and considerations to prioritization of future cleanup activities at Hanford.

Cleanup at the Hanford Site is a costly, long-term, and technically challenging mission that began in 1989. Approximately 25% of the overall Hanford Site cleanup has been completed to-date. Extensive nuclear waste inventories in tanks and other forms; heavily contaminated formerly used nuclear materials processing facilities; as well as near-surface, vadose zone, and groundwater contamination are major parts of the remaining cleanup effort. It is anticipated that more than $100 billion will be expended on cleanup during the next 50 years. Yet, while earlier studies have evaluated portions of the Hanford Site and some receptors, a comprehensive, site-wide review of the risks to human health and resources from contamination, waste management, and cleanup activities has never occurred. Thus, periodic reviews should be conducted that consider risks to human health, water resources, ecological resources, and cultural resources for the remaining cleanup. These types of reviews are essential for sequencing and planning future cleanup actions that ultimately span multiple generations.

The Risk Review Project focuses on anticipated cleanup work remaining to be completed as of October 2015. This interim progress report presents both the results of the first set of 25 EUs of approximately 60 EUs to be assessed as part of the Risk Review Project. Evaluations included here represent all nine of the EUs for tank waste and farms, and all five of the EUs for groundwater plumes, but only 3 of 9 major facilities for decommissioning and final disposition, 4 of 22 legacy source sites (former near-surface disposal areas), and 4 of 17 operating facilities supporting the cleanup mission.

The Risk Review Project is not intended to substitute for or preempt any requirement imposed under applicable federal or state laws or treaties. As important, the Risk Review Project is not intended to make or replace any decisions made under the Tri-Party Agreement and/or 2010 Consent Order, or amendments. Furthermore, the Risk Review Project is neither a CERCLA risk assessment nor a Natural

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[86] In this Risk Review Project, human health and resources evaluated include groundwater and the Columbia River, facility workers, co-located people, the public, and ecological and cultural resources. Collectively, humans and these resources also are referred to as "receptors".

[87] Additionally, while earlier studies have evaluated portions of the Hanford Site, there has never been a comprehensive, site-wide review of the risks to human health and resources from contamination, waste management, and cleanup activities.

Resources Damage Assessment evaluation. The Risk Review Project is not intended to interpret treaty rights that exist between the United States and Native American Tribes.

5.2. SUMMARY OF KEY ASSUMPTIONS AND RESULTS

The Risk Review Project is relying primarily on previously obtained primary data, safety analyses, risk analyses, environmental impact assessments, remedial investigations, and similar information sources. Tens of thousands of pages of information and even more data have been reviewed and integrated to form the basis for this report. The methodology used reflects input from state and federal regulatory agencies, Tribal Nations, non-governmental agencies, the public, and independent experts (CRESP 2015). Still, important uncertainties and data gaps remain that require assumptions to carry out the project. The major general assumptions that have been used to guide the Risk Review Project are as follows:

1. The existing data and uncertainties regarding radionuclide and contaminant inventories, physical-chemical forms, and distribution of existing environmental contamination, as well as future events, allow for rough order of magnitude differentiation across EUs between radionuclide and chemical hazards (e.g., contained in engineered systems), existing environmental contamination, and potential impacts and risks to receptors.
2. Three evaluation periods have been selected, with assumed time frames to facilitate the Project's evaluation: active cleanup (50 years or until 2064), including during the current status and during cleanup actions, and recognizing that all cleanup may not be completed within this period; near-term post-cleanup (100 years post-cleanup or 2064 to 2164); and, long-term post-cleanup (1000 years post-cleanup or 2164 to 3064, although impacts projected to occur beyond this time frame are also noted when indicated from prior studies).
3. Screening thresholds for groundwater and the Columbia River have been selected based on existing risk-informed regulatory criteria that reflect water quality associated with designated highest beneficial uses (e.g., drinking water quality for groundwater, and ecological protection for the Columbia River).
4. Institutional controls are assumed to be effective for the duration of federal control of designated land areas and the EUs contained therein. Furthermore, institutional controls are assumed only to be effective for 100 years after the transfer of land areas from federal to non-federal control. Some areas of the Hanford Site are currently planned to be under federal control for very long periods (e.g., greater than 300 years for permitted disposal areas in the Central Plateau). Periods of planned federal control may change over time in response to changes in public policy or other decisions. Changes in assumptions of institutional controls may necessitate changes in the end-states of an EU (i.e., changes in final barriers or physical-chemical forms or amounts of remaining contaminants) and cannot be predicted. Failure of barriers or institutional controls may result in higher exposure, which may in the future require additional cleanup of residual contamination.

The current risks that are in the highest risk rating group are at specific EUs from (1) loss of nuclear safety controls from major natural hazards (e.g., from seismic events, volcanic ashfall, or wildfire) or other external events (e.g., prolonged loss of power or water), or operational accidents (including facility fires) that can effect human health and a broad range of receptors, and (2) contamination of groundwater from further spread of existing groundwater contamination, migration of contaminants from legacy surface disposal sites and the vadose zone, or unplanned release of contaminants from engineered facilities (e.g., waste tanks). Current significant threats to the Columbia River from contaminants in the River Corridor are being treated, and significant threats from groundwater contaminants to the Columbia River from the Central Plateau are either being treated or would not be realized for a long time and only if they are not treated during the active cleanup period.

The highest rated risks during cleanup are (1) to workers, co-located people, and controlled access groups from operational accidents, and (2) to ecological and cultural resources from physical disruption or introduction of invasive species, either because of insufficient planning, selected cleanup methods, or lack of a prior knowledge.

The major risks remaining after cleanup are from potential failure of institutional or engineered controls, which may affect human health, water resources, and ecological resources. In addition, ***safety of consumptive practices*** (such as those associated with some Tribal Nation cultural practices and some recreational activities) cannot be assured without both risk assessment and appropriate biomonitoring.

5.3. INTERIM OBSERVATIONS

Prioritization and sequencing of cleanup activities should consider risks from nuclear, chemical, and physical hazards and existing environmental contamination, as well as a range of other factors, including regulatory requirements, funding and personnel, project continuity, and stakeholder input. The following interim observations should be regarded as preliminary because there are approximately 35 EUs remaining to be evaluated. The final report will contain the results of all evaluations of these units as well as final observations. Interim observations fall into one of four categories: (1) general; (2) sequencing of cleanup; (3) planning for and activities associated with cleanup; and (4) key information gaps.

GENERAL OBSERVATIONS

1. At the Hanford Site, current hazard and risk conditions reflect the inventory, site access controls that are in place, and cleanup actions already completed. These controls and completed actions have greatly reduced threats to human health and ecological resources, as well as addressing some of the groundwater contamination. When considering future cleanup, different hazard and risk considerations are important for specific aspects of the cleanup:
    a. **To inform sequencing of cleanup activities –** *nuclear, chemical, and physical safety* (i.e., hazards, initiating events and accident scenarios) *and the threats to groundwater* and the Columbia River *are the primary risk considerations*.
    b. **To inform selection, planning and execution of specific cleanup actions –** potential *risks and impacts to worker safety, ecological resources, and cultural resources are the primary risk considerations*.
    c. **To inform cleanup criteria** (i.e., cleanup levels to meet regulatory standards) **–** *future land use, protection of water resources, land ownership and control, durability of institutional and engineered controls, and legal/regulatory requirements are the primary considerations that influence future human health risk estimates*. Risks to human health should be considered in combination with risks to environmental and ecological resources for establishing cleanup criteria. The establishment of end-state cleanup criteria is not the focus of the Risk Review Project.

2. Currently, members of the public, whether located at the official Hanford Site boundary or at the controlled access boundary (river and highways), usually have Low to ND risks, even if postulated radioactive contaminant releases are realized.

3. Timing of cleanup of a specific EU **may reduce** worker risk (e.g., by radioactive decay) **or may increase worker risk** (e.g., by facility deterioration, insufficient trained workforce availability, repetitive or chronic exposures due to maintenance, potential for complacency).
    a. Worker risk varies with respect to the nature of hazards, complexity, duration of project, technical approaches, and controls or mitigation measures in-place to ensure worker health and safety.
    b. DOE and its contractors have accident rates approximately two-thirds less than comparable non-DOE work. Ongoing vigilance is needed to maintain this excellent record.
4. The ecological resources on the Hanford Site are very important to the Columbia River Basin Ecoregion, where the shrub-steppe habitat has decreased at a far greater rate region-wide than on the Hanford Site. Stewardship by the DOE has helped protect these resources.
5. The historical and cultural significance of the Hanford Site to Tribal Nations stretches over 10,000 years. The Hanford Site also is considered to have important historical significance to western settlement, which began in the early 1800s and only ended at the site to make way for the Manhattan Project. Finally, the site played a major role during the Manhattan Project Era and after World War II during the Cold War Era. DOE's stewardship helps assure that the site's historical and cultural significance will continue to be recognized.

INFORMING CLEANUP SEQUENCING

1. **Address parts of specific evaluation units earlier.** For several EUs, specific activities, hazards or risk characteristics warrant being addressed before the EU as a whole.
2. **Highest priority group based on evaluation of potential risks to human health and the environment.** For the facilities and activities evaluated under the Risk Review Project to date, the major cleanup activities that are in the highest priority group based on evaluation of potential risks to human health and the environment are as follows (*not in any specific order*):
    a. **Reduction of threats posed by tank wastes.** (Appendix E) Hydrogen gas generation[88] poses a threat to nuclear safety and human health through hydrogen flammability events that may result in atmospheric or subsurface release of waste or contaminants from containment (worker risk from tank vapors are discussed below). Tc-99 and I-129, both being persistent and highly mobile in the subsurface, pose threats to groundwater through potential leakage from tanks[89]. Risks posed by hydrogen gas generation can be somewhat reduced through removal of water soluble Cs-137. Groundwater threats can be substantially reduced by removal of water-soluble constituents from a selected set of tanks.[90] This interim observation is consistent with the priority given by the agencies to

[88] Hydrogen generation rate is primarily related to Cs-137 and Sr-90 content of the waste.
[89] The threat to groundwater from tank leakage has been mitigated in the near-term through interim stabilization of single shell tanks (SSTs) by removal of pumpable liquids.
[90] For hydrogen generation – 200 East DSTs, 200 West DST SY-103 and single shell tanks East B-202, B-203, B-204, and West T-201 have times to 25% of the lower flammability limit of less than 6 months under unventilated conditions. Cs-137 removal would most significantly increase time to 25 percent of the lower flammability limit for tanks AZ-101, AN-102, AN-107, AP-101, AP-103 and AP-105. For groundwater threat, greater than 70% of the GTM is from – 200 East DSTs, SY-101 and SY-103 (200 West DSTs) and single shell tanks, AX-101, S-105, S-106, S-108, S-109, SX-106, TX-105*, TX-113*, TX-115*, U-109, U-105 (* indicates assumed SST leaker).

treat LAW at WTP as early as possible if Cs-137, Tc-99 and I-129 separated from the waste are not returned to the tanks. However, the risk profile will not be reduced significantly nor increased if Cs-137, Tc-99 and I-129 are returned to the tanks during LAW treatment.

b. **Reduction or elimination of risks associated with external events and natural phenomena (severe seismic events, fires, loss of power for long duration).** Facilities affected are WESF (cesium and strontium capsules), CWC, and PUREX waste storage tunnels.

   i. **For WESF** (Appendix H.4)**:**

      The primary scenario that causes release of radionuclides from capsules stored in the WESF pool cells is an accident that results in the loss of all water from the pools cells, which provides cooling and radiation shielding. The design basis seismic event alone cannot cause the loss of all pool cell water by itself: release of significant quantities of radionuclides can only be caused if multiple root causes occur (some in sequence, some in parallel) that include man-made errors, natural events, and external events. The storage pool structures have been exposed to high radiation fields for an extended period of time. An initial assessment completed indicates that the storage pools currently are safe, although the long-term integrity of the structures is uncertain.[91] DOE proposes to over-pack and then transfer cesium and strontium capsules to onsite dry storage.[92]

   ii. **For Central Waste Complex** (Appendix H.3)**:**

      Estimated unmitigated doses from incident scenarios to the co-located person exposed to the worst design basis event at the Central Waste Complex is from a large fire involving more than eight drums or 82.5 Ci (dose equivalent) of material with 770 rem. The risk may increase because the Central Waste Complex continues to receive wastes, but currently is unable to ship wastes to off-site disposal, due to WIPP being closed and also because budgets have been insufficient to support repackaging wastes into standard containers. Localized accumulation of material at risk without a disposition pathway can increase overall risk. Consideration also should include reductions in the amount of material at risk for similar facilities that require interaction with other offsite facilities that may not be available.

   iii. **For PUREX** (Appendix F.4):

      1. A design basis seismic event could lead to a total structural failure of the 202-A building and both tunnels, causing an estimated unmitigated combined 250 rem dose to the co-located person.

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[91] A separate DOE-initiated review of the condition of the WESF concrete structure and the reliability of the initial DOE estimate is in progress.

[92] The capsules may experience significantly higher temperatures in dry storage than in pool storage. The elevated temperatures, combined with the variable and uncertain chemical composition of some capsules, could raise concerns about the integrity of the capsules over time as storage is likely for at least decades (see Appendix H.4). This concern would be part of the safety analysis associated with the dry storage design process.

2. The wood ceiling and wall structure of Tunnel #1 are vulnerable to fire or collapse in about 30 years[93] due to ongoing degradation occurring from continued exposure to the gamma radiation from equipment being stored. These events could release a large fraction of the 21,200 Ci radiological inventory to the environment.[94]

c. **Dependence on active controls (e.g., reliance on power, cooling water, active ventilation) to maintain safety for additional facilities with large inventories of radionuclides.** These conditions are (1) air handling ducts at WESF, and (2) sludge at K-Basins (sludge treatment project; Appendix H.2).

   i. During the design basis event earthquake, contaminants from WESF's hot cell and ventilation system are the hazard sources that produce doses to the co-located person [Co-located person: 21 rem].

   ii. Current safe storage relies on maintaining the K-Basin sludge submerged under water to reduce radiation exposure to workers and prevent fires of reactive metal fragments. Safe processing of K-Basin sludge also requires keeping it wet during retrieval, transfer, interim storage, and processing to prevent pyrophoric constituents from igniting.

3. **Cleanup actions that could cause substantial human health risks**. The following cleanup activities themselves could cause substantial risks to human health and therefore warrant consideration of interim actions, and different cleanup approaches and timing (recognizing that mitigation measures would be both necessary and implemented before and during remedial actions):

   a. **Retrieval, treatment, and disposal of contaminated soils underlying Building 324 and disposal of the building after grouting the contaminated soils in the building** (Appendix F.2)**.** Currently, no migration of soil contamination to groundwater has been indicated, suggesting that required cleanup is not urgent. In addition, the excavation and transfer of the soils through the B-Cell floor may not be technically feasible and/or may present challenging risk scenarios. As a result, approaches that allow for immobilization and in situ decay of the soil contaminants (Cs-137, Sr-90) warrant further consideration.

   b. **Retrieval, treatment, and disposal of materials from 618-11 within caissons, vertical pipe units, and burial grounds** (Appendix D.2) because of the characteristics of wastes (high activity, pyrophoric, poorly characterized) to be retrieved. The possible event of a fire and/or release from 618-11, jeopardizes continued operations and worker safety at the Columbia Northwest Generating Station because of the proximity of the two facilities. The current cover over the buried wastes, but not present over the caissons and vertical pipe units, is effective in limiting water infiltration to the wastes where the cover is present. These conditions warrant consideration of instituting interim mitigation measures and delaying waste retrieval until closure of the generating station.

4. **Groundwater Threats** (Appendix G). Many of the threats and current impacts to groundwater are being interdicted and/or treated. The greatest threats and impacts to groundwater that are not currently being addressed are from:

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[93] The time estimate of 30 years has large uncertainty, and can be shorter or longer.
[94] The document safety analysis for this facility provides a detailed analysis of potential upset events (see Appendix F.4).

a. **Groundwater plumes not currently being actively addressed.** Tc-99 and I-129 are already in groundwater in 200 East Area (200-BP-5; EU CP-GW-1). The 200-BP-5 I-129 plume extends to the southeast (200-PO-1; EU CP-GW-1) but may be too dispersed for effective remediation other than natural attenuation.

b. **Vadose zone threats to groundwater not currently being addressed.** Tc-99, I-129 and Cr(VI) are in the vadose zone associated with BC Cribs and Trenches (EU CP-LS-1; Appendix D.4) and the legacy sites associated with B-BX-BY tank farms (EU CP-TF-6; Appendix E.7), both located in the 200 East Area. Sr-90 results in a very high rating in B-BX-BY because of the large inventory but also is relatively immobile and will naturally decay. Infiltration control (e.g., capping) and other approaches, may reduce the flux of these contaminants from the vadose zone into groundwater. Uranium currently is being extracted from perched water in B-Complex.

c. **324 Building, where relatively modest interim actions could reduce threat.** The largest risk for migration of Cs-137 and Sr-90 from the soils until cleanup can be completed (through a combination of D4, soil treatment and/or removal and natural attenuation) is from breakage of a main water pipe and infiltration of precipitation and run off in close vicinity of the building. Building 324 is currently being maintained in a safe surveillance and maintenance mode pending completion and evaluation of a pilot project and assurances that resources are available to complete a multi-year soil remediation and D4 activities. Current risks from potential water infiltration and resultant contaminant migration may be mitigated through water supply modifications, infiltration controls, and additional groundwater monitoring[95].

d. **618-11 waste site, where relatively modest interim actions could reduce threat**. At 618-11, the potential for release of additional contaminants to groundwater can be mitigated by providing a cover that prevents infiltration but maintains gas venting over the caissons and vertical pipe units (currently gravel covered area).

5. **Operating facilities have a time dependent risk, which create additional challenges.** Unplanned changes in inventory can occur over time, with delays in planned processing resulting in increased risk. The hazard and risk profiles change as funding is available to implement identified plans. For example, with processing delays along with, waste storage conditions may deteriorate or additional waste may accumulate. In addition, operating facilities rely on interfaces with existing facilities (e.g., WIPP, T Plant, off-site processing and disposition facilities) and planned facilities (e.g., dry capsule storage for cesium and strontium capsules, Phase 2 K-Basin Sludge Processing). Outages or delays in availability of interfacing facilities may result in processing disruptions.

PLANNING FOR, AND ACTIVITIES ASSOCIATED WITH, CLEANUP

1. Selective retrieval targets of 99% or the limits of multiple technologies applied to the group of 26 DSTs and 42 SSTs that comprise 90% of the total GTM within all tanks, would result in a residual GTM of 1% of the initial inventory. Waste retrieval targets of 90% of the GTM or the limits a single technology (if greater than 90%) would result in a residual of less than an additional 1% of the current GTM, and with a cumulative result that is indistinguishable from a target of 99% across all tanks, considering the inventory uncertainties. Selective waste retrieval

[95] While groundwater monitoring does not prevent infiltration or contaminant migration, it does mitigate risks by providing early warning of a change in the subsurface contaminant spatial distribution.

targets as indicated may allow for significant acceleration of tank waste retrievals and much more rapid reduction in groundwater threats from tank wastes than currently planned. Recognizing that waste retrievals are most efficiently carried out on tank farm by tank farm basis, selective extents of retrieval focusing on tanks with large inventories of contaminants that threaten groundwater, can be accomplished for individual tanks within each tank farm, allowing for different extents of retrieval while completing retrievals at an entire tank farm. Retrieval targets also should consider the extent of retrieval for specific contaminants that threaten groundwater rather than solely on volumetric-based retrieval targets. Further evaluation of this concept is warranted. A tank farm waste retrieval and processing system plan evaluation of this approach is suggested.

    a. A target of 90 % reduction in GTM across all SSTs and considering in-tank grouting of residual waste inventory would reduce the threat of groundwater contamination from SSTs to substantially less the GTM from the existing environmental contamination in the vadose zone in the 200 West and 200 East Areas from leaks and legacy disposal activities in the proximity of the SST farms.

2. During the active cleanup period, worker risks from chronic, sub-acute and acute exposures to hazards, and industrial type accidents are the major human health considerations.
    a. Prior to active cleanup, surveillance and maintenance, chronic radiation exposures and chemical exposures such as to poorly characterized vapors at tank farms, constitute the greatest worker risks.
    b. During cleanup action, worker risks can be high at legacy waste disposal sites that are not, or cannot be, fully characterized. D&D workers may encounter asbestos, radiation, and chemical hazards (including PCBs, lead, beryllium).
3. For almost all cases, the potential for adverse impacts to ecological resources from contaminants has already been mitigated either by removal actions or by the presence of engineered barriers (e.g., cover materials, buildings or engineered structures). Uptake of contaminants from groundwater in the riparian zone and groundwater discharge to the benthic zone, of the Columbia River remain the most important pathways for contaminants to impact ecological resources. An additional potential future pathway includes through irrigation and plant uptake associated with use of contaminated groundwater.
4. Physical disruption and invasive species are the primary mechanisms of adverse impacts on ecological resources at the Hanford Site. Patch size and interdiction of patches is an important aspect of ecological value, and should be considered during cleanup. Decreasing the footprint of cleanup activities on the EU and buffer are one of the most important mechanisms of reducing risk to ecological resources. Planning for remediation requires careful consideration of how the activities will disrupt eco-receptors and ecosystems on the EU, and surrounding areas (including vehicular traffic, people, roads, traffic routes, lay-down areas), reducing effects where possible, and specifically avoiding high quality ecological resource areas on or off the EU. Allowing non-native species to invade an EU or the surrounding buffer can disrupt and damage high quality native resources and is preventable. If high quality resources on the EU and buffer are disturbed, it may not be possible to restore them. Thus protection of ecological resources during remediation is the best option and is superior to trying to repair damaged resources

5. Ecological restoration[96] is an important step in remediation, and must be carried out with native species, processes and structure, and monitoring to assess efficacy is critical to determining how to do restoration for future cleanup activities. The value of ecological resources at any given EU depends upon the resources there and in the surrounding buffer, the historical presence of resources of high value, the remediation and restoration history on the EU and buffer, and chance/weather/fires. These factors affect the ecological restoration potential during remediation.
6. The Manhattan Project/Cold War era built environment is well understood as extensive inventories have been completed to document the historical importance of the era's buildings and structures and which of those buildings and structures will remain after remediation has ended.
7. Physical exposure and disruption during remediation are the primary mechanisms for adverse impacts on cultural resources from activities associated with cleanup of specific EUs. Planning for remediation, particularly at the earliest stages, should include (a) how remediation activities, such as road traffic and heavy equipment through the cleanup area could impact potential cultural resources that are, or could be present within and adjacent to, the area undergoing cleanup and (b) the mitigation measures that could avoid or limit the impact. Limiting the footprint of activities associated with remediation can decrease the chance that a cultural resource will be exposed or adversely impacted during cleanup. Additionally, limiting the footprint decreases the chance that indirect impacts, such as the visibility of a site that Native Americans consider to be important to their culture, will occur.
8. Remediation of the 100-K Area waste sites (EU RC-LS-2) currently is a "work in progress" where soil cover and vegetation have been removed in some areas, and active dust suppression is required, so there is increased potential for dispersal and/or transport to groundwater of contaminants remaining in the waste sites. Remediation and re-vegetation of the site will reduce infiltration and transport of residual vadose zone contamination to groundwater. Re-vegetation needs to consider topography and native plants.

Key Information Gaps

1. There is a need for regular updating of assumptions within the DSA regarding where the maximum exposed individual (public) is located, as the use of the Hanford Site evolves.
2. Contaminant inventories at many of the EUs are highly uncertain. Further characterization of contaminated or potentially contaminated areas needs to be carried out to the extent necessary to make informed cleanup decisions and assure that residual risks to human health, water resources and ecological resources are below acceptable thresholds.
3. Additional risk analyses will be needed to evaluate risks to human health as part of planning for new controlled access activities. Current analyses do not provide sufficient resolution to understand potential safety risks to a broader range of people present between 100 m from facility or activity boundaries to the Hanford Site security boundaries. Additional mitigation measures, such as biomonitoring, also may be necessary for controlled access that includes gathering or consumptive activities such as Tribal cultural activities.

[96] In this report, the term "restoration" does not refer to Natural Resource Damage Assessment considerations. Instead, as used here, ecological restoration refers to a process that includes such activities as environmental assessment, vegetation assessment, geographical and contour considerations, re-vegetation, and monitoring, among other processes.

4. The condition of infrastructure and the impacts of infrastructure challenges on the waste management and long-term cleanup efforts, and resulting risks, are subjects of current evaluation and planning by DOE.
5. For many existing groundwater plumes and for many areas of contamination in the vadose zone, the vertical distribution of primary contaminants is highly uncertain because of limited characterization data.
6. For most EUs and areas on the Hanford Site, there has not been a recent evaluation or inventory of the ecological resource level (e.g., habitats). Planning and sequencing to reduce risk to eco-receptors depends on avoiding and protecting high quality resources (especially large patches, or smaller patches close to large patches).
7. For most EUs and areas on the Hanford Site, there has not been any survey of the nature and extent of invasive species, especially on large patches of high quality resources (Levels 3-5 resources, including habitat for important species and threatened or endangered species). There should also be monitoring in the years following cleanup to determine the extent of non-native species invasions to determine efficacy of measures to prevent invasion.
8. The majority of the Hanford Site has not been surveyed for cultural resources related to the Native American and Pre-Hanford Eras. There likely are cultural resources present from those eras, particularly those that are not directly visible. Cultural resources reviews are carried out on a case-by-case basis when cleanup actions, or other activities may disrupt specific land areas or land transfers are being considered.
9. Existing cultural resources records oftentimes are not compiled or organized in ways that would be helpful during planning for cleanup at a particular location. Cultural resources reviews would benefit from a more streamlined process that provides information in a more timely fashion and with sufficient detail for planning and sequencing of remediation actions while still protecting the cultural resources.

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